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Linköping, 14-15 April

Tomohiko Sakao, Tobias Larsson & Mattias Lindahl
Editors

Linköping University
KTH VETENSKAP OCH KONST
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Industrial
Product-Service Systems (IPS²)

Proceedings of the 2nd CIRP IPS² Conference

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Preface

Manufacturers in developed countries today regard services as increasingly important. Some manufacturing firms are strategically shifting from a “product seller” towards a “service provider”. As a result, their offerings have come to form a combination of physical products and services. Along with this trend, concepts such as Industrial Product-Service Systems (IPS²) are found in not only theoretical but also practical fields in industries. An IPS² is defined as “an integrated industrial product and service offering that delivers value in use”.

This integrated offering and its way of development provides opportunities for companies and their customers to design more innovative solutions. IPS² has potential for better environmental performance, as well. On the other hand, this has a great impact on such companies. Delivering IPS² is not an easy task, and may force companies to change organizational structures and their mindsets.

The CIRP IPS² Conference is organized by the CIRP IPS² Working Group. This 2nd CIRP IPS² Conference has 69 technical papers in the proceedings from 14 countries. This shows the interests of the topic within CIRP and the outside research community at large. The conference has 12 technical sessions, 2 keynote speeches and 2 industry study visits. Over 100 participants are expected to attend the conference. This IPS² conference will focus on research and practice into marketing, design, development, manufacturing, delivery, use, maintenance, and end-of-life of IPS². The topics to be addressed include manufacturing methods, development methods, service quality, information communication technologies, service networks, business models, and environmental performance.

Reflecting the high degree of participants’ sharing backgrounds and disciplines, we will make a challenge on the way of organizing sessions in this conference. Unlike the tradition of CIRP conferences, presentations will be short with 10 minutes while long discussion across different presentations will be facilitated by session chairpersons with some 30 minutes after all the presentations in each session. We understand this has pros and cons, but in this particular case we believe this is, at least, a good attempt and hope this to produce more fruitful results.

We would like to take this opportunity to thank all the authors for their high-quality research papers, skilled session chairpersons, companies offering industry visits, the international scientific committee members for their support in reviewing the papers and the local organising committee for their efforts in preparing this conference. We would also like to thank our sponsors; VINNOVA (The Swedish Governmental Agency for Innovation Systems), our gold sponsor Linköping municipality and our silver sponsors Servicestaden AB, Polyplank AB, SIG PM, Blekinge Institute of Technology, Department of Management and Engineering at Linköping University and The Faste Laboratory at Luleå University of Technology for their support for the conference.

Conference chairpersons,

Tomohiko Sakao (Linköping University)

Tobias Larsson (Luleå University of Technology)

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Keynote

A Service based Platform Design Method for Customized Products

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Abstract

In this paper, we propose a method for developing service based product platforms to generate economical and feasible design strategies for a product family and evaluate design feasibility within dynamic market environments. We will model design strategies for a product family as a market economy where product family platform configurations are generated through market segments based on services. A coalitional game is employed to evaluate which services provide more benefit when included in the platform based on the marginal profit contribution of each service. To demonstrate implementation of the proposed method, we use a case study involving a family of mobile products.

Keywords

Product Family Design, Service based Platform Design, Service Quality, Coalitional Game

1 INTRODUCTION

Companies that generate a variety of products increasingly utilize services to satisfy customers' needs, offer differentiated products, and survive in today's competitive market environment. Additional services provide value-added functions or activities in the life cycle of products and flexibilities in product development. Customized products or services are an important source of revenue for many companies, particularly those working with in a mass customization environment where customer satisfaction is of paramount importance. Mass customization depends on a company's ability to provide customized products or services based on economical and flexible development and production systems [1]. By sharing and reusing assets such as components, processes, information, and knowledge across a family of products and services, companies can efficiently develop a set of differentiated economic goods by improving flexibility and responsiveness of product and service development [2]. Product family design is a way to achieve cost-effective mass customization by allowing highly differentiated products to be developed from a common platform while targeting products to distinct market segments [3].

Historically, design has been adapted to changing environments, such as customers' preferences, technologies, economic situations, company's strategies, and competitive moves. Strategic adaptability is essential in capitalizing on future investment opportunities and responding properly to market trends in a dynamic environment [4]. The value of services depends on market segmentation strategies that are identified by information derived from the relationship between customer needs and service providers [5]. In dynamic market environments, the valuation of a product increases the flexibility in decision-making for developing new products or redesigning existing products and affects product life cycles [6]. To identify the valuation of services in a product family, we investigate strategic service sharing among products for designing a platform using market based decision making. Market-based product design is one way to reflect various and dynamic market environments by capturing dynamic factors, such as customer needs and trends, companies' strategies, regulations, resources, and technologies, in product design. Game theoretic approaches provide a rigorous framework for managing and evaluating strategies to achieve players' goals using their complete or incomplete information and knowledge [7].

The research presented here is motivated by the need to provide a basis of service based design methods in product family development. In this paper, we extend concepts from product family design and mass customization to service design. We use a module-based service model to facilitate product design and represent the relationships between functions and services in a product. The objective of this research is to propose a method for developing a service based product platform to generate economical feasible design strategies for a product family and evaluate design feasibility within dynamic market environments. We model design strategies for a product family as a market economy where product family platform configurations are generated through market segments based on services. A coalitional game is employed to evaluate which services provide more benefit when included in the platform based on the marginal profit contribution of each service.

The remainder of this paper is organized as follows:. Section 2 reviews related literature and background for customized family design as well as market based design decision making. Section 3 describes the proposed method to determine a service based platform for designing customized families of products using a module-based service model and a coalitional game. Section 4 gives a case study using a family of mobile products. Closing remarks and future work are presented in Section 5.

2 LITERATURE REVIEW AND BACKGROUND

2.1 Customized Product and Service Design

Modular design concepts have been applied to increase a variety of products and develop a product family that is created by adding, substituting, and/or removing one or more modules from the platform [2]. In a highly competitive market, modular design concepts can be considered as appropriate marketing strategies by providing the broadest market segment.

A typical approach to create a variety of services is to provide customers with various options and choices related to individual customer needs, which often warrant additional charges as they add value to the initial offering [8]. Based on theories and methodologies for mass customized product design, families of services and service platforms have been developed and applied to provide solutions in various customized service industries [9,10]. Meyer and DeTore [9] proposed a platform-based approach to develop new services using methods and processes for applying product family and product platform design and used this approach to define a new service platform in an international insurance company. Jiao et al. [10] discussed how design theories and methodologies for products and manufacturing systems can be applied to the design of service delivery systems for mass customization. They considered a service delivery system as a product system instead of an operational system. Perters and Saidin [11] investigated key factors for the implementation of mass customization in a services context and used service modules to represent the levels of modularization of the scope of work and process in designing mass customization processes. Li [12] introduced some concepts and assumptions for service package and service product module level in service innovation and service product development. Moon et al. [13] proposed a method to identify a service platform along with variant and unique models for service family design using a service process model and a fuzzy c-mean clustering method based on functional similarities.

2.2 Market based Design Decision Making

Market based decision making methods can provide the ability of investigating additional flexibility and strategic value in engineering design and product development. A game theoretic approach can be used as a market based method to evaluate design strategies that are affected by company's decision, competitors' action, and new technologies. A game is a description of a strategic interaction that includes constrains based on players' actions. Game theory provides reasonable solutions for various games and evaluates their properties [7, 14]. In engineering design, game theoretic approaches have been applied to model strategic relationships between designers for sharing design knowledge and solving design problems. The economic models and mathematical models of engineering design are developed and utilized to determine product design strategies for maximizing company's profits by integrating game theoretic approaches.

Xiao et al. [15] applied game theoretic approaches and design capability indices to model the relationships between engineering teams that were described as cooperative, non-cooperative, and leader/follower protocols, and facilitate collaborative decision-making during a product realization process. Fernandez et al. [16] proposed a framework for establishing and managing collaborative design spaces by combining elements of cooperative and non-cooperative behaviour, and formulating strategic and extensive games with utility theory. Lewis and Mistree [17] presented mathematical constructs for modeling a multidisciplinary design optimization problems using game theoretic principles and the compromised Decision Support Problem (DSP) in a collaborative, sequential, and isolated design environment. Huang et al. [18] described a multi-stage non-cooperative configuration game between platform products and supply chains to determine the optimal configuration decisions of a manufacturer and suppliers for mass customization, and demonstrated the applications of the proposed game and solution procedure using a series of simulation experiments and a numerical example. Moon et al. [19] introduced a market-based negotiation mechanism to support product family design by determining an appropriate number of common modules using a dynamic multi-agent system in an electronic market environment. Ford and Sobek [20] applied real options concepts to product development processes for managing uncertainty through flexibility impacts project behaviour, performance, and value. Gamba and Fusari [21] proposed a stochastic dynamic framework for valuing the contribution of modularization process and modular operations in the design of systems using real options. In the next section, we discus service-based platform design and the proposed coalitional game for product family design.

3 SERVICE BASED PLATFORM DESIGN FOR A PRODUCT FAMILY

Figure 1 shows the proposed method to determine a service based platform for a product family using a top-down and module-based approach. The proposed method consists of four phases: (1) identify market segments, (2) develop platform design strategies, (3) identify service quality, and (4) determine a platform strategy. The market study begins by establishing target markets and customers. In the initial phase, customer needs are analyzed to develop market segments for a product family. Customer needs are also used to identify required functional requirements for individual, as well as a range of products. Then, platform design strategies are developed using a modular approach. In this paper, we introduce a metric for quality that reflects how well services satisfy customers' needs through the product. After evaluating different platform design strategies using service quality and the coalitional game theoretic approach, a final platform is determined to generate a product family.

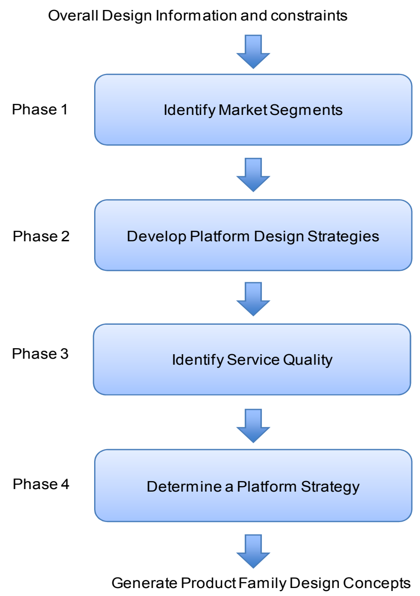

Figure 1: Service based product platform design

3.1 Phase 1: Identify Market Segments

Dividing a market into homogenous groups of consumers' preference is known as market segmentation [22]. Because a market segment provides guidelines for determining and directing customer requirements, it can be used to identify the criteria for designing a product family more accurately [23]. The basic development strategy within any product family is to leverage the product platform across products that target multiple market segments. In the initial phase, customers are classified into groups based on their characteristics and preferences. Products are also clustered as groups based on potential suitability for customers. For example, Meyer and Lehnerd [22] introduced three platform leveraging strategies based on market segments within a grid during the conceptual design phase.

In product design, customers' preference may vary based on specific functional requirements. Service preference information can help develop market segmentation for a product family by identifying an initial platform based on core common services. For example, Figure 2 shows three platform leveraging strategies for service based product family design based on approaches applied by Mayer and Lehnerd [22].

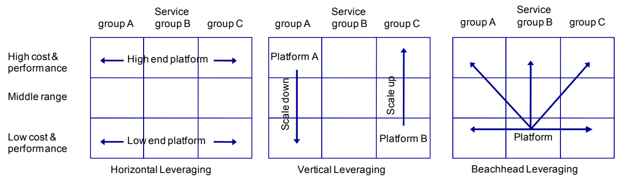

Figure 2: Three platform leveraging strategies for service based design

3.2 Phase 2: Develop Platform Design Strategies

3.2.1 Module based Service Presentation

Based on the concepts of the product module-based design [24], we assume that a service can be decomposed into service modules, which provide specific services, and the modules are achieved by the combination of product modules. As shown in Figure 3, a product is categorized into two different levels in a conceptual design phase: (1) a strategic level and (2) an operational level. The strategic level consists of service modules for developing service design strategies. The operational level is represented by product functions and provides a designer with cost information related to specific product functional modules and design strategies. To effectively define the relationships between functional hierarchies in the strategic and operational levels, an appropriate representation scheme must be adopted for the product.

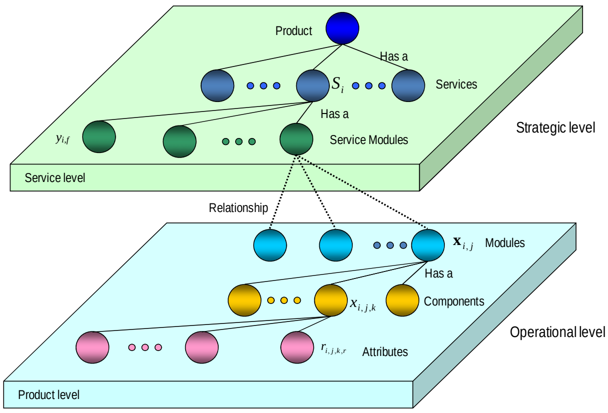

Figure 3: Product strategic and operational levels and hierarchy

Suppose that a product has I services, $P = (S_1, S_2, \ldots, S_I)$, and a service consists of f_i service modules, $S_i = (y_{i,1}, y_{i,2}, \ldots y_{i,f}, \ldots, y_{i,f_i})$, where $y_{i,f}$ denotes service module f in service i. For product modules, suppose that a service consists of m_i product functional modules, $S_i = (\mathbf{x}_{i,1}, \mathbf{x}_{i,2}, \ldots, \mathbf{x}_{i,j}, \ldots, \mathbf{x}_{i,m_i})$, where $\mathbf{x}_{i,j}$ is functional module j in service i, and consists of a vector of length nm, $x_{i,j} = (x_{i,j,1}, x_{i,j,2}, \ldots, x_{i,j,k}, \ldots, x_{i,j,n_m})$, and the individual scalar components $x_{i,j,k}$ (k=1, 2,…, n_m) of a functional module $x_{i,j}$ are called functional features. Each functional feature consists of several attributes, $a_{i,j,k,t}$ (t=1, 2, …, t_n) $\in A_i$, representing the component, $x_{i,j,k} = (a_{i,j,k,1}, a_{i,j,k,2}, \ldots, a_{i,j,k,t}, \ldots, a_{i,j,k,t_n})$, where t_n is the number of attributes defined by product analysis and A_i denotes the set of attributes in product service i.

Based on a module based design approach, we introduce service module cost based on product module cost to develop service cost in the proposed service hierarchy.

Different from the product cost, the service cost includes operational cost related to service delivery processes and operations. In this research, the operational cost can be identified by attributes that are related to product components. The product module cost is used to determine the expected design cost for product family and platform strategies in the next section.

3.2.2 Platform Design Strategy and Cost Model

A designer generates a feasible set of products and platform strategies to satisfy product requirements using traditional methods. The different platform strategies are constructed by combining the different functional modules into common and variant modules. A well-defined platform reduces production costs by improving economies of scale and reducing the number of different components that are used [19, 23].

An appropriate platform level for a product family can be determined by minimizing the production costs associated with commonality levels. The appropriate platform level for the product family can be represented as a mathematical programming model in which production costs are minimized, customer satisfaction is maintained, and profit is maximized [19]. Based on a proposed product design concept, product cost can be determined by total expected product volume, material cost, direct labor, production resource usage, tooling and capitalization costs, system cost (overhead or indirect costs), and development costs [25].

To develop platform strategies based on common modules, we introduce an expected strategy cost that represents additional costs for developing a new platform for a product family. Such costs could come from redesigning components, creating convenient interfaces, or having some components essentially overdesigned for most of the product family such that it works sufficiently for one specific product.

Suppose that a product family consists of I products, $PF = (P_1, P_2, \ldots, P_i, \ldots, P_I)$. Let A be a set of strategies for increasing the platform level and let $c(s_y)$ be the expected strategy cost for strategy $s_y\,(y = 1,2,\ldots,S)$. Then, the expected strategy cost can be calculated as follows [19]:

$$c(s_y) = \eta \times \frac{\sum_{i \in I} C_i^a}{f \times r} \qquad (1)$$

where C_i^a is the additional design cost of product i associated with the new platform, η is a factor for overhead cost, and f is a strategy weight function as follows:

$$f = \begin{cases} 1, \text{if a module is unique} \\ l, \text{otherwise} \end{cases} \quad (2)$$

and r is a volume penalty factor related to product sales quantity. Hence, the expected total product cost, TC, for the product family using platform strategy, s_y, can be calculated by:

$$TC(s_y) = \sum_{i \in I} C_i + c(s_y) \quad (3)$$

Where C_i is the product cost of product i. For a given set of products, the value of $c(s_y)$ varies depending on the strategy for platform design. The expected strategy cost function will be used to determine a platform for a product family and can be developed by various cost functions based on products' characteristics and/or company's strategy in product family development. The next section introduces a service quality model for evaluating functions in a product.

3.3 Identify Service Quality

To evaluate and measure performance of a product based on services, we propose a quality metric that is positively related to product quality, customer preference, and price. In this paper, we introduce two quality levels to determine the performance of a product: (1) marginal quality and (2) full quality. The marginal quality is defined as the level of quality that customers want to buy a product with their preference. Customers have zero preference if the quality of the product is below the marginal quality. Full quality is represented as the level of quality that customers are willing to pay the price for purchasing a product. The full quality is determined by services depending on customers' preferences in market segments. Figure 4 shows two service quality functions of a product for different customers' groups. In between marginal and full qualities, customers have various preferences related to service's quality.

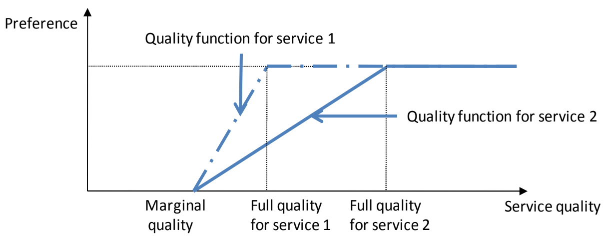

Figure 4: Relationship between preference and service quality for a product

We assume that the quality of a product consists of service qualities. To determine the value of customers' reference related to the service quality, Q_s, we assume that customers in the market are categorized into two homogenous groups, normal and specific. The value of the preference, $U(Q_s)$, can be represented by a utility function shown as follows:

$$U(Q_s) = \begin{cases} 0, & \text{if } Q_s \le Q_M \\ \dfrac{f_{n,q}(Q_s) + f_{s,q}(Q_s)}{2}, & \text{if } Q_M < Q_s \le Q_F^N \\ \dfrac{1 + f_{s,q}(Q_s)}{2}, & \text{if } Q_F^N < Q_s \le Q_F^S \\ 1, & \text{if } Q_F^S < Q_s \end{cases} \quad (4)$$

where Q_M is the marginal quality of a product, Q_F^N is the full quality of a product for a normal customer group, Q_F^S is the full quality of a product for a specific customer group, $f_{n,q}$ is a normal quality function and $f_{s,q}$ is a specific quality function. The specific quality represents the interaction of product functions and services: it is a measure that indicates what services are needed to make product functions for the specific customer group. In terms of product family design, this measure allows us to explore how a particular product platform can best be used to develop a family that provides high services to customer groups. The next section discusses a game theoretic approach for determining a platform design strategy.

3.4 Phase 4: Determine a Design Strategy

A coalitional game is designed to model situations wherein some of players have cooperation for seeking a goal [14]. A coalitional model focuses on the potential benefits of the groups of players rather than individual players. In the coalitional model, the sets of payoff vectors are used to represent the value or worth that each group of individuals can achieve through cooperation.

A platform level problem can be considered as a module selection problem under a collaborative situation. Additionally, the game theoretic framework provides a useful technique for evaluating strategies in dynamic market environments. To determine a product platform, we decide which modules provide more benefit based on the marginal contribution of each module.

We assume that each module in a product is modeled as a player. Then, we consider the following module selection problem. Each potential coalition can be represented as a platform design strategy and be independent of the remaining players. To determine modules for platform design, we consider the set of all possible coalitions and evaluate the benefits of different coalitions.

In order to formulate the proposed scenario as a coalitional game, we must first identify the set of all players, N, and a function, v, that associates with every nonempty subset S of N (a coalition) [14]. A real number $v(S)$ represents the worth of S and the total payoff that is available for division among the members of S. The function v satisfies the following two conditions: (1) $v(\emptyset) = 0$, and (2) (superadditivity) If $S, T \subset N$ and $S \cap T = \emptyset$, then $v(S \cup T) \ge v(S) + v(T)$. Based on the definition of the coalitional game [14], the proposed game can be defined as:

- N: players who represent (variant) modules
- $v(S)$: the benefit of a coalition, $S \subset N$

where a coalition, S, represents a potential platform design strategy that consists of several modules.

Here, we use the Shapley value to analyze the benefits of a product family and determine the product platform [26]. The Shapley value is a solution concept for coalitional games and is interpreted as the expected marginal contribution of each player in the set of coalitions [26]. Shapley value is defined as follows:

$$\varphi_i(N, v) = \sum_{T \subseteq N, i \in T} \frac{(|T| - 1)!\,(n - |T|)!}{n!} [v(T) - v(T \setminus \{i\})] \quad (5)$$

where $\varphi_i(N, v)$ is the payoff of player i, $|T|$ is the players' number in the coalition T, $T \setminus \{i\}$ is the players' coalition excepted player i, n is all players' numbers, and $v(T)$ is the payoff of the coalition T. Through the Shapley value, we can determine a platform design strategy based on the payoff of each varietal module by the marginal contribution it makes to the platform.

In the proposed approach, we use profits to evaluate players' coalitional benefits. We assume that the price of a product can increase with increasing quality. Then, for product i profit, π_i, can be formulated based on the overall design strategy quality and product cost as follows:

$$\pi_i = \Pr_i \alpha_i - \alpha_i C_i = (Pc_i Q_i)\alpha_i - \alpha_i C_i \qquad (6)$$

where, $\Pr_i$ is the price of product i, C_i is the product cost of product i, α_i is the sales quantity of product i, Pc_i is the coefficient of the price for product i, and Q_i is the service quality of product i. Hence, the payoffs of coalitions, v, can be calculated by difference between the expected profit and the current profit. The coalitional benefits for a product family based on a platform strategy, s_y, are formulated as follows:

$$v(s_y) = \sum_{i \in I} \pi_i(s_y) - \sum_{i \in I} \pi_i(s_0)$$
$$= \sum_{i \in I} (Pc_i Q_i(s_y)\alpha_i - \alpha_i(C_i + c(s_y)) - \sum_{i \in I} (Pc_i Q_i(s_0)\alpha_i - \alpha_i C_i) \qquad (7)$$

where s_0 is the current design strategy. The terms $c(s_y)$ and $Q_i(s_y)$ are estimated by the expected strategy cost function and the quality function as mentioned in Sections 3.2.2 and 3.3, respectively.

To determine the product sales quantities, we use the proportion of market segmentation grids that are covered by a product. The sales quantity of product i, α_i is formulated as follows:

$$\alpha_i = \sum_{d,e \in M_i} (\beta_{i,d} \times \gamma_{i,e} \times TD) \qquad (8)$$

where M_i is the set of the market segmentation grids of product i, $\beta_{i,d}$ is the proportion of the market segmentation grids at x-axis (d=1,2,…,D) for product i, $\gamma_{i,e}$ is the proportion of the market segmentation grids at y-axis (e=1,2,…,E) for product i, and TD is the amount of total demands for products in the market. If several products are involved in the same segments, the segment ratio of each product is calculated by the proportion of the number of the products in the same segment.

Based on the results of marginal contributions for different modules, we can determine a platform strategy based on consideration of better product sales depending on services in market segmentations. The proposed method can provide designers with candidate modules for improvement and opportunities for re-design in dynamic market environments. In the next section, the proposed method is applied to determine a platform design strategy using a case study of a family of mobile phone products.

4 CASE STUDY

To demonstrate implementation of the proposed method, a family of mobile products consisting of N73, N76, N78-1, and N79-1 is investigated from the Nokia N70 phone family. These items are shown in Figure 5. The Nokia N70 series family products provide a good example of common and variant functions for services related to vision accessibilities as shown in Table 1. These products offer the opportunity to create a product family with the vision services as common functions that constitutes the product platform.

The objective in this case study is to determine a platform design strategy represented by vision accessible services for the mobile product family subject to a dynamic market environment. This case study focuses on how to determine the marginal contributions of modules related to vision accessible services for the new platform design of the mobile product family using the proposed game at the conceptual design stage of development.

Figure 5: Nokia N70 series products [27]

Table 1: Vision accessible services for four products[1]

	Vision Services	N73	N76	N78-1	N79-1
F1	**Tactile key markers**	**Yes**	**No**	**Yes**	**Yes**
F2	Standard key layouts	Yes	Yes	Yes	Yes
F3	Key feedback - tactile	Yes	Yes	Yes	Yes
F4	Key feedback - audible	Yes	Yes	Yes	Yes
F5	Audible identification of Keys - when pressed	No	No	No	No
F6	Audible identification of Keys - feedback	Yes	Yes	Yes	Yes
F7	**Adjustable font style**	**No**	**Yes**	**Yes**	**No**
F8	**Adjustable character size**	**No**	**Yes**	**Yes**	**Yes**
F9	Display Characteristics (color display)	Yes	Yes	Yes	Yes

4.1 Phase 1: Identify Market Segments

Figure 6 shows current market segmentation grids for the mobile products with respect to vision services and market prices. The products have different vision accessibility services and market prices depending on market segments as shown in Table 1. For example, N73 covers no vision impairment and low price market. In Table 2, we can consider F2, F3, F4, F6, and F9 as common modules for the phone family. And, F1, F7, and F8 are considered as variant modules.

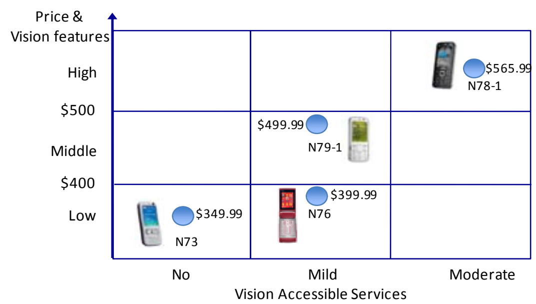

Figure 6: Market segmentation grids for the four products

4.2 Phase 2: Develop Platform Design Strategies

In Phase 2, we facilitate function configuration for developing platform design strategies by identifying relationships between functions and market segments at a conceptual design phase. Using Service and Component Matrix, we can determine the relationship between vision services and components as shown in Table 2. We consider that a cell phone consists of eleven components [28]. Among the components, we assume that a main board includes a program for supporting services.

[1] http://www.nokiaaccessibility.com

Table 2: Service component matrix for the products

Vision Services	Power converter	Power cable	Upper case	Lower case	Speaker	Display unit	Keypad	Microphone	Antenna	Main board	Battery	Components #
F1			x				x					2
F2			x				x					2
F3			x				x					2
F4			x		x		x			x		4
F5			x		x		x			x		4
F6			x		x		x			x		4
F7			x			x	x			x		4
F8			x			x	x			x		4
F9			x			x	x			x		4

To develop a new platform consisting of common modules and variant modules, we need to determine marginal contributions of the variant modules (F1, F7, and F8). The marginal contributions of modules can help decide which the services are included to a new platform for increasing benefits and accessible services in product family design. Table 3 shows service configuration strategies that consist of the variant modules for the phone product family. To determine the expected strategy cost as mentioned in Section 3.2.2, we considered the number of components that are related to vision services and use a unit additional cost, C^a, for each component. For example, since the Tactile key marker is related to two components, Upper case and Keypad, the additional cost of the Tactile key marker is $2C^a$. We assume that a factor of overhead cost and a volume penalty factor are 2 and 1, respectively. The expected strategy cost for the product family can be calculated by Equation (1). Table 3 shows the results of the expected strategy cost for the platform strategies.

Table 3: The Expected additional strategy cost for the platform strategies

Strategy	Additional component design cost					Expected additional strategy cost
	N73	N76	N78-1	N79-1	Total	
S1-F1F7	$4C^a$	$2C^a$	-	$4C^a$	$10C^a$	$5C^a$
S2-F1F8	$4C^a$	$2C^a$	-	-	$6C^a$	$3C^a$
S3-F7F8	$8C^a$	-	-	$4C^a$	$12C^a$	$6C^a$
S4-F1F7F8	$8C^a$	$2C^a$	-	$4C^a$	$14C^a$	$7C^a$

In the vision service point of view, Table 4 shows a comparison of current market segments and the expected market segments for new platform design strategies.

Table 4: Comparison to current market segments and the expected market segments

Platform strategy	N73	N76	N78-1	N79-1
Current	No	Mild	Moderate	Mild,
S1	No, Mild	Mild	Moderate	Mild, Moderate
S2	No, Mild	Mild	Moderate	Mild
S3	No, Mild, Moderate	Mild	Moderate	Mild, Moderate
S4	No, Mild, Moderate	Mild, Moderate	Moderate	Mild, Moderate

4.3 Phase 3: Identify Service Quality

Based on the platform design strategies, the expected service qualities for the products can be calculated by the value of preference as mentioned in Section 3.3. We assume that the service quality of a product is depended on the number of vision services in the product. We consider customers with vision impairment as the specific group. Figure 7 shows the functions of service quality for two customer groups. The marginal quality was determined by the number of common vision services. The full quality of the normal group was determined by the service quality of N73. While the full quality of the specific group was the maximum number of vision services.

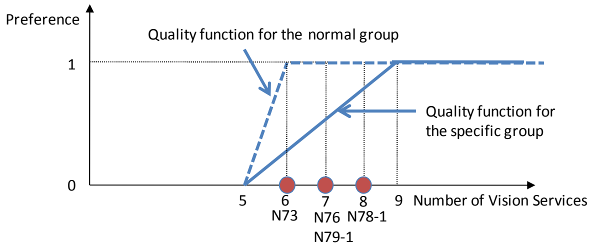

Figure 7: Preference and service quality for the phones

Table 5 shows the expected service qualities of the products with respect to vision services. The expected preference values of the products for the platform strategies are calculated by Equation (4) as mentioned in Section 3.3. For example, the expected service quality of N73 in S1 is 0.75, because the functions of N73 consist of F1, F2, F3, F4, F6, F7, and F9, and the preference values of the normal and specific groups are 1 and 0.5, respectively. We performed normalization of the value of the expected strategy quality for a product to compare current quality with strategy qualities as shown in Table 5.

Table 5: The expected service qualities of the products (normalization)

Strategy	N73	N76	N78-1	N79-1
Current	0.625 (1.0)	0.75 (1.0)	0.875 (1.0)	0.75 (1.0)
S1	0.75 (1.2)	0.875 (1.17)	0.875 (1.0)	0.875 (1.17)
S2	0.75 (1.2)	0.875 (1.17)	0.875 (1.0)	0.75 (1.0)
S3	0.875 (1.4)	0.75 (1.0)	0.875 (1.0)	0.875 (1.17)
S4	0.875(1.4)	0.875 (1.17)	0.875 (1.0)	0.875 (1.17)

4.4 Phase 4: Determine a Platform Strategy

For the case study, we assume that the expected demands for the products are determined by the result of market analysis as shown in Figure 8 and the amount of total demands for the cell phone products is 100,000. For example, the market demands of Low Price and No Impairment are is 50% and 50%, respectively. And then, the amount of demands for the product is 25,000. We also assume that the product cost of each product is 80% of the market price in Figure 6. We consider the current price of the product as the coefficient of the price to obtain a new product' price along with the normalized service quality. Revenue for each product family based on platform strategies and the expected service qualities can be calculated by Equation (7) as shown in Table 6. To determine a platform strategy, the proposed coalitional game was applied to obtain the marginal contributions of vision services.

Table 6: Revenue of current and the proposed product families (unit: $)

Strategy	N73	N76	N78-1	N79-1	Additional Cost	Total
Current	1,750,000	1,200,000	452,800	900,000		4,302,800
S1	4,550,000	1,110,000	452,800	2,775,000	$295{,}000C^a$	$8{,}887{,}800 - 295{,}000C^a$
S2	4,550,00	1,110,000	452,800	900,000	$157{,}500C^a$	$7{,}012{,}800 -157{,}000C^a$
S3	8,925,000	600,000	452,800	2,775,000	$414{,}000C^a$	$12{,}752{,}800 -414{,}000C^a$
S4	7,875,000	1,850,000	452,800	2,775,000	$483{,}000C^a$	$12{,}952{,}800 -483{,}000C^a$

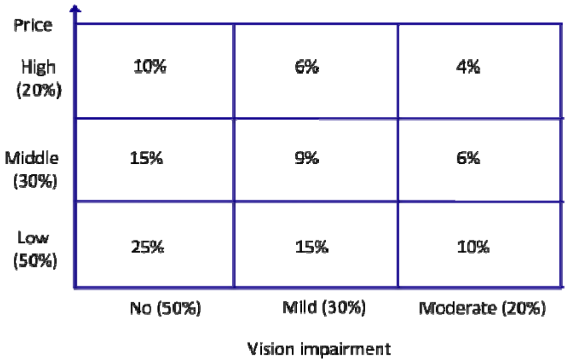

Figure 8: The Expected market demands for market segments

The game between three variant modules for platform design of this product family is defined as the proposed coalitional game that is described in Section 3.4. Table 7 summarizes the coalitional game for determining vision services with three players. To determine marginal contributions for each variant module, the coalitional benefits of the design strategies were calculated by Equation (7). Since there is no benefit in a single module design strategy according to the definition of a coalitional game, we defined four collaborations as the combination of three variant modules for design strategies. Therefore, the payoff vector of the game is $\boldsymbol{v}(0, 0, 0, 0, 4585000\text{-}295000C^a, 2710000\text{-}157500C^a, 8450000\text{-}414000C^a, 8650000\text{-}483000C^a)$.

Table 7: The Proposed coalitional game for platform design

Game	Modules for vision services
Players (N)	F1, F7, F8
Coalition (G)	G1(ϕ), G2(F1), G3(F7), G4(F8), G5(F1, F7), G6(F1, F8), G7(F7, F8), G8(F1, F7, F8)

To determine the marginal contribution of each variant module, we used the Shapley value as mentioned in Section 3.4. The Shapley values of the variant modules (F1, F7, F8) are $(1282500\text{-}986416C^a, 4152500\text{-}226666.67C^a, 3215000\text{-}157916.67C^a)$.

Based on the marginal contributions of the variant modules, we can decide a platform strategy for a family according to company's service strategy and market situations. Figure 9 shows the results of sensitivity analysis based on various additional design cost for marginal benefits with respect to vision services. Since the contributions of F1, F7, and F8 are depended on the redesign cost, C^a, additional vision services for a new platform can be selected by design constraints. For example, if C^a is less than \$13.64, we can consider the Adjustable Font Style Service as the first candidate that will be included in a new platform to increase vision services based on common components.

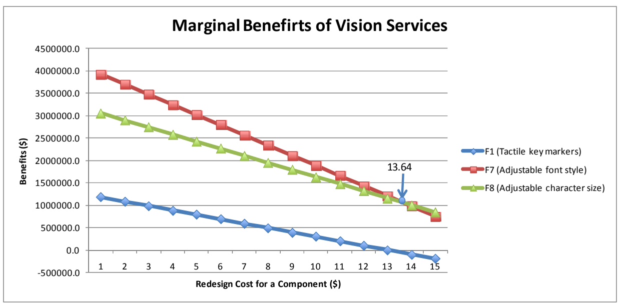

Figure 9: Marginal benefits of vision services with respect to redesign cost

Through the case study, we demonstrated that the proposed coalitional game could be used to determine a platform strategy by selecting functions that provide more benefits with respect to vision services in product family design.

5 CLOSING REMARKS AND FUTURE WORK

This research present the foundational knowledge of the field providing an economical and strategic view based on engineering design for product family and mass customization in dynamic market environments. By extending concepts from product design to service design, we have introduced a method for developing a service based platform through a game theoretic approach in a dynamic market environment. We considered a platform level selection problem as a strategic module selection problem under collaboration situation. In this game, strategies for players represent various platform design methods depending on common and variant services in a product family. Therefore, functions for designing a platform can be determined by selecting service strategies with respect to customers' preferences. We have applied the proposed method to determine a platform for a family of mobile phones in a case study. Through the case study, we demonstrated that the proposed method could be used to determine appropriate functions for a platform according to services. Therefore, we expect that the method can help to facilitate product family design based on services for different market segments in dynamic market environments.

To improve the proposed method, we need to develop a technique that can identify functional module configuration based on services and customers' requirements for establishing design strategies effectively. Since the product cost and the expected strategy cost are sensitive to estimate players' payoffs in a game, cost models are developed by product and service characteristics, company's strategies, and a market environment. Future research efforts will be focused on improving the efficiency of the method, developing product and service cost models for design strategies in various product family environments, and comparing to the proposed game with other decision-making methods for determining a design strategy in a product family.

6 REFERENCES

[1] Silveria, G.D., Borenstein, D., and Fogliatto, F.S., 2001, Mass Customization: Literature review and research directions. International Journal of Production Economics, 72(1): p. 1-13.

[2] Simpson, T.W., 2004, Product Platform Design and Customization: Status and Promise. Artificial Intelligence for Engineering Design, Analysis, and Manufacturing, 18(1): p. 3-20.

[3] Shooter, S.B., Simpson, T.W., Kumara, S.R.T., Stone, R.B., and Terpenny, J.P., 2005, Toward an Information Management Infrastructure for Product Family Planning and Platform Customization. International Journal of Mass Customization, 1(1): p. 134-155.

[4] Smit, H.T.J. and Trigeorgis, L., 2004, Strategic Investment: Real Options and Games. Princeton, New Jersey: Princeton University Press.

[5] Gunes, E.D. and Aksin, O.Z., 2004, Value Creation in Service Delivery: Relating Market Segmentation, Incentives, and Operational Performance. Manufacturing & Service Operations Management, 6(4): p. 338-357.

[6] Bollen, N.P.B., 1999, Real Options and Product Life Cycles. Management Science, 45(5): p. 670-684.

[7] Gibbons, R., 1992, Game Theory for Applied Economics. Princeton, NJ: Princeton University Press.

[8] Kratochvil, M. and Carson, C., 2005, Growing Modular: Mass Customization of Complex Products, Services and Software. Heidelberg, Germany: Springer.

[9] Meyer, M.H. and Detore, A., 2001, Perspective: Creating a platform-based approach for developing new services. The Journal of Product Innovation Management, 18(3): p. 188-204.

[10] Jiao, J., Ma, Q., and Tseng, M.M., 2003, Towards high value-added products and services: mass customization and beyond. Technovation, 23(10): p. 809-831.

[11] Peters, L. and Saidin, H., 2000, IT and the mass customization of services: the challenge of implementation. International Journal of Information Management, 20(2): p. 103-119.

[12] Li, J.H. 2004, Strategy of Mass Customization-based Services Product Innovation. in IEEE International Engineering Management Conference. Singapore.

[13] Moon, S.K., Simpson, T.W., Shu, J., and Kumara, S.R.T., 2008, A Method for Platform Identification to Support Service Family Design. International Journal of Services Operations and Informatics, 3(3/4): p. 294-317.

[14] Osborne, M.J. and Rubinstein, A., 2002, A Course in Game Theory. Massachusetts, MA: MIT.

[15] Xiao, A., Zeng, S., Allen, J.K., Rosen, D.W., and Mistree, F., 2002, Collaborating Multidisciplinary Decision Making using Game Theory and Design Capability Indices. in 9th AIAA/ISSMO Symposium on Multidisciplinary Analysis and Optimization. 4-6, September, Atlanta, Georgia.

[16] Fernandez, M.G., Panchal, J.H., Allen, J.K., and Mistree, F., 2005, Concise Interactions and Effective Management of Shared Design Spaces - Moving beyond Strategic Collaboration Towards Co-design. in ASME International Design Engineering Technical Conference & Computers and Information in Engineering Conference. September, 24-25, Long Beach, CA, Paper No. DETC2005-85381.

[17] Lewis, K. and Mistree, F., 1998, Collaborative, Sequential, and Isolated Decisions in Design. Journal of Mechanical Engineering, 120(4): p. 643-652.

[18] Huang, G.Q., Zhang, X.Y., and Lo, V.H.Y., 2007, Integrated Configuration of Platform Products and Supply Chains for Mass Customization: A Game-Theoretic Approach. IEEE Transactions on Engineering Management, 54(1): p. 156-171.

[19] Moon, S.K., Park, J., Simpson, T.W., and Kumara, S.R.T., 2008, A Dynamic Multi-Agent System Based on a Negotiation Mechanism for Product Family Design. IEEE Transactions on Automation Science and Engineering, 5(2): p. 234-244.

[20] Ford, D.N. and Sobek, D.K.I., 2005, Adapting Real Options to New Product Development by Modeling the Second Toyota Paradox. IEEE Transactions on Engineering Management, 52(3): p. 175-185.

[21] Gamba, A. and Fusari, N., 2009, Valuing Modularity as a Real Option. Management Science, 55(11): p. 1877-1896.

[22] Meyer, M.H. and Lehnerd, A.P., 1997, The Power of Product Platforms: Building Value and Cost Leadership. New York, NY: The Free Press.

[23] Simpson, T.W., Siddique, Z., and Jiao, J., 2005, Product Platform and Product Family Design: Methods and Applications. New York, YN: Springer.

[24] Kamrani, A.K. and Salhieh, S.M., 2000, Product Design for Modularity. Boston, MA.: Kluwer Academic Publishers.

[25] Magrab, E.B., 1997, Integrated Product and Process Design and Development: The Product Realization Process. Boca Raton, NY: CRC Press.

[26] Shapley, L.S., 1971, Cores of Convex Games. International Journal of Game Theory, 1(1): p. 111-129.

[27] Nokia, http://www.nokiausa.com. 2010.

[28] Holtta-Otto, K. and de Weck, O., 2007, Degree of Modularity in Engineering Systems and Products with Technical and Business Constraints. Concurrent Engineering: Research and Applications, 15(2): p. 113-126.

Session 1A:
Customers and Users

User-Centric and Contextual Interaction in IPS^2

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Abstract

In the SFB/TR29 a focus lies on Human Factors and their integration into Industrial Product-Service Systems (IPS^2) to prevent errors and malfunction due to e.g. changing structures and conditions. Thus, it is necessary to integrate adaptive, contextual and user-centric interaction techniques into IPS^2. In this article an approach is presented that enables the predictive and automatic detection of human errors and malpractice and their contextual prevention. Therefore cognitive user models, actual knowledge of the systems and the operator and multimodal human-machine interacting mechanisms are used. This approach provides the base for an efficient and error-free execution of services within IPS^2.

Keywords

Industrial Product-Service Systems, Cognitive User Models, Multimodality, Error Prevention.

1 INTRODUCTION

Industrial Product-Service Systems (IPS^2) are characterized by an integrated and reciprocal determined design, development, provision and utilization of products and services. This includes the possibility to substitute partial aspects of services and products [1] during the design and provision phases of IPS². A strict separation of both the services and the products is no longer possible. In regard to these interdependencies of products and services and the involved human operators an IPS^2 can be described as socio-technical system. Socio-technical systems comprise a structured set of humans and technologies that interact in a defined way to process a specific product [2]. They also refer to the relationships and interrelationships between technical processes and human behavior.

For IPS² this means that the subsystem human operator controls the technical system, i.e. the technical system is influenced by the social system. All information within an IPS² is carried out or supported by technical components. Also the technical system itself is content of the communication within IPS², e.g. when a component or a process have to be maintained by two distributed human operators. This shows that within the socio-technical system IPS² both partners (i.e. human and technical system) are important factors that have to be taken into consideration in all phases of the live-cycle. In sum, this leads to three aspects that are important for IPS²: (1) interaction between humans, (2) human-computer interaction and (3) interaction between technical components.

Especially in the provision-phase the first two kinds of interaction are very important because several stakeholders are part of an IPS² (i.e. service provider and product provider). The involved parties are responsible for the productivity and stability of the whole system. But each involved party has different aims (e.g. maximization of profit, security or availability) and requirements (e.g. organizational policies, procedures, structures and conditions of work). Hence, the social system of IPS² is formed by a heterogeneous group of companies, groups and individuals.

There is a need to support all involved stakeholders individually regarding the current context. This includes the interaction between all components. But the primary goal is to support all kinds of interaction involving humans. Thus a special focus is laid on human factors and the support of cognitive processing of operators while interacting. This includes information gathering and processing as well as decision-making and actions.

For this reason an approach was developed that enables the predictive and automatic detection of human errors and malpractice and their contextual prevention integrating cognitive user models, actual knowledge of the systems and the operator and multimodal human-machine interacting mechanisms. This approach provides the base for an efficient and error-free execution of services within IPS^2.

1.1 Illustrative Scenario

As an example for the motivation of the conceptual frameworks presented in this article a typical process of repairing a technical component within the provision-phase of IPS² is described as it was performed in a preceding research experiment [3]. The findings of this experiment indicate the need of contextual support of human operators within IPS² with special focus on human cognition and human factors.

The scenario of the experiment is reported briefly in the following. The aim was to repair a clamping device of a high-speed spindle for micro production that did not work properly. Concerning the provided manual the human operator has to check the steel springs inside the spindle housing and if applicable change broken springs to repair the spindle.

This scenario was conducted with untrained participants (students of engineering courses). They had to solve the problem with help of a written manual. In the manual the process of disassembling and assembling was described in several successive steps. Since the participants did not have any knowledge about terminology and necessary tools every step contained detailed information on the required tool and the corresponding interaction. In some steps graphical visualizations were included; some contained written advices for the correct handling.

The results of the experiment showed that all participants were able to follow the instructions to execute the task. But in one case it happened that against strongly advice in the manual to hold the spindle safely with one hand, a participant loosened all holding screws without holding the spindle safely. The spindle fell on the working plate and was seriously damaged. The user was not aware of his faulty workmanship, i.e. his mental processes did not fit the actual state of the technical system or the technical system did not considered the participants actual knowledge.

The described incident needs to be considered especially in socio-technical systems such as IPS². As mentioned in the introduction, IPS² are characterized by a heterogeneous group of stakeholders and individuals within a mutable and changing system. Therefore, special efforts have to be made to guarantee the use of the technical components in IPS².

In the described incident the easiest solution to overcome the mismatch between technical system and human operator could have been to control the conducting user by a second user or a technical method (i.e. supervision). Other possibilities are constructive modifications to prevent the drop of the spindle. But in both cases the individuality of human operators regarding cognition is not taken into account.

Colloquial said, it lies in the nature of human to make mistakes. Most of all learning and experience of human beings is building upon error making. In a technical sense an error means in general that the recommended and failure free procedure is interrupted and requires the intervention of the user or a supervisor. Possible reasons for wrong behavior could be (1) the user does not know the correct procedure and is trying to solve the problem using his knowledge and reasoning, (2) the user does know the correct procedure but makes the mistake by accident, (3) the user remembers wrong the correct procedures and makes the mistake by purpose, or (4) there is no procedure yet since this machine state had never occurred before and had not been described.

In all these cases the user could interact with the system in different ways either solving the problem or failing. The idea to prevent an incident by an assisting supervisor is in most cases not practical (due to costs, time and resources). Thus, it seems to be a promising approach to integrate knowledge of the human and the scheduled tasks into the technical system. This helps to supervise the behavior of operators within IPS² and allows the technical system to initiate notifications, warnings and assistance when differences occur. By this approach, all except the last action (4) could be prevented if reference patterns for the user's interaction exist.

In the following chapters, this approach of cognitive user model supported human-computer interaction and the corresponding frameworks for contextual and multimodal user support within IPS^2 are described in detail.

2 COGNITIVE USER MODEL SUPPORTED HUMAN-MACHINE INTERACTION

As shown in the previous chapter, IPS^2 integrate different stakeholders that are responsible for the technical components and processes such as maintenance, operation and provision of components. This implies a vivid and changing system during operation relating to working conditions, responsibilities and procedures. That means that employees are not able to concentrate only on a single working process or a specialized set of procedures but need to handle different tasks and working conditions (i.e. there is a need of multi-tasking). Thus, for instance, a business model change within an IPS² can lead to a change of responsibilities and tasks of an employee who has to adapt to this changes. This adaptation of the human operator to a new environment or to new working conditions involves complex and dynamic information processing (e.g., following new rules or slightly different procedures). Regarding psychological findings humans have restricted and limited capabilities and resources [4]. This has an influence on the interaction with changing environments, the amount of represented data to perform a task and the possibilities to integrate new knowledge into procedures. Especially for IPS^2 this is a critical aspect in regard to the mutability of these systems. This means that there is a growing chance of malpractice or errors in comparison to conventional systems. In order to be able to profit from all advantages of an IPS² and its universalism it is necessary to provide systems that take into account human factors and human cognition. Cognitive user model supported human-computer interaction seems to be a good candidate to provide a technical system with manageable and adaptable knowledge of human information processing and reception. This provides a base for contextual and individual support of human operators within IPS^2.

For this reason an approach that enables the predictive and automatic detection of human errors and malpractice and their contextual prevention by either adapting the technical system or by providing multimodal support methods was developed. For this, cognitive user models (i.e. optimal task models) are compared with online user behavior to reveal irregularities. Detection leads to the estimation of future consequences for the system state based on a system knowledge base and probability functions. If the benchmarking system forecasts a critical situation, suitable counter actions or support are initiated (e.g. assistance functions, adaptation of the technical system). Additionally, this approach enables human operators to access online help and contextual support that is provided by external experts through state-of-the-art service devices (e.g. head-up displays, augmented reality components).

2.1 Cognitive user models

Cognitive modeling attempts to provide symbol structures for selected cognitive processes and attempts to show that these symbol structures can generate the corresponding cognitive behavior [5]. Modeling can be done within cognitive architectures, i.e. software frameworks integrating cognitive and psychological theories, such as visual information processing, decision-making, and motor commands. For an overview, see [6]. These architectures are independent of the simulated task and its domain and require a constant task-development in time [7]. Formal cognitive user models can be applied to predict the users' behavior and future needs by simulating observable user behavior. In the case of operator tasks cognitive user models are able to simulate operator behavior for specific tasks [8]. Two levels of cognitive architectures can be differentiated: high-level and low-level approaches [9].

High-level architectures such as Goals Operators Methods and Selection Rules (GOMS; [10]) describe behavior on a basic level and define cognitive processes involved as a pre-coded sequence of human actions. In the area of usability and human performance prediction they are most suitable to investigate errors and difficulties in using interfaces. Complex phenomena as for example signal-detection or decision-making are not fully describable within high-level architectures.

Low-level architectures, for example Executive-Process/Interactive Control (EPIC; [11]), Atomic Components of Thought - Rational (ACT-R; [12]) and Soar [13], describe human behavior on an atomic level. They allow a more detailed insight into cognitive processes than high-level architectures. Most low-level architectures use production systems to simulate human processing and

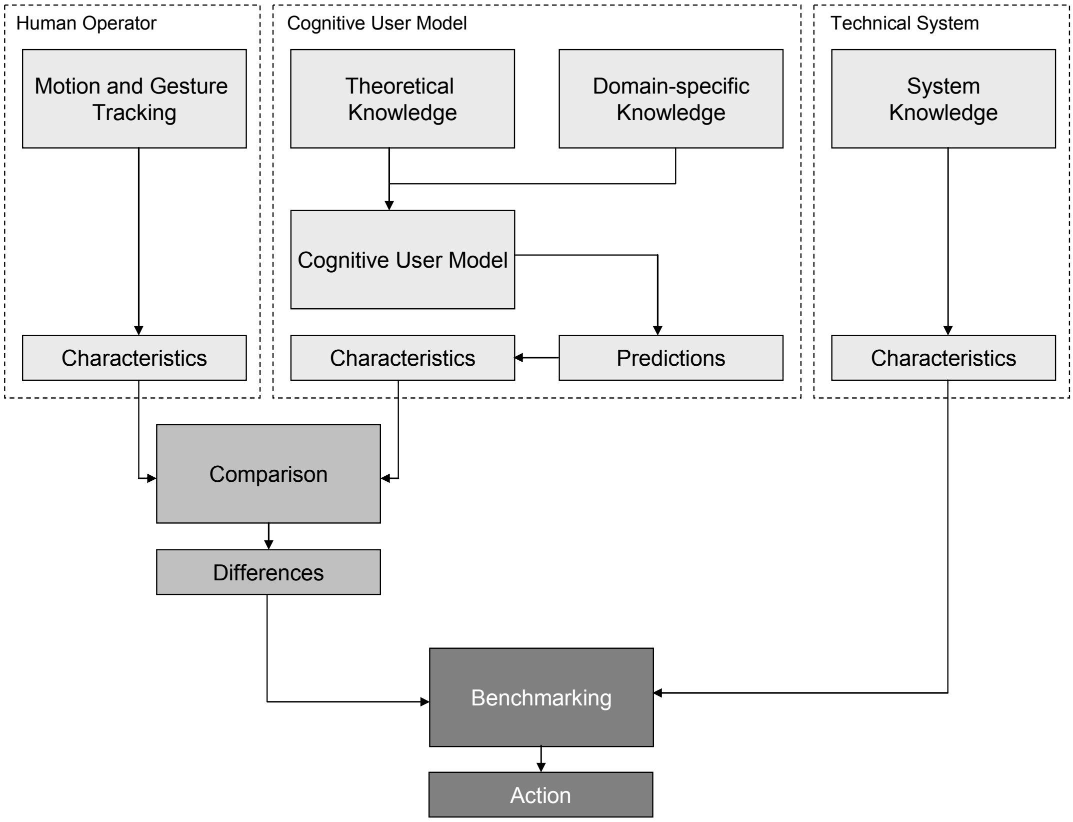

Figure 1: Conceptual framework for cognitive user model supported human-computer interaction within IPS². Illustrated are the three consecutive steps: date gathering, comparison of human and simulated data to detect differences and benchmarking of the differences in respect to the actual system state. The process ends with an initiating an action if necessary.

cognition. The use of independent production rules allows cognitive models to react on external stimuli (bottom-up processes) and to model interruption and resumption of cognitive processes. Complex paradigms (e.g., dual-tasking, decision-making, and time-estimation) and their underlying processes can be simulated with cognitive models [14, 15]. The predictions of cognitive models based on low-level architectures are more natural and take into account human complexity and dynamic.

Most cognitive user models are applied to predict user behavior offline. These models are used to evaluate alternative designs of human-computer interfaces [16]. In the context of adaptive user interfaces in some cases high-level cognitive user models are applied to predict emotions or workload of humans interacting with a technical system [17, 18, 19].

The development of high-level models to simulate and predict human cognition is a contemporary topic in the cognitive research community [20]. Simplifying the model-building process and improving concepts for sharing and reusing model components are the main objectives. Examples like ACT-Simple [9], ACT-Stich [21], G2A [22] and HTAmap [23] represent high-level frameworks that compile existing high-level models to ACT-R syntax (for an overview see [23]).

2.2 Conceptual Framework

The aim of the conceptual framework is to establish the fundamentals for contextual support of human operators within IPS^2 taking into account human cognition and human factors. This approach combines simulated operator behavior by cognitive user models with sensory knowledge of the technical system and the behavior of the operator. The technical data acquisition allows algorithms to detect critical situations based on formal online data. This approach enables the automatic initiation of supportive or provisional support actions within an IPS² by the technical system to prevent malpractice due to human errors (e.g. errors of emission or confusion).

The contextual framework consists of three consecutive steps: (1) date gathering, (2) comparison of human and simulated data and (3) benchmarking of differences in respect to the actual system state. The process ends with initiating an action whenever necessary. In the following these consecutive steps are described in more detail. The conceptual framework is illustrated in Figure 1.

In the first step required data is gathered. For online data gathering (i.e. human date and technical data) several methods and mechanisms exist. Human data can be gained by using motion or gesture tracking software and hardware. Technical data can be provided by sensors that are already integrated parts of technical systems or added for this purpose (e.g. sensors for process stability, target values and goal-orientation). For the simulation of operator behavior cognitive user models are used. These cognitive user models provide quantitative and theoretical data of ideal operators for specific tasks (e.g. eye movements, execution times) within IPS² that tend to be error-prone (e.g. changing a technical device). The data can be provided by cognitive models and used for further processing. All data is processed and defined characteristics are extracted from both the online data and the simulated data (e.g. sequences, times, cornerstones) that are provided in a general-purpose format for ongoing analyses.

The second step deals with the comparison of the simulated and the online operator data. Abstracted data of the cognitive user model is compared to online user data in real-time to reveal differences. These differences can occur for instance on the level of execution times or action sequences and provide a contextual view on the behavior of human operators.

The last step within the conceptual framework comprises the benchmarking of revealed differences in context to the actual system state. Differences between the behavior of human operator and cognitive user model are combined with the gathered characteristics of the technical system. By using machine learning algorithms pattern can be recognized in the data that allows forecasting critical situations or states of the system. These situations are benchmarked and classified using a system knowledge base provided by the IPS². That way, appropriate measures can be taken in time. For a detailed description of possible actions please refer to chapter 3.

Due to the complexity of cognitive user modeling and of human cognition this approach should be initially applied for specific tasks and could be extended in the future. Therefore a learning mechanism is integrated into the conceptual framework (not displayed in Figure 1). This learning algorithm feed backward the initiated action and its utility for the given context, the benchmarked situation and the success to the cognitive user model and the benchmarking module. The cognitive user model uses the information to update its knowledge base (i.e. declarative and procedural memory) and in this way can use the data in subsequent simulations and predictions. Analog the benchmarking module updates it knowledge base. This mechanism allows providing a system that learns and adapts itself to the user behavior and the conditions of IPS² such as multimodality and interpretability.

2.3 Discussion

The presented approach allows integrating human cognition and human factors into IPS². The conceptual framework uses cognitive user models to support human operators interacting with technical systems and to prevent malpractice or human errors. It allows for a formal integration of human aspects into technical systems. At the current state parts of the theoretical framework are developed including cognitive user models, software and hardware frameworks and algorithms to gain, compare and benchmark data from different sources. Regarding the complexity and the level of cognitive modeling decisions have to be made if high- or low-level cognitive user models should be used. Both seem to be good means to simulate operator behavior. But it is not determined on which level the comparisons between human and cognitive user model should be made. For the comparison a set of characteristics needs to be identified to compare empirical data and simulated data on both an overall (e.g. sequences) and a detailed level (e.g. eye-movements). But there are some problems concerning this point. First it has to be shown that characteristics derived from theoretical knowledge are comparable to human data. In the case of cognitive user modeling there is the need to take into consideration several levels of analysis such as the interaction within cognitive user models (i.e. between or within separate modules) and the interaction of a cognitive user model with its environment [24]. Using a multilevel approach of data analysis helps to reveal overlapping characteristics that are applicable for human and simulated data. A second problem is the huge variety of user behavior performing a task (i.e. intra- and interpersonal differences). To overcome these problems, a solution could be to provide cognitive user models of specific and formal tasks as described in the scenario that contain several procedures to perform the task. Furthermore, these models are able to extend their knowledge base and to adapt their internal processes to the captured human behavior. The last challenge is the possibility to perform the comparison in real-time. This is critical for the whole system. Without a near to real-time capable comparison of human and simulated data none contextual support based on simulated cognitive processes is possible. Regarding this problem a solution could be to either use very simple matching algorithms. Or it could be possible to predict several user behaviors and map the predictions and its preconditions to the current system and user states in order to decide an appropriate simulation as the cases arises.

3 CONDITION-BASED REGULATION

To err is human, so errors can never totally be avoided. But with efforts consequences of errors can be minimized, systems can be stopped into a failsafe mode and users can be assisted and advised before or close to the moment of making an error. An approach of how a user's interaction can be compared with a reference user model was introduced in the previous chapter. In this chapter, first examples of existing condition-based regulations will be given, and then the conceptual framework for the implementation within IPS² is introduced.

3.1 Fault-tolerance and regulation

There exist already many successful concepts for avoiding errors while interacting with machines or computers. Examples for mutual controlling in human-human interaction can be found in command bridges of vessels as well as in cockpits of commercial aircrafts (i.e. crew coordination concepts), where one person is acting and the other person is monitoring the actions. Also for human-computer interaction examples exist like in systems, which control the user's inputs and proof them for correctness and appropriateness in the current context. This can be found in software applications to avoid false inputs for example in text forms or in a more complex way in fly-by-wire systems within aircrafts. In these systems steering inputs are controlled by control laws that limit the set of commands depending on the situation to prevent undesirable conditions of the aircraft [25].

A final example for computer-computer controlling also comes from flight data computers. There, three individual computers monitor each others in a computer framework. If one system behavior is different from the remaining two, the one will be shut down to avoid unforeseen consequences caused by a malfunctioning system [26].

Daily life condition-based warnings and notifications are known from all kind of systems for example in the automotive sector. Navigation systems give multimodal warnings regarding the speed limit by comparing the movement of the GPS-sensor with the internal map data. To inform the user several mechanisms can be used such as a vibrating steering wheel, displays and spoken information. Assisting systems can already adapt to the driver's and the car's condition to reduce potential errors due to exceeding work load [27]. In the automotive sector also approaches exist for a *Context-Sensitive Error Management during Multimodal Interaction with Car Infotainment and Communication applications* [28].

Examples for systems entering failsafe mode in critical situations can be found in the area of industrial automation. Light barriers protect human operators against welding robotics or touching cutting or drilling tools. Is the light barrier broken, the machines stop or move into a failsafe position [29].

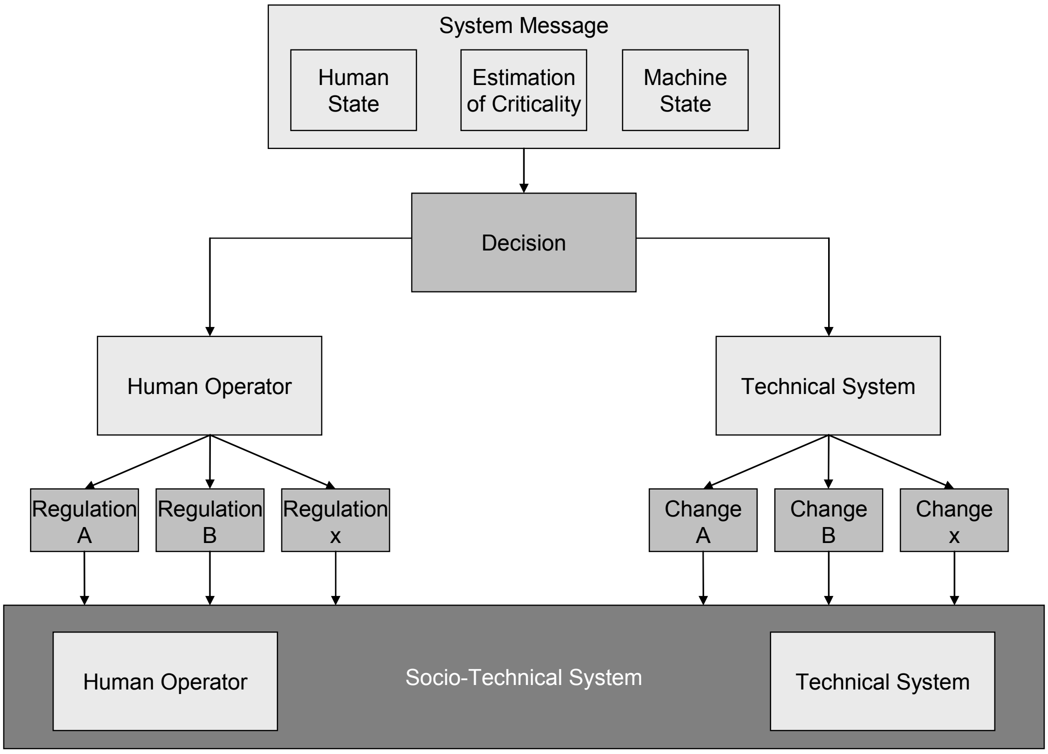

Figure 2: Conceptual framework for condition-based regulation of human-operators and technical components within IPS². The regulation is initiated by a system message about the human-operator's state, the machine's state and an estimation of the situation's criticality. The assisting system decides to regulate the human operator and/or to change the state of the technical system. This leads finally to a new state of the socio-technical system.

3.2 Conceptual framework

After the comparison of the user state with the reference model a message is generated in case of a mismatch (please refer to chapter 2). The provided message contains information on the machine state, the estimation about how critical the current situation is and the state of the human operator.

The second conceptual framework deals with the choice of an appropriate support mechanism for the human operator. This consists of three steps: (1) deciding to assign the action to the human operator or the technical system, (2) definition of the granularity of the action and (3) the accomplishment of an action. This framework is illustrated in Figure 2.

In the first step the incoming message of the pre-located system is analyzed by a rule-based decision making component. It has to be decided to regulate the user, to change the machine state or both. For example if the situation is estimated for being very critical, the machine could be stopped and the user informed about the reason.

On the second level the complexity and granularity of the future action should be made. On the human side decisions have to be made regarding the user's situation, knowledge, state and equipment. It has to be determined which modality is possible and optimal for the current state to inform or warn the user. If the user wears a head-mounted display, visual text warnings could be shown or augmented reality components could be displayed. On the machine side the processes regarding the machining can be adapted by changing the order, by re-organization the system state or stopping running processes and actions.

The third level facilitates the initiation of an action. Regulating notifications on one or even on both sides lead to a new state of the socio-technical system and thus affect both the human operator and the technical component that are computed by the first framework.

Part of the research for this realization of this conceptual framework is also the analysis of possible dependencies between the human-operator and the technical components during the regulation. Another focus lies on the selection of corresponding support systems and in the design of the regulations for a multimodal support concept.

3.3 Discussion

The presented approach enables to regulate the human user or to change the machine state dependent on the condition of the holistic socio-technical system. Prevention and assistance in malpractice has several advantages for the provision-phase within IPS². (1) The operator is protected and supported by a surrounding system and can be stopped by technical components before injuring himself or anybody else. (2) By rule of logic everything is possible after an error occurs, so the user can even do more mistakes and even impair the situation. By providing online benchmarking mechanisms all actions can be assessed and avoided by the technical system if necessary. And (3) interruptions due to human errors of planned processes, which lower the productivity and stability of processes, can be avoided by contextual and human-centric support.

A weak point of this approach is that only notifications or support information can be provided in conditions which are already known or which were supposed to occur. A second weak point lies in the system itself, wrong decisions might be made and inappropriate notifications and process changes might be executed.

For a successful implementation of the introduced concept a detailed task analysis has to be conducted, a decision rule set has to be generated and a classification of possible consequences of every task's step has to be made.

4 SUMMARY

The described approach enables a user-centric and contextual interaction within IPS². This is done by providing a theoretical base for the benchmarking of operator behavior by cognitive user models and a mechanism to initiate appropriate support actions whenever differences are revealed between the human and simulated behavior. The presented concept of condition-based regulation of operator support mimics the monitoring by an instance, which should ideally be a second and experienced human operator. The focus lies more on the assistance of the human operator than in supervision since controlling or even the feeling of it can have a negative impact on human operators.

All described concepts and theoretical accounts of this paper will be implemented, tested and evaluated in a scenario which is used in the collaborative research project SFB/TR29, i.e. manufacturing of components for watches by micro production. The concepts and frameworks offer and require various possibilities for collaboration and cooperation within the distributed research project (e.g. agent-based regulation, knowledge generation and knowledge base initiation).

The introduced approach cannot replace conventional and existing efforts to minimize malpractice of user interaction. But this approach can lead to a higher productivity of a socio-technical system and therefore will make IPS² more attractive for application since this approach offers a high flexibility and mutability of human and technical parts. The approach also does not lead to error-free interactions of operators but will probably lead to more error-tolerant systems. Consequently this will raise the usability and the use of IPS².

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] Meier, H., Uhlmann, E., Kortmann D., 2005, Hybride Leistungsbündel - Nutzenorientiertes Produktverständnis durch interferierende Sach- und Dienstleistungen. wt Werkstattstechnik online, 95. Jahrgang, 7/2005, S. 528-532, Springer-VDI-Verlag.

[2] Emery, F. E., Trist, E. L., 1960, Socio-technical systems. In C. W. Churchman and M. Verhust (Eds.): Management science, models and techniques. Vol. 2 (pp. 83-97). Oxford: Pergamon.

[3] Höge, B., Schlatow, S., & Rötting, M., 2009, A Shared-Vision System for User Support in the Field of Micromanufacturing. In Proceedings of HCI International 2009 - Posters. 855-859. Springer-Verlag Berlin Heidelberg 2009.

[4] Wickens, C. D. (1984). Engineering psychology and human performance. Gelnview, Illinois et al.: Scott Froseman and Company.

[5] Tack, H. W. (1995). Wege zu einer differentiellen kognitiven Psychologie. In Bericht über den 39. Kongress, der Deutschen Gesellschaft für Psychologie in Hamburg, Hogrefe, 172-185.

[6] Pew, R. W., Mavor, A. S., 1998, Modeling Human and Organizational Behavior: Application to Military Simulations. National Academic Press, Washington D.C.

[7] Howes, A., Young, R. M., 1997, The role of cognitive architecture in modeling the user: Soar's learning mechanism. Human-Computer Interaction 12, 4, 311-343.

[8] Dzaack, J., 2008, Analyse kognitiver Benutzermodelle für die Evaluation von Mensch-Maschine-Systemen. Dissertation. Technische Universität Berlin.

[9] Salvucci, D. D., Lee, F. J., 2003, Simple Cognitive Modeling in a Complex Cognitive Architecture. In S. Ashlund, K. Mullet, A. Henderson, E. Hollnagel & T. White (Eds.), Proc. of CHI 2003, ACM Press, 265-272.

[10] Card, S. K., Moran, T. P., Newell, A., 1983, The Psychology of Human-Computer Interaction. Lawrence Erlbaum, Hillsdale, NJ.

[11] Meyer, D. E., Kieras, D. E., 1997, A computational theory of executive cognitive processes and multiple-task performance: Part 2. Accounts of psychological refractory-period phenomena. Psychological Review 104, 749-791.

[12] Anderson, J. R., Bothell, D., Byrne, M. D, Douglass, S., Lebiere, C ., Qin, Y., 2004, An integrated theory of the mind. Psychological Review 111, 1036-1060.

[13] Ritter, F. E., Shadbolt, N. R., Elliman, D., Young, R. M., Gobet, F., Baxter, G. D., 2003, Techniques for modeling human and organizational behavior in synthetic environments: A supplementary review. Wright-Patterson Air Force Base, OH: Human Systems Information Analysis Center.

[14] Dzaack, J., Kiefer, J., Urbas, L., 2005, An approach towards multitasking in ACTR/PM. In: Proceedings of the 12th Annual ACT-R Workshop, Trieste.

[15] Dzaack, J., Trösterer, S., Pape, N., Urbas, L., 2007, A computational model of retrospective time estimation. Cognitive Systems Research Special Issue 8, 3, 208-215.

[16] Jürgensohn, T., 2002, Bedienermodellierung. In K.-P. Timpe, T. Jürgensohn & H. Kolrep (Eds.), Mensch-Maschine-Systemtechnik – Konzepte, Modellierung, Gestaltung, Evaluation (pp. 107–148). Düsseldorf: Symposion Publishing.

[17] Berthold, A., Jameson, A., 1999, Interpreting symptoms of cognitive load in speech input. Proceedings of the seventh international conference on User modeling, p. 235 – 244.

[18] Conati, C., 2002, Probabilistic assessment of user's emotions during the interaction with educational games. Applied Artificial Intelligence, 16, 555–575.

[19] Li, X., Ji, Q.,2005, Active affective state detection and user assistance with dynamic bayesian networks. IEEE Transactions on Systems, Man and Cybernetics, 35, 2005.

[20] Ritter, F. R., Haynes, S. R., Cohen, M., Howes, A., John, B., Best, B., 2006, High-level Behavior Representation Languages Revisited. In Proc. ICCM '06, Edizioni Goliardiche, 404-407.

[21] Matessa, M., 2004, An ACT-R modeling framework for interleaving templates of human behavior. In Proc. 26th Conference of the Cognitive Science Society, 903-908.

[22] St. Amant, R., Ritter, F. E., 2004, Specifying ACT-R models of user interaction with a GOMS language. Cognitive Systems Research, 6, 71-88.

[23] Heinath, M., 2009, Entwicklung einer Simulationsumgebung zur Integration von Benutzermodellierungswerkzeugen in den Systementwicklungsprozess. Dissertation. Technische Universität Berlin.

[24] Dzaack, J., Urbas, L., 2009, Multilevel Analysis of Human Performance Models in Safety-Critical Systems. Proceedings of HCI International 2009 (DVD), San Diego.

[25] Favre, C., 1996, Fly-by-wire for commercial aircraft: the Airbus experience. In Mark B. Tischler (Ed.) Advances in Aircraft Flight Control (pp 212-216). Taylor & Francis, London, UK.

[26] Brière, D., Traverse, P., 1993, Airbus A320/A330/A340 electrical flight controls – a family of fault-tolerant systems, Proc. 23rd IEEE Int. Symp. On Fault-Tolerant Computing (FTCS-23), Toulouse, France, 616-623.

[27] Bachfischer, K., Bohnenberger, T., Hofmann, M., Wäller, C., Wu, Y., 2007, Kontext-adaptive Fahrerinformationssysteme am Beispiel eines Navigationssystems. In KI - Künstliche Intelligenz, 2007(3), 57-63.

[28] McGlaun, G., Lang, M., Rigoll, G. & Althoff, F. (2004), Kontextsensitives Fehlermanagement bei multimodaler Interaktion mit Infotainment- und Kommunikationseinrichtungen im Fahrzeug. Useware 2004: Nutzergerechte Gestaltung Technischer Systeme, Düsseldorf: VDI-Berichte Nr. 1837, 57-65.

[29] Wood, R., 2007, Design Considerations for Robotic Welding Cell Safety. Welding Journal - New York, 86(7), 38-41.

Lifecycle Cost oriented Evaluation and Selection of Product-Service System Variants

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Abstract

The markets of capital goods manufacturer are dynamically changing throughout the last years. Offering Product-Service Systems (PSS) provide a promising starting point to obtain competitiveness and to realize the changed customer demands. For fulfilling the demands by PSS, an individual PSS-configuration is necessary. After this configuration process several PSS-variants are available.

The customers' investment decisions for one of these variants are mainly based on the comparison of the purchase costs, neglecting other costs, which arise over the PSS-lifecycle. Thus, for supporting the customers, the paper presents a concept for evaluating and selecting the suitable PSS by a Lifecycle Cost Indicator.

Keywords

Product-Service Systems, Lifecycle, Cost

1 INTRODUCTION

The markets of capital goods manufacturer are dynamically changing throughout the last years. Due to the cumulative merging of regional to international markets local manufacturers have to cope with an increasing amount of competitors [1]. Additionally, customers of the capital goods manufacturer are increasingly expected to be provided with holistic solutions [2]. In the capital goods industry these solutions consist of a physical product core enhanced by mainly non-physical services [3] combined in a system that deliver value in use [4]. Thus, Product-Service Systems (PSS) represent an approach for tailoring specific solutions which offer the ability to satisfy individual customer needs. Also the competitiveness of capital goods manufacturer can be enhanced [5]. In order to fulfill the customer needs by suitable PSS, an individual configuration of PSS is necessary. After this configuration process several PSS-variants are available. Further on, the customers' investment decisions for one of the offered variants have to be support by economical key figures.

2 CONFIGURATION OF PSS

Generally a configuration is defined as a process that enables the compilation (selection and combination) of pre defined physical components. Thereby, a component is described by a set of properties and shows decisive dependencies on other components. These dependencies are represented by the configuration rules [6]. Transferring this definition to the PSS-configuration means that configuration methods need to be extended, because of the characteristics of the non-physical components [7]. Thus, beyond the physical components also non-physical components have to be selected and combined. However, configuration of physical products is different to configuration of PSS. First, the existing interrelations of physical and non-physical components have to be taken into account. Additionally, the individual needs resulting from the customer specific product lifecycle have to be considered when the PSS is configured. An approach which is coping with these challenges has been developed by Aurich in 2007 [5]. At the end of a PSS-configuration process several PSS-variants exist which fulfill the needs of the customer. Up to now the investment decision for one of these variants is mainly based on the purchase costs [8]. However, the purchase costs of PSS in the capital goods industry determine just 10-50% of the whole costs arising over the entire PSS-lifecycle. The overall costs are called lifecycle costs (LCC) [9]. As a consequence, it is possible that the PSS-variant with the lowest purchase costs is not the one with the lowest lifecycle costs. Hence, the investment decision should be aligned at the LCC [10].

3 TOWARDS LIFECYCLE COSTS

For assessing the costs arising throughout the whole lifecycle the method of lifecycle costing was developed in the USA – initially for calculating the economic feasibility of complex, large-scaled projects in industrial plant construction [11]. For evaluating the costs the lifecycle has to be divided into the different lifecycle phases. Referring to the German VDI-guideline 2884 the lifecycle from the customers' point of view comprises the investment phase, the utilization phase and the disinvestment phase [12]. Within these phases there are different cost types that have to be considered, e. g. purchase costs, installation costs, operation costs, maintenance costs and recycling costs [13]. Each of these cost types can be decomposed into different sub-cost types. This decomposition is known as a cost breakdown structure [14]. Regarding to the individuality of PSS the LCC depends on different customer specific lifecycle characteristics. These lifecycle characteristics are used to describe the PSS-application, the environmental conditions during utilization, the intensity with which the PSS is used and the overall lifespan of the physical product core. Only if detailed information of the just mentioned characteristics is available a calculation of the exact LCC is possible. Up to now, it is hard to get these characteristics and to find an algorithm which can process them. Thus, a calculation of the LCC can not be realized.

4 CALCULATION MODEL FOR THE LIFECYCLCE COST INDICATOR

Consequently, the customers have to be supported by an adequate indicator to prevent one-sided investment decisions. This indicator – called lifecycle cost indicator (LCCI) – supports the customers by evaluating and selecting the suitable PSS. Although the LCCI does not represent the value of the real lifecycle cost, it enables a holistic investment decision.

Based on the described situation the following section presents a model for calculating the LCCI. The model is divided into four steps. These steps are “Identification of main cost types”, “Identification of cost determining factors”, “Identification of cost determining factor-combinations” and “Comparison and evaluation of cost determining factor combinations”.

4.1 Identification of main cost types

This step aims at the identification of the application-specific main cost types (MCT). Therefore, all costs that arise throughout the PSS-lifecycle have to be identified. Furthermore, the amount of these costs compared to the LCC has to be estimated qualitatively. Expert interviews are used to determine the cost types for each lifecycle phase and to estimate the share of these costs to the LCC. For example, experts for the utilization phase are the service technicians and the customer. Typical cost types of this phase are maintenance costs or storage costs. Three different categories are available which can be used to describe share of the costs to the LCC. A decisive cost type makes either a high (++), a middle (+) or a low (o) share of the LCC. The cost types that seem to have a high share are defined as application-specific MCT (Figure 1). Only the MCT are used to calculate the LCCI. The choice of the MCT is conducted due to the Principle of Pareto which means that 80% of the LCC are determined by 20% of the cost types. Thus, the costs that are not defined as MCT could be neglected.

4.2 Identification of cost determining factors

The amount of costs arising within a specific MCT is influenced by different factors. These factors are named cost determining factors (CDF). CDF are properties that could be assigned to the physical and non-physical PSS-components as well as to specific lifecycle characteristics. For example, the choice of a ductile tool will lead to high wear effects when it is applied in high abrasive environment. Due to this, a shortened lifespan and consequently increasing repair costs could be expected. The goal of this step is to identify the CDF of the previously defined MCT.

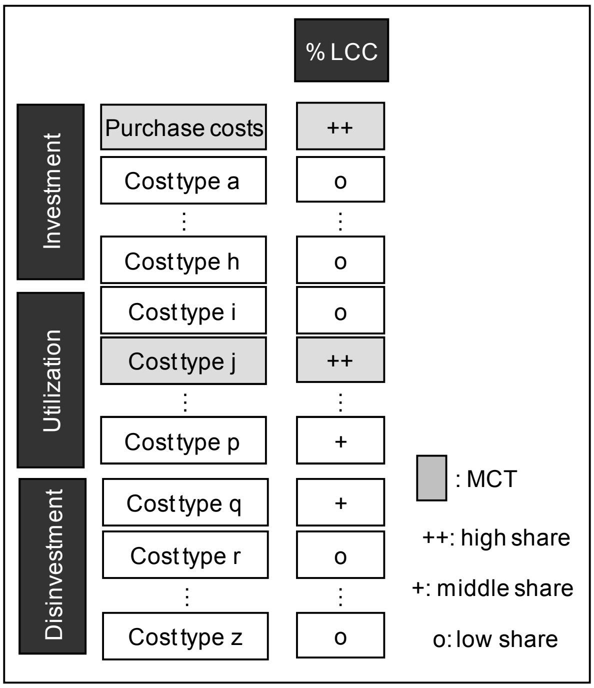


Figure 1: Phase-specific cost type list.

For identifying the CDF a matrix is used. This matrix contains all MCT (vertical line) and the identified CDF (horizontal line) (Figure 2).

In each cell the influence of the CDF to the regarded MCT has to be assessed. Three categories are available for assessing the influence – strong (++), middle (+) and weak (o) influence. A strong influence means that the value of the MCT strongly depends on the chosen CDF. If a CDF is assigned to have middle influence, the CDF shows a principle influence on the MCT, but in very low level. If no or just a marginal influence is expected, then the appropriate cell has to be marked with the symbol for a weak influence. The most important CDF for calculating the LCCI can also be identified according to the Pareto principle. Only these CDF are used in the following steps.

4.3 Identification of CDF-combinations

In the third step all possible combinations between the different CDF are generated. Therefore, the different values of each CDF have to be defined and documented. For example, a CDF for a physical component (PC 1) could be the width of the product. Concerning a cm-scale

		% LCC	Physical components				Non-physical components				Lifecycle characteristics			
			PC1	PC2	⋮	PCn	NPC1	NPC2	⋮	NPCm	LC1	LC2	⋮	LCp
Investment	Purchase costs	++	+	o	⋮	++	o	o	⋮	o	++	++	⋮	+
	Cost type a	o	o	o	⋮	o	+	+	⋮	o	o	o	⋮	+
	…	…	…	…		…	…	…		…	…	…		…
	Cost type h	o	o	o	⋮	o	o	o	⋮	o	+	o	⋮	o
Utilization	Cost type i	o	o	++	⋮	+	o	+	⋮	o	o	o	⋮	+
	Cost type j	++	++	o	⋮	+	++	+	⋮	o	++	o	⋮	+
	…	…	…	…		…	…	…		…	…	…		…
	Cost type p	+	o	o	⋮	++	o	+	⋮	o	o	++	⋮	+

++: strong influence +: middle influence o: weak influence

Figure 2: Matrix of the CDF.

	Utilization – Cost type 2					
	CDF 1 = PC 1		CDF 2 = NPC 1		CDF 3 = LC 2	
	Class 1	Class 2	Class 1	Class 2	Class 1	Class 2
Combination 1	X		X		X	
…	…					
Combination n	X			X	X	

Figure 3: Possible CDF-combinations.

by covering a width of 1,40m to 2,00m 60 different values are possible. Thereby, the quantity of combinations depends on the amount of possible values of a CDF. Because of this the quantity of combinations could increase exponentially. For reducing this quantity, several CDF values have to be classified. Regarding the mentioned width of a product the following classes could be generated:

- Class 1: 1,40 – 1,50m
- Class 2: 1,51 – 1,90m
- Class 3: 1,91 – 2,00m

A class has to be heterogeneous in contrast to other classes and homogeneous concerning the class itself. That means that the CDF-values within one CDF-class should affect the LCCI in the same way. The CDF-classes however should affect the LCCI differently. Because of this, the classification should also be done by experts. The result of the classification is a defined number of classes for each of the CDF. Based thereon, the combination is conducted concerning these CDF-classes (Figure 3).

4.4 Comparison and evaluation of CDF-combinations

Creating the scheme for calculating the LCCI is the aim of the last step. The influence of each combination of the previous step to the regarding MCT has to be relatively assessed to the other combinations. The comparison is conducted pair wise. Comparing a combination with another one, the following statements are possible:

- One of the combinations leads to lower or higher MCT (mark with "-1" or "1")
- Both combinations lead approximately to the same MCT (mark with "0") (Figure 4)

After the comparison of each possible pair, the relative weights representing the expected level of influence on the MCT for each combination could be calculated. Based on the relative weights, a ranking of the combinations could be derived.

Further on, based on this ranking combination-specific cost rates could be calculated. Therefore, the definition of an operating time depending factor – e. g. operation hours or driven kilometers – is necessary. In addition, regarding to this factor, the cost rate for the most (CR_{max}) and less (CR_{min}) cost intensive combination has to be calculated or estimated, respectively. Based on these costs and the calculated relative weights (see Figure 4) the cost rates for the remaining combinations are calculated by the following equation:

$$CR_x = CR_{min} + (W_x - W_{min}) \cdot \frac{(CR_{max} - CR_{min})}{(W_{max} - W_{min})} \quad (1)$$

where CR_x is the cost rate of combination x; CR_{min} and CR_{max} is cost rate of the most and less cost intensive combination; W_x is the relative weight of combination x; W_{min} and W_{max} is the relative weight of the most and less cost intensive combination.

The results of this step are cost rates for the MCT of each application the PSS is used for. The cost rates of every MCT are the basis for calculating the LCCI of all possible PSS-variants suitable to the customer's lifecycle. The calculated LCCI does not represent the real arising LCC, but supports the comparison of the PSS-variants and therewith the customers' investment decision.

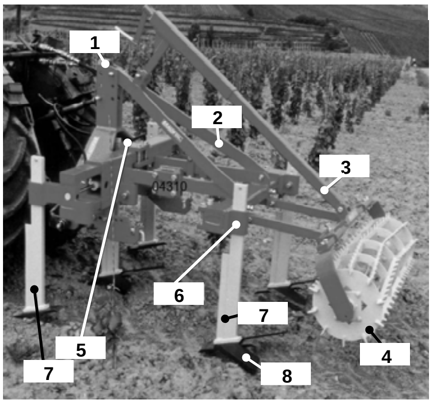
5 LCCI-CALCULATION USING THE EXAMPLE OF A CULTIVATOR

A cultivator with a rotary harrow is used for illustrating the

	Comb. 1	Comb. 2	Comb. 3	Comb. 4	Comb. 5	Comb. 6	Comb. 7	Comb. 8	Weight
Comb . 1		-1	1	1	1	1	1	1	20 %
Comb . 2	1		0	1	0	1	1	1	20 %
Comb . 3	-1	0		1	0	1	1	1	17 %
Comb . 4	-1	-1	-1		0	1	0	1	11%
Comb . 5	-1	0	0	0		1	1	1	16 %
Comb . 6	-1	-1	-1	-1	-1		0	1	6 %
Comb . 7	-1	-1	-1	0	-1	0		1	8 %
Comb . 8	-1	-1	-1	-1	-1	-1	-1		1 %

Figure 4: Pair wise comparision of the CDF-class combinations.

suggested concept. The cultivator is a tool for winegrowers basically used for loosen compacted soil (Figure 5). As to operate the cultivator it is usually mounted to a smaller tractor through which also its rotary harrow is propelled. The cultivator might be composed of various components, depending on the environmental conditions and the tasks the customer have to fulfill throughout the lifecycle. Due to this, different physical and non-physical components and therewith different cultivator variants become necessary.



1 - Under Frame	2 - Mounting Frame	3 - 3-Point Mounting
4 - Rotary Harrow	5 - Tool Holder 1	6 - Tool Holder 2
7 - Tool 1	8 - Tool 2	

Figure 5: Cultivator with rotary harrow.

The following steps have to be executed for each of the applications the cultivator is used throughout its lifecycle. In this case loosening – as the main application of the cultivator – is underlying the example.

In the first step the MCT are defined by experts of the production development and distribution in cooperation with the customer. Due to this, all cost types are gathered and their shares of the LCC are estimated. Concerning the cultivator the purchase costs, the maintenance costs, the costs for the service technicians, the storage costs and the recycling costs are defined as the relevant cost types. After the qualitative estimation of their share of the LCC purchase costs and maintenance costs are determined as the only MCT. Consequently, the LCCI is only calculated based on these two cost types.

Further on, the purchase costs are neglected, because they only depend on the chosen PSS-variant. The value of the purchase costs is calculated by the chosen physical and non-physical PSS-components. In order to identify the CDF of the maintenance costs, the physical and non-physical PSS-components as well as specific lifecycle characteristics are analyzed. Based on this analysis, the influence of the defined CDF regarding the maintenance costs is assessed. Thereby, the qualitative assessment is also carried out by experts. The following list presents the resulting CDF with its related CDF-classes:

- Tool composition
  - Strongly wearing tools
  - Weakly wearing tools
- Spare part
  - New part
  - Remanufactured part
- Soil type
  - Strongly stressing soil
  - Weakly stressing soil

Afterwards, all possible combinations of the CDF-classes are determined. For example, a strongly wearing tool composition could be used in a weakly stressing soil, whereby the customer chooses new spare parts. In this case there are eight combinations possible (Figure 6).

The next step deals with the comparison and the evaluation of the combinations regarding their influence on the maintenance costs. The combinations are compared pair wise. The underlying question is “Does the combination lead to a longer (1) or shorter (-1) lifespan or is the lifespan for both combinations approximately the same (0)?”. For example, when choosing combination 1 (strong wear, new parts, strong stress) a shorter lifespan is expected than choosing combination 2 (strong wear, new parts, weak stress). Hence, the according cell is marked with “-1”. After the comparison of all combinations the relative weights of the combinations can be computed. In the example combination 6 gets the highest and combination 3 the lowest weight (Figure 7). That means that the longest lifespan could be expected by choosing combination 6 and the shortest by choosing combination 3, respectively. The next step aims at determining the lifespan. The lifespan of a PSS assigned to combination 3 is estimated by experts with 30.000m and the lifespan of a PSS assigned to combination 6 with 50.000m. Based on these values, the lifespan of all the other combinations could be calculated by using the introduced equation. As cost rate for replacing tools by new tools 1.200,-€ is used.

CDF	Tool composition		Spare part		Soil type	
CDF-classes	Strong wear	Weak wear	New part	Remanuf. part	Strong stress	Weak stress
Combination 1	X		X		X	
Combination 2	X		X			X
Combination 3	X			X	X	
Combination 4	X			X		X
Combination 5		X	X		X	
Combination 6		X	X			X
Combination 7		X		X	X	
Combination 8		X		X		X

Figure 6: All possible combinations of CDF-classes.

Maintenance costs									
	Comb. 1	Comb. 2	Comb. 3	Comb. 4	Comb. 5	Comb. 6	Comb. 7	Comb. 8	Weight
Comb. 1		-1	1	-1	-1	-1	-1	-1	0,05
Comb. 2	1		1	1	0	-1	1	-1	0,16
Comb. 3	-1	-1		-1	-1	-1	-1	-1	0,02
Comb. 4	1	-1	1		-1	-1	1	-1	0,11
Comb. 5	1	0	1	1		-1	1	-1	0,16
Comb. 6	1	1	1	1	1		1	1	0,23
Comb. 7	1	-1	1	-1	-1	-1		-1	0,08
Comb. 8	1	1	1	1	1	-1	1		0,20

1: longer lifespan 0: same lifespan -1: shorter lifespan

Figure 7: Pair wise comparison of the CDF-classes regarding the maintenance costs.

For calculating the LCCI for each PSS-variant with strongly wearing tools and the use of remanufactured parts, additional information about the soil type of the customer is necessary. Only based on this information the appropriate CDF-combination can be identified. Assuming i. e. a strongly stressing soil CDF-combination 7 has to be used for calculating the maintenance costs. The lifespan of a PSS assigned to combination 7 is 35.714m. Considering the calculated lifespan, the intensity with which the customer will use the PSS throughout the lifecycle and the contract duration the resulting value of the maintenance costs are calculated. The LCCI of the dedicated PSS-variant results from the combination of the calculated maintenance costs and its purchase costs.

After the LCCI-calculation for each suitable PSS-variant a ranking is generated, whereas the most beneficial PSS-variants are listed on top (no. 1-3) (Figure 8). Comparing these PSS-variants to the low priced variants with respect to the purchase costs (no. 4-6) an investment decision based on the purchase costs would lead to additional costs of approximately 20%. The case study shows that the LCC oriented selection could gain an economical benefit for the customer. Especially for PSS that cause high costs throughout their lifecycle the calculation of the LCCI is recommended.

6 CONCLUSION

The paper shows how a LCC oriented evaluation and selection of suitable PSS is achieved. Therefore, a concept for calculating the Lifecycle Cost Indicator (LCCI) is presented. The calculated LCCI does not represent the real arising LCC, but supports the comparison of suitable PSS-variants. Based on this a holistic investment decision by the customer could be realized.

For calculating the LCCI some preliminary work is required. Section 4 describes this work in a structured sequence. Further on, section 5 illustrates the concept by an example. The results of the example show how a lifecycle oriented view is necessary during the investment decision. Neglecting the costs that arise throughout the lifecycle could cause economical disadvantages.

Future research will spend on key figures that are based on further aspects. These aspects could represent resource- or ecologic-specific figures. Therefore, a concept for combining these figures with the LCCI is necessary. This concept also allows to weight different key figures, so that the different customers' interests could be considered. Hence, a more holistic evaluation and selection of PSS will be possible.

No.	Physical component	Non-physical component	Purchase costs of the PSS [€]	LCCI [€]
1	UF (1000-1400mm) + MF (short)+ TL (Plow+SECHE)	5 year maintenance; 24/7; remanufacture parts	3.380	6.080
2	UF (1000-1400mm) + MF (long) + TL (Plow+SECHE)	5 year maintenance; 24/7; remanufacture parts	3.480	6.180
3	UF (1000-1400mm) + MF (short) + TL (Plow+SECHE)	5 year on-site maintenance; 24/7; remanufacture parts	3.480	6.180
4	UF (900 -1300mm) + MF (short) + TL (plow)	-	2.530	7.330
5	UF (900 -1300mm) + MF (long) + TL (plow)	-	2.630	7.430
6	UF (1000 -1400mm) + MF (short) + TL (plow)	2 year maintenance; 24/7; remanufacture parts	2.810	7.010

UF: Under Frame MF: Mounting Frame TL: Tool

Figure 8: Ranking of suitable PSS-variants.

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8 REFERENCES

[1] Fähnrich, K.-P-, Meiren, T., 2007, Service Engineering: State of the Art and Future Trends, Spath, D., Fähnrich, Advances in Services Innovations, Springer, Berlin: 3-16.

[2] Aurich, J. C., Schweitzer, E., Fuchs, C., 2007, Life Cycle Management of Industrial Product-Service Systems, Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses, Springer, London: 171-176.

[3] Aurich, J.C., Fuchs, C., Wagenknecht, C., 2006, Life Cycle Oriented design of Technical Product-Service Systems, Journal of Cleaner Production, 14/7: 1480-1494.

[4] Baines, T.S., et. al., 2007, State-of-the-art in product-service systems, Journal of Engineering Manufacture, 221 (B), 1543-1552.

[5] Aurich, J.C., Wolf, N, Siener, M., Schweitzer, E., 2009, Configuration of Product-Service Systems, Journal of Manufacturing Technology Management, 20/5: 591-605.

[6] Scheer, C., 2006 Kundenorientierter Produktkonfigurator: Erweiterung des Produktkonfiguratorkonzeptes zur Vermeidung kundeninitiierter Prozessabbrüche bei Präferenzlosigkeit und Sonderwünschen in der Produktspezifikation, Dissertation, Berlin.

[7] Maier, H., 2004, Life Cycle-Based Service Design for Innovative Business Models, Annals of the CIRP, 53/1: 393-396.

[8] Fleischer, J., Weismann, U., 2007, Interorganizational controlling of production equipment, Production Engineering, 1/4: 395-400.

[9] Datta, P.P., Roy, R., 2009, Cost Modelling Techniques for Availability Type Service Support Contracts: a Literature Review and Empirical Study, Proceedings of the 1st CIRP IPS² Conference, Cranfield: 216-223.

[10] Westkämper, E., Alting, L., Arndt, G., 2000, Life Cycle Management and Assessment: Approaches and Visions Towards Sustainable Manufacturing, Annals of the CIRP, 49/2: 501-522.

[11] Kremin-Buch, B., 1998, Strategisches Kostemanagement – Grundlagen und moderne Instrumente, Gabler, Wiesbaden.

[12] VDI e. V. (Hrsg.), 2003, VDI-Richtlinie 2884: Beschaffung, Betrieb und Instandhaltung von Produktionsmittel unter Anwendung von Life Cycle Costing (LCC), Beuth, Berlin.

[13] VDMA e. V. (Hrsg.), 2006, VDMA-Einheitsblatt 34160: Prognosemodell für die Lebenszykluskosten von Maschinen und Anlagen, Beuth, Berlin.

[14] Kang, J.-G., Brissaud, D., 2007, A Product Lifecycle Costing System with Imprecise End-of-Life Data, Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses, Springer, London: 467-472.

How to educate customers about industrial product service systems – the role of providing information

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Abstract

So called industrial Product-Service Systems (IPS²) are of growing importance in today's globalized economies. As is the case with all kinds of innovative problem solutions, however, the potential of IPS² to solve specific problems needs to be recognized by customers. It is therefore necessary for suppliers to educate about this potential by informing about IPS². As ill selected information provision might lead to rejection of IPS², adequate information strategies need to be developed. These information strategies are the main focus of this contribution. We focus on necessary steps for developing information strategies, such as the generation of knowledge about individual markets and customers. Building on this, we then develop an information model containing possible information dimensions and highlight suitable information combinations for educating customers about IPS². This model can be considered a toolbox for generating customized information strategies with regard to IPS².

Keywords

PSS information and training, information strategies, overcoming innovation barriers

1 INTRODUCTION

Industrial Product Service Systems (IPS²) could pose a solution to many problems of companies from developed industrial nations [1]. These companies are no longer able to profitably provide superior technological artefacts and complement these with product accompanying services to add value [2, 3]. Both products and added services are subject to imitation, the costs for research and development can often not be amortised owing to fierce competition on globalized markets [4]. Customized innovative product service bundles, such as IPS², can provide the competitive edge that companies are looking for [1].

However, as is the case with all kinds of innovations, IPS² can be encompassed by severe barriers to adoption. These reside in perceived risk and uncertainty on the customer side which are caused by a lack of understanding and knowledge about the innovative IPS² solution. It is therefore crucial to identify ways of communicating IPS² benefits and potentials, in order to improve IPS² adoption.

This paper deals with strategies of informing about IPS². We focus on necessary steps for developing information strategies, such as the generation of knowledge about individual markets and customers. Building on this, we then develop an information model containing possible information dimensions and highlight suitable information combinations for educating customers about IPS². This model can be considered a toolbox for generating customized information strategies with regard to IPS².

2 CLASSIFICATION OF INDUSTRIAL PRODUCT SERVICE SYSTEMS IN AN INNOVATION CONTEXT

2.1 Characteristics of Industrial Product Service Systems

The goal of offering IPS² is to establish a customer-supplier relationship which cannot be easily broken up by out-suppliers [4]. IPS² are stamped by an integrated and mutually determining process of planning, developing, provisioning, and using of goods and services [5]. This integrated development of product-service mixes tailored to fit individual customers' needs can generate entirely new barriers to imitation, allowing a company more long-term competitive advantages [4].

When it comes to the configuration of a tailor-made problem solution for an individual customer, one inherent characteristic of IPS² is of utmost importance: the possibility of partially substituting product-based and services-based components. This allows for flexible adjustments of IPS² solutions along their life cycle [6]. Such flexibility can be made use of either when suppliers recognize the possibility of cutting costs or when customers' are faced with changing business conditions, e.g. owing to market dynamics [7].

2.2 Industrial Product Service Systems as Really New Products

IPS² can inherit all characteristics of very new innovations, so-called Really New Products (RNPs) [8-10]. As is the case with RNPs, IPS² are new problem solutions to existing customer problems. This is because of the integrated planning and developing of product and service components and the flexibility option which forms part of an IPS² offer.

In contrast to common combinations of products and services, these components cannot be evaluated separately. An IPS² solution can therefore not easily be categorized into existing solution categories. Rather, they form completely new categories. This is another main characteristic of RNPs [11].

The innovative character of IPS² stemming from focusing on customer problems and providing new combinations of products and services is one of the main reasons, why IPS² can pose a central factor for long-term company success. With IPS², customers might be able to do something they have never been able to do before. This crucial role for company success is also characteristic for RNPs [8, 12-14].

As illustrated, IPS² possess the main characteristics of RNPs and can therefore be classified as such an innovation. Problems of IPS² adoption are due to their being RNPs and are discussed in the following.

2.3 Barriers to the adoption of Industrial Product Service Systems

IPS² create entirely new solution categories, as shown in chapter 2.2. Customers are therefore faced with substantial difficulties when assessing IPS², as no inferences about benefits and drawbacks can be made from other solutions of the same solution category.

These difficulties of understanding benefits and drawbacks of IPS² innovations result in high perceived risks and uncertainty on the customer side [10, 13, 15, 16], which are main reasons for innovation failure [10, 17]. The newer the IPS² solution is, the higher the potential barriers to adoption are going to be. This is due to the fact that the perceived complexity of IPS² solutions rises with their degree of newness [13, 18, 19].

Perceived complexity, in combination with the high degree of newness is also the reason why great cognitive effort is needed to understand IPS² [8]. This is another barrier to the adoption of IPS², as individuals are cognitive misers [20, 21] possess only limited cognitive resources [20, 22] and therefore try to keep the cognitive effort as low as possible. If too much mental strain is caused by the evaluation of IPS², this will have detrimental effects on their diffusion.

Against this background, marketing IPS² is a formidable challenge. Therefore, the marketing of IPS² is discussed in the following chapter.

3 MARKETING INDUSTRIAL PRODUCT SERVICE SYSTEMS

3.1 The importance of stabilizing preferences

Stability of customer preferences is especially important with regard to IPS² development. Throughout all stages, from idea generation for possible IPS² solutions to launching new IPS² in the market, a company's main goal needs to be customers' long term satisfaction [23]. To achieve this goal reliable customer feedback about their individual problems and wishes needs to be gathered. Without such feedback, true customer needs cannot be met by the IPS² developed. However, customers are often not aware of their true problems [24, 25], or do not know the true worth of a solution [26]. This is due to the fact that customers do not think in dimensions of problems, but rather in dimensions of currently known problem solutions, which already exist in the market [27]. However, if individuals cannot understand a new problem solution, no reliable preferences can be measured [28]. Consequently, when applying marketing research techniques to analyze customer feedback which triggers decisions for IPS² development, such forecasting methods are prone to fail [10]. When designing IPS² to meet requirements which do not actually correspond to customer needs, the market introduction of these IPS² will fail. Such a failure of market introduction can have devastating long term effects for the supplier company. This is because the quality of market introduction positively correlates with company success [29] as the biggest monetary losses occur during the market introduction phase [30].

Hence, stabilizing customer preferences to gather reliable customer feedback about the desired IPS² characteristics is important not only for the profitability of an IPS² and customer satisfaction, but it is also crucial for long-term company success. Stable preferences, however, depend on an adequate level of knowledge for innovative IPS², which a supplier can only create by conveying information. An inadequate choice of the information to be conveyed in combination with a lack in understanding this information are the two main barriers to build adequate preferences, which is why suppliers have to provide high quality information [22]. This is even more the case, as individuals do not chose between different solutions, but rather between different descriptions of solutions [31]. These descriptions then trigger the processing of knowledge and the building of preferences.

When dealing with the processing of knowledge research has often been based on categorization literature, whose main assumption is that product categories serve to organize knowledge rather than to make use of and apply knowledge [11, 32]. Customers might for example learn about a new laptop by categorizing it with existing laptops. As RNP by definition create new product categories, categorization cannot be applied [10]. Even consumers with expertise in the domain of RNP have difficulties understanding and appreciating the benefits of such products [33]. This is due to the conceptual distance separating RNP from previously encountered categories, which makes it extremely difficult for consumers to use prior knowledge to build their representations of these innovations [34]. As a consequence, customers need to form new knowledge structures for RNP [35].

Therefore, means of stabilizing preferences by conveying information warrant thorough investigation. The following chapter provides an introduction to the information topic, by dealing with prerequisites for successful information strategies.

3.2 Prerequisites for successful information strategies

Customer specific information is often very costly. However, as soon as the company recognizes the potential to differentiate from competitors and to stabilize customer preferences, the information strategy will be implemented among its business strategies. The first step towards a specific information strategy therefore is to build up an awareness within the company of the importance of such a strategy. This forms the basis to put the concept into praxis and requires a process of changing one's own view [36].

The next step is to gather information about the customer, which is essential to fulfill the specific information demands. The company has to gain knowledge about the customer and deduce his needs and desires. Furthermore, uncertainties and risks perceived by the customers need to be identified. These uncertainties and risks, which arise with the complexity of IPS² [17] have to be anticipated by the company to meet the information needs of the customer [36]. Through these steps the company gets to know the present knowledge and preferences of a potential customer and is then able to develop an information package, which fits the customer. With this information package the customer can be informed strategically.

These connections are shown in Figure 1.

3.3 The importance of adequately informing about Industrial Product Service Systems

As shown, informing about IPS² potentials is necessary for future IPS² success. Moreover, certain requirements such as the acquisition of knowledge about customers have to be met in order to allow for the development of information strategies. The next step on the way to suitably informing about IPS² is the selection of the right kind of information. To facilitate this choice process, relevant information dimensions are pointed out, aspects which need to be taken into consideration with regard to IPS² are highlighted.

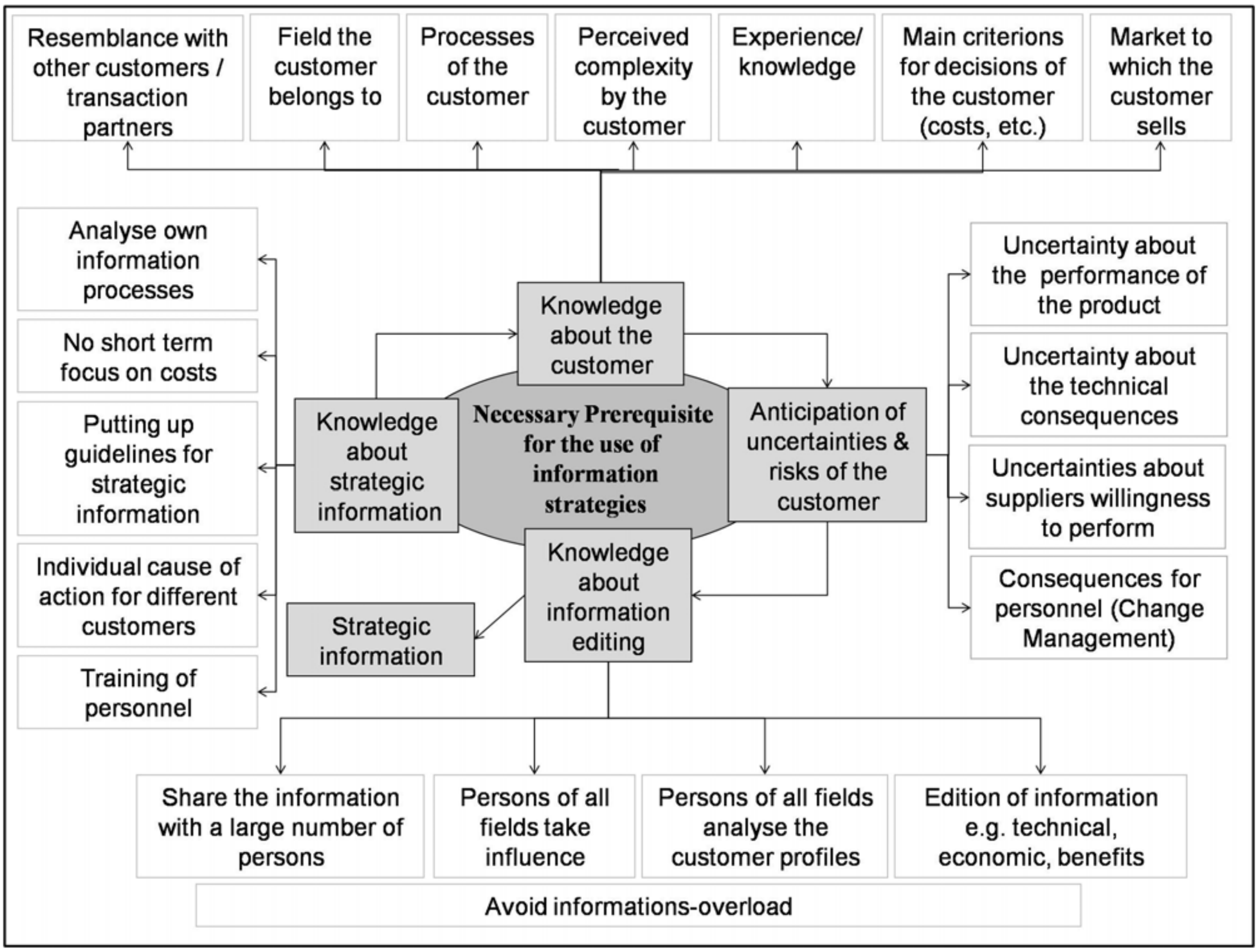

Figure 1: Strategic information

When marketing new solutions, which are sold to a customer for the first time, the amount of information which needs to be provided is higher than when marketing incrementally new solutions [37]. Furthermore, companies are generally tempted to provide the greatest possible amount of information to customers, with detrimental effects for customers' decision quality [9]. Hence, the first question companies need to find an answer to is how much information should be provided.

Another aspect which needs careful consideration is the aspect of information complexity and information detail. While explaining in detail all the aspects and technical features of a PSS might reduce the perceived risk of this PSS, it might also increase the perceived complexity and therewith strengthen barriers to IPS² adoption.

Against this background of perceived complexity and the cognitive strain going alongside with it, information dimensions need to be build alongside two dimensions:

processing information and processing tools. These are explained in the following.

Processing tools as parts of information strategies for IPS²

Processing tools facilitate the understanding of the information provided. These tools are especially important for IPS², as the potential high degree of newness and complexity of IPS² increases the cognitive strain associated with understanding these solutions. Processing tools can help alleviate this strain.

Two different kinds of processing tools are promising with regard to IPS², *analogies* [see e. g. 10, 11, 34, 38] and *mental simulations* [see e.g. 10, 39-42]. As Hoeffler (2003) [10] argues, both techniques stabilize preferences by reducing uncertainty.

In an analogy, information from a familiar domain (the base) is used to understand a novel domain (the target) [34]. New benefits may be learned through analogies to other products that provide similar benefits in another domain [11]. As an example El Houssi, Morel and Hultink (2005) [38] explained the use of the SmartPen (target), a device which biometrically identifies its user, by comparing it to a fingerprint (base).

A mental simulation, by contrast, is the imitative mental representation of an event or a series of events [41]. Customers, who are interested in buying a chainsaw might for example be told to imagine how to use and where to store it. Aspects they might previously not have considered, such as the need for sufficient space to store the chainsaw, can be stimulated by creating such mental representations of future events. The use of mental simulations is well established as a cognitive tool for making product evaluations and product adoption decisions and help customers learn about RNP [14, 43, 44]. Such visual processing mechanisms enable customers to imagine a product purchase, simulate a product experience, and to understand better the consequences of product usage [14, 44].

Hence, suppliers are faced with the question of whether and to what extend to use analogies and mental simulations when informing about IPS².

Processing information as part of information strategies for IPS²

Processing information deals with question of which kind of information to provide to customers. One can generally distinguish two different kinds of knowledge about innovative solutions, how-to-knowledge and principles knowledge [24, 45]. How-to-knowledge deals with the question of how an innovative IPS² works. It consists of information which customers need to be provided with to be able to use an innovation [24, 45]. Relevant aspects of how-to-knowledge are, amongst others, the quantity of innovation to secure and ways of using the innovation. The higher the complexity of the focal innovation is, the greater the amount of how-to-knowledge needed is going to be. When an adequate level of how-to-knowledge is not being provided, the innovation is likely to be rejected [24].

Principles-knowledge deals with the question of why an innovative IPS² works. It consists of the functioning principles underlying an innovation. Although it is usually possible to adopt an innovation without having any principles-knowledge, the danger of misusing the innovation is greater in this case [24]. Moreover, principles-knowledge should be of special importance in industrial goods markets, where only a complete understanding of the solution provided can enable customers to see how value can be created by using this solution and how problems can be solved.

Hence, IPS² suppliers are faced with the question of how much how-to-knowledge and how much principles-knowledge to provide to customers.

4 DEVELOPING AN INFORMATION TOOLBOX

In sales literature two dominant types of selling strategies are discussed, benefit selling and character selling. Using benefit selling means to inform the customer about the benefits which are connected with the different features of the product [46, 47]. In contrary to this character selling or feature selling means to concentrate on the features of the product and less on the benefits [46, 47]. As shown in a sales context customers are more susceptible to benefit selling [47].

When informing about RNP in general and specifically about IPS^2, companies must also decide which information should be delivered. The company can give information about the benefits which the IPS^2 provides to the customer, or about technical features. Giving benefit information to the customer seems to be quite suitable, as RNP deliver new benefits to customers. The customer is able to do something which he was never able to do before [8, 14]. For a successful adoption of the innovation it is necessary that customers understand how new benefits meet their needs [48]. But as customers often fail to recognize these benefits it is essential to communicate them and therefore use benefit information.

Technical information about the RNP might also be provided to customers. RNP do not only offer new benefits, but mostly do this by using a new technology [9], especially in case of IPS^2. The more complex a product is from a technical point of view, the higher are the perceived risk and uncertainty on the customer side which result from the incompetence to evaluate the technical features [15]. The customer is not able to value the performance of the product [26]. If the company succeeds in giving technical information to customers through which they understand the product, the perceived complexity and consequently also the perceived risk are diminished. Therewith, adoption barriers are reduced and customers are enabled to form stable preferences. But on the other hand there is evidence in literature that quantitative information is difficult to understand and to elaborate for individuals [49-51]. As technical information is often quantitative in nature it could make the evaluation task more complex, possibly too complex to create stable preferences. Anderson and Jolson 1980 [49] even show that as the technical level of an advertisement rises, readers perceive the product more difficult to operate.

These two possibilities of informing customers can be operationalized by the two different kinds of knowledge, how-to-knowledge and principles knowledge. As described in part 3.3 how-to-knowledge deals with the question of how an IPS2 works, principles knowledge with the question of why it works. Consequently, how-to-knowledge informs the customer about the benefits which are connected with the IPS2, principles knowledge delivers technical information [24, 45]. To successfully adopt an RNP both types of knowledge are important, the delivery of how-to-knowledge is even inevitable for the adoption. As stated in 3.3, if an adequate level of how-to-knowledge is not provided, the innovation will probably be rejected [24]. Therefore the amount of the different kinds of information provided is an important factor.

One of the key aspects in information processing of individuals is the cognitive load the customer faces. Individuals only possess limited cognitive resources [20, 22], and as they are cognitive misers [20, 21] they are only willing to use a certain amount to process information. If too much information is delivered to a customer not all information is processed and the risk is very high, that important information is ignored. Additionally, the individual uses heuristics when facing information overload which are context dependent and do not lead to stable preferences [22, 52].Therefore, the cognitive load is not only affected by the amount of information, but also by the information complexity and detail. On the other hand Backhaus and others state that in the case of selling new solutions to a customer the need of information is maximal, because the customers possess no previous knowledge [37]. Consequently the company is in an area of conflict between providing enough but not too much information.

To summarize, the dimensions of information which can be manipulated by the company are how-to-knowledge and principles knowledge, the amount of information, the detail of this information and the amount of quantitative values it contains. In addition to this the two processing tools explained in part 3.3 can be varied, mental simulations and analogies. The combination of these parameters which should be used depends on the degree of innovativeness / newness of the product. If a product is only incrementally new, the amount of information which must be given to the customer is relatively low. Customers should not have great difficulties understanding the product and therefore giving how-to-knowledge should be sufficient. The perceived complexity and the cognitive load are small. The higher the degree of innovativeness gets, the more important it is to deliver additional principles knowledge to explain the customer how the product works. Within this principles knowledge the company has to decide about the detail of the information and the amount of quantitative information. The higher the amount of principles knowledge is the higher is the perceived complexity and the cognitive load. As a high detail of information and a great amount of quantitative information also add to the cognitive load, these two should decline with the amount of principles knowledge given. Otherwise the individual will not be able to process the information properly.

Additionally, the cognitive load should be reduced by using the two processing tools mental simulation and analogies. If the cognitive load and consequently the

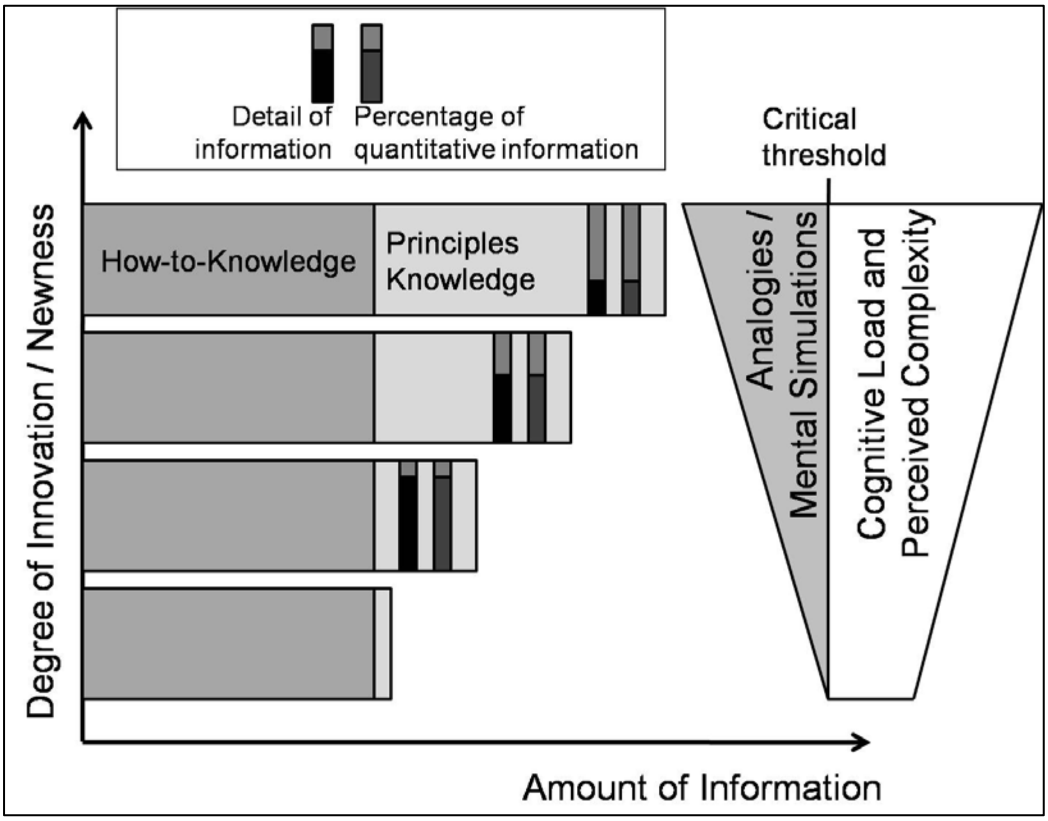

Figure 2: Information toolbox

perceived complexity increase over a critical threshold, the individual will not form stable preferences.

Therefore in case of highly innovative IPS² it is absolutely necessary to use these processing tools in addition to the given information, to enable the customer to process the information provided.

The explained connections are shown in Figure 2, which offers a helpful tool to plan customer specific information strategies.

5 CONCLUSION

As shown, IPS² could enable companies to satisfy customers' long term preferences and therewith to stay competitive in today's globalized economy. However, the potentially high degree of newness and complexity of IPS² leads to barriers to their adoption. To overcome those barriers, information strategies are needed.

This paper establishes a framework for such information strategies, which can be used as a basis for informing about IPS². To do so, prerequisites for information strategies are highlighted and relevant information dimensions are explained.

While being a suitable tool to help companies develop information strategies for IPS², our framework warrants empirical validation, e.g. through experimental testing.

Hence, further research will be build on our framework and provide such empirical validation.

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7 REFERENCES

[1] Rese, M., Karger, M., Strotmann, W., 2009, The dynamics of Industrial Product Service Systems (IPS2) – using the Net Present Value Approach and Real Options Approach to improve life cycle management, CIRP Journal of Manufacturing Science and Technology, 1: 279-286.

[2] Schreiner, P., 2005, Gestaltung kundenorientierter Dienstleistungsprozesse, DUV, Wiesbaden.

[3] Busse, D., 2005, Innovationsmanagement industrieller Dienstleistungen, DUV, Wiesbaden.

[4] Rese, M., 2006, IPS2 Cost Decisions and Price-Decisions in time of Value based management, Plötner, O., Spekman, R. (eds), Bringing Technology to Market, Wiley New York, 61-76.

[5] Meier, H., Uhlmann, E., Kortmann, D., 2005, Hybride Leistungsbündel – Nutzenorientiertes Produktverständnis durch interferierende Sach- und Dienstleistungen, wt Werkstattstechnik online, 95/6: 528–532.

[6] Karger, M., Strotmann, W., Richter, A., Sadek, T., 2008, Flexibility of Industrial Product Service Systems - an Assessment Based on Concept Modelling, 3rd Annual Conference on Business Market Management, St. Gallen.

[7] Rese, M., Steven, M., Soth, T., Strotmann, W., 2009, Profitability of Industrial Product Service Systems (IPS²) – Estimating price floor and price ceiling of innovative problem solutions, Proceedings of the 1st CIRP IPS² Conference Cranfield, 243-248.

[8] Zhao, M., Hoeffler, S., Dahl, D., 2009, The Role of Imagination-Focused Visualization on New Product Evaluation, Journal of Marketing Research, 46: 46-55.

[9] Aggarwal, P., Cha, T., Wilemon, D., 1998, Barriers to the Adoption of Really New Products and the Role of Surrogate Buyers, Journal of Consumer Marketing, 15: 358-371.

[10] Hoeffler, S., 2003, Measuring Preferences for Really New Products, Journal of Marketing Research, 40: 406-420.

[11] Gregan-Paxton, J., Roedder John, D., 1997, Consumer Learning by Analogy: A Model of Internal Knowledge Transfer, Journal of Consumer Research, 24: 266-284.

[12] Stern, T., Jaberg, H., 2007, Erfolgreiches Innovationsmanagement. Erfolgsfaktoren - Grundmuster - Fallbeispiele, 3. überarb. u. erw. Aufl., Gabler, Wiesbaden.

[13] Hoeffler, S., 2002, Conceptualizing Newness and Positioning Really New Products, Advances in Consumer Research, 29: 267.

[14] Dahl, D., Hoeffler, S., 2004, Visualizing the Self: Exploring the Potential Benefits and Drawbacks for New Product Evaluation, Journal of Product Innovation Management, 21: 259-267.

[15] Herzenstein, M., Posavac, S., Brakus, J., 2007, Adoption of New and Really New Products: The Effects of Self-Regulation Systems and Risk Salience, Journal of Marketing Research, 44: 251-260.

[16] Hoeffler, S., Moreau, C. P., Kubowicz, C., 2005, The Role of Positioning in Building Evolutionary Bridges for Revolutionary Products, Advances in Consumer Research, 32: 457-458.

[17] Ram, S., Sheth, J., 1989, Consumer Resistance to Innovations: The Marketing Problem and its Solutions, Journal of Consumer Marketing, 6: 5-14.

[18] Goldenberg, J., Lehmann, D., Mazursky, D., 2001, The Idea Itself and the Circumstances of its Emergence as Predictors of New Product Success, Management Science, 47: 69-84.

[19] Gourville, J., 2006, Eager Sellers and Stony Buyers: Understanding the Psychology of New Product Adoption, Harvard Business Review, 84: 98-106.

[20] Bettman, J., Luce, M., Payne, J., 1998, Constructive Consumer Choice Processes, Journal of Consumer Research, 25: 187-217.

[21] Henry, W., 1980, The Effect of Information-Processing Ability on Processing Accuracy, Journal of Consumer Research, 7: 42-48.

[22] Payne, J., Bettman, J., Schkade, D., 1999, Measuring Constructed Preferences: Towards a Building Code, Journal of Risk and Uncertainty, 19: 243-270.

[23] Zhao, M., Hoeffler, S., Zauberman, G., 2007, Mental Simulation and Preference Consistency Over Time: The Role of Process- Versus Outcome-Focused Thoughts, Journal of Marketing Research, 44: 379-388.

[24] Rogers, E., 2003, Diffusion of Innovations, 5. Auflage, The Free Press: New York, London, Toronto, Sydney.

[25] Ariely, D., Loewenstein, G., Prelec, D., 2006, Tom Sawyer and the Construction of Value, Lichtenstein, S., Slovic, P. (eds.), The Construction of Preference, Cambridge University Press: Cambridge, 271-281.

[26] Peters, E., 2006, The Functions of Affect in the Construction of Preferences, Lichtenstein, S., Slovic, P., (eds.), The Construction of Preference, Cambridge University Press: Cambridge: 454-463.

[27] Kothari, A., Lackner, J., 2006, A Value Based Approach to Management, Journal of Business & Industrial Management, 21: 243-249.

[28] Fischhoff, B., 2006, Constructing Preferences From Labile Values, Lichtenstein, S., Slovic, P., (eds.), The Construction of Preference, Cambridge University Press: Cambridge: 653-667.

[29] Henrad, D., Szymanski, D., 2001, Why Some New Products Are More Successful Than Others, Journal of Marketing Research, 38: 362-375.

[30] Robertson, T., 1971, Innovative Behavior and Communication, Holt Rhinehart and Whinston Inc.: New York.

[31] Tversky, A., 1996, Contrasting Rational and Psychological Principles of Choice, Zeckhauser, R., Keeney, R., Sebenius, J., (eds.): Wise Choices: Decisions, Games, and Negotiations, Harvard Business School Press: Boston, S. 5-21.

[32] Fiske and Neuberg 1990

[33] Moreau, C., Lehmann, D., Markman, A., 2001, Entrenched Knowledge Structures and Consumer Responses to New Products, Journal of Marketing Research, 38: 14-29.

[34] Gregan-Paxton, J., Hibbard, J., Brunel, F., Azar, P., 2002, "So That's What That Is": Examining the Impact of Analogy on Consumers' Knowledge Development for Really New Products, Psychology & Marketing, 19: 533-550.

[35] Moreau, C., Markman, A., Lehmann, D., 2001, "What is it?" Categorization Flexibility and Consumers' Responses to Really New Products, Journal of Consumer Research, 27: 489-498.

[36] Rese, M., Strotmann, W., Rasmussen, W., Schons, L., 2008, Wie schnürt man ein optimales Informationspaket für erklärungsbedürftige Leistungen?, 10. Paderborner Frühjahrstagung - Reagible Unternehmen in dynamischen Märkten, 26. March.

[37] Backhaus, K., 2003, Industriegütermarketing, 7. Auflage, Vahlen; München.

[38] El Houssi, A., Morel, K., Hultink, E., 2005, Effectively Communicating New Product Benefits to Consumers: The Use of Analogy versus Literal Similarity, Advances in Consumer Research, 32: 554-559.

[39] Zhao, M., Hoeffler, S., Dahl, D., 2009, The Role of Imagination-Focused Visualization on New Product Evaluation, Journal of Marketing Research, 46:.46-55.

[40] Taylor, S., Pham, L., 1999, The Effect of Mental Simulation on Goal-DirectedPerformance, Sheikh A. (ed.), Imagery and Human Development, NJ,Baywood: Amityville 253-268.

[41] Taylor, S., Schneider, S., 1989, Coping and the Simulation of Events, Social Cognition 7: 174-194.

[42] Pham, L., Taylor, S., 1999, From Thought to Action: Effects of Process- Versus Outcome-Based Mental Simulations on Performance, Personality and Social Psychology Bulletin, 25: 250-260.

[43] Phillips, D., 1996, Anticipating the Future: The Role of Consumption Visions in Consumption Behavior, Advances in Consumer Research, 23: 70-75.

[44] Shiv, B., Huber, J., 2000 The Impact of Anticipating Satisfaction on Consumer Choice, Journal of Consumer Research 27: 202-216.

[45] Binsack, M., 2003, Akzeptanz neuer Produkte, Vorwissen als Determinante des Innovationserfolgs, Gabler Verlag: Wiesbaden.

[46] Homburg, C., Krohmer, H., 2006, Marketingmanagement, Strategie – Instrumente –

Umsetzung – Unternehmensführung, 2. Auflage, Gabler Verlag: Wiesbaden.

[47] Homburg, C., Schäfer, H., Schneider, J., 2002, Sales Excellence, Vertriebsmanagement mit System, 2. Überarbeitete Auflage, Gabler Verlag: Wiesbaden.

[48] Barczak, G., Bello, D., Wallace, E., 1992, The Role of Consumer Shows in New Product Adoption, Journal of Consumer Marketing, 9: 55-67.

[49] Anderson, R., Jolson, M., 1980, Technical Wording in Advertising: Implications for Market Segmentations, Journal of Marketing, 44: 57-66.

[50] Yalch, R., Elmore-Yalch, R., 1984, The Effect of Numbers on the Route to Persuasion, Journal of Consumer Research, 11: 522-527.

[51] Burkell, J., 2004, What are the chances? Evaluating risk and benefit information in consumer health materials, Journal of the Medical Library Association, 92: 200-208.

[52] Timmermans, D., 1993, The Impact of Task Complexity on Information Use in Multi-attribute Decision Making, Journal of Behavioral Decision Making, 6: 95-111.

Product Service Systems and the Base of the Pyramid: A Telecommunications Perspective

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Abstract

The paper draws on an emerging discussion about how mobile telecommunication may positively impact development in emerging economies from a Base-of-the-Pyramid (BoP) perspective. Secondly, Product Service Systems (PSS) literature suggests this industry can contribute to reduced environmental impacts focusing on user value and stakeholder involvement. PSS and BoP literature is reviewed in the context of the "missed calls" phenomenon in developing countries. These are often intentional and used for free communication using pre-negotiated codes, providing a burden for telecom providers in terms of lost income and diminished infrastructure capacity. Based upon research at a main telecom provider, the review is input for a discussion on the most important requirements for developing alternative triple bottom line service solutions which will benefit all stakeholders involved.

Keywords

Product Service Systems, Base-of-the-Pyramid, telecom industry, missed calls, service design

1 INTRODUCTION

Product service systems (PSSs) have received increasing attention as a study object from scholars as a result of a call for more systemic views on sustainable product design, for higher factor improvements, and for more attention to the use stage in product life cycles. It calls for an understanding on the co-evolution of industrial production and social patterns, arriving at partnerships between companies and other stakeholders, including final users. Development of Product Service Systems is commonly considered to belong to the design domain [1]. Key aspects of Product Service System development include full life cycle considerations, mapping relevant actors, and understanding social structures and behaviours.

The focus of PSS development as described in literature has been on original equipment manufacturers moving away from the development of physical products only, to the development of a system of products and services which are jointly capable of fulfilling specific client demands, while re-orienting current unsustainable trends in production and consumption practices [2] with both environmental benefits (for example dematerialization) and economical benefits (the recognition that services in combination with products could provide higher profits than products alone). Some scholars associate PSS with social benefits and impacts as well. For example the replacement of a product by a service can have implications in terms of employment for company personnel at many lifecycle stages [3].

The concept of PSS has gained in usage, especially in Europe, and exemplifies the 'service economy'. However, its application to non-western regions, such as the Asia Pacific region, and especially developing countries, is a relatively unexplored area [4]. According to Ness [4], PSS has the potential not just for greening of business but also for achieving economic development, improving the lives of the poor. Social benefits in such context could for example include the manufacturing, maintenance and repair of products within local communities, generating employment for poor women.

In search of design paradigms that advocate triple bottom line product development within the context of emerging economies, the Base-of-the-Pyramid concept has received substantially more attention than PSS. So-called BOP propositions suggest the development of products and services attractive to customers in emerging economies, engaging in sustainable business ventures, generating income for both western multinational corporations and customers and partners in emerging markets. Like in the PSS paradigm, also here an important role is attributed to the role of design. Also here, understanding consumer behaviour (in particular in the context of local cultures) is an important aspect, and social benefits are focused on much more than in PSS development.

The telecom sector is one of the traditionally western market industries that has recently discovered the potential of BOP markets, and are quite successful serving them. This sector provides, in addition to PSS and BOP, a third, less scholarly, starting point for this paper: the so-called "missed calls" phenomenon that telecom providers experience in developing countries. These are calls that are terminated by the caller before the receiving party answers), and constitute a familiar phenomenon in emerging mobile markets across Africa and Asia [5], providing a burden for telecom providers in terms of lost income and diminished infrastructure capacity.

Goal of the paper

This paper aims to review the utility of BOP protocols in the context of the telecommunications industry wishing to contribute to sustainable service development for emerging economies in a commercially attractive way, and to bring together PSS and BOP methodology in a joint application arena. Section 2 will provide background knowledge on BOP, and section 3 will discuss the telecom industry's increasing interest in emerging markets, as well as the challenges that exist in doing so. Section 4 will zoom in on the 'missed calls' phenomenon, and discuss challenges and opportunities from a design perspective. Section 5 concludes with a discussion and directions for further research.

2 THE BASE OF THE PYRAMID

In 2005, well-known scholar CK Prahalad, alongside Stuart Hart, launched his ideas on what has become known as the “Base of the Pyramid” principles. In his book “The fortune at the bottom of the pyramid: Eradicating poverty through profit”, he explains how treating the poor as consumers instead of victims, can eliminate poverty [6].

Prahalad, a well-known academic, management consultant and author of several best selling books, has been working on how to eradicate poverty for several years. He disagrees with earlier stands on how to eradicate poverty, such as a large increase, “a Big Push”, in Western foreign aid that would help ensure the successful economic development of the poorest countries, as advocated by Sachs [7]. Sachs’ reasoning is that people at the base of the pyramid need their entire income or more just to survive, and as such have no money that can be invested in the future. This makes the poorest to become trapped in poverty, with low or negative economic growth rates. Without the possibility to accumulate capital, they have no means to pull themselves out of this down wording spiral. Only if the gap between what they can afford and what they need is closed, the poor countries can “break out of their poverty trap and begin growing on their own”. Prahalad instead feels that development aid has totally failed to solve the problem of poverty. Corruption has made very few people in those developing countries very rich while most have not gained any help at all. He argues that it has become strikingly evident that development aid, charity or 'global business-as-usual' would not deliver solutions to poverty as had been expected.

Prahalad, together with Stuart Hart, further developed his ideas based on market-based solutions rather than foreign aid and illustrated them with a number of cases in his book “The Fortune at the Bottom of the Pyramid”, with as subtitle “Eradicating Poverty through Profits”. He explains how treating the poor as consumers instead of victims, can eliminate poverty. Because of their large numbers, Prahalad claims that the poor represent a big potential buying power. By treating the poor as consumers instead of aid recipients, the poor will get access to better and cheaper products and services, a higher sense of dignity and value and thus the ability to climb out of the poverty trap.

Prahalad and Hart state that multinational corporations (MNCs) have ignored the fact that there is an unknown and unexploited fortune at the base of this economic pyramid. By turning their attention towards the poor in the world, there are possibilities of large economic profit. Large firms tend to assume that people at the bottom of the economic pyramid have no assets to spend beyond basic necessities such as water, food and shelter. They also assume that illiteracy, poor infrastructure and unstable governments make the BoP a difficult market to build a profitable business in. Prahalad contradicts these assumptions by showing that many MNCs already have started successful and profitable projects in these markets.

2.1 Criticising the Bottom of the Pyramid proposition

Prahalads claims about poverty being a means to alleviate poverty by simply targeting the poor as consumers, has met a lot of criticism for being unclear about the mechanisms that link this to actual poverty reduction [8]. Oosterlaken [9] warns that it should not too easily be assumed that a win-win situation of profit plus poverty reduction arises whenever a company successfully introduces an innovative product or technology in a developing country. When people are living in acute poverty and struggle even to meet their most basic needs, they cannot possibly be viewed as a profitable market for large corporations [10].

Walsh et al. point out that Prahalad is so consistent to showing the positive effects of his BoP propositions that he only presents success stories in his book [11]. Prahalad himself states that his *“… book is concerned about what works. This is not a debate about who is right. I am less concerned about what may go wrong. Plenty can and has. I am focused on the potential for learning from the few experiments that are going right. These can show us the way forward.”* Walsh counter replies saying that if so many projects have gone wrong and so few have succeeded, it is even more important to figure out the difference between a success and a failure.

2.2 The poor as consumers: market challenges

A dilemma occurs when looking at the poor as consumers. The BoP proposition does not differentiate between priority and non-priority areas [10]. Prahalad even argues that BoP is a lucrative market for “luxury” goods, saying, “We should not assume that the poor are too concerned with fulfilling their basic needs to ‘waste’ money on non-essential goods.” Still, the BOP proposition could lead to poor people spending the little money they have on television, cell phones and shampoo, instead of higher priority needs such as education, health and nutrition [8].

This leads to a problem introduced by Jaiswal [10] as undesirable inclusion and exclusion. When giving poor the opportunity to buy e.g. single cigarettes instead of a whole packet, it includes them in a market that perhaps never should have been opened for them as it is beyond their real needs. Karnani examines this moral dilemma with the sales of a popular skin-whitening cream sold in India. Hammond and Prahalad [12] introduce us to this product by telling how a poor woman, having had the opportunity to buy this cream, feels that she has “a choice and feels empowered because of an affordable consumer product targeted at her needs.” Karnani feels that this is not empowerment. Yes, Unilever, the producers of this skin-lightening cream have the right to make a profit of the sales and women have the right to buy this cream, but Karnani feels that the BoP proposition goes too far by commending the company for empowering women and helping eradicate poverty. Prahalad disagrees by arguing that the poor have the right to decide themselves how to spend their money, and that it is patronizing and arrogant for anyone else to decide what is best for them. But Karnani states that the poor are vulnerable and easily exploited, lacking education (often being illiterate) and proper information, and are thus not always able to make choices that are in their best interest [8].

Informal economies

The vast majority of people at the base of the pyramid operate within the large but hidden informal economy. These economic activities do not appear in official GDP or PPP statistics [12]. While the informal economy in developed countries is mainly due to tax evasion, in the developing world it is simply too complicated and costly to enter the formal economy. De Soto [13] found that it took 289 days and $1231 to register a business in Peru. These disadvantages encourage the poor to operate in the extralegal economic sector.

Within this informal economy, rules are not based on laws but on social contracts. Social boundaries are stronger and more respected than formal legal documentation [13]. To successfully operate in these informal markets, organizations need to respect and appreciate the benefits they entail. For example, the most successful micro loan programs have relied on group lending and peer pressure to ensure payback [14].

In his book “The Mystery of Capital”, De Soto challenges the assumption that poor people are in fact poor. He claims that the poor in the developing world are often asset-rich but capital-poor. They often possess land but lack the formal titles, preventing them from obtaining the full value of the possession, as they cannot use their land as collateral to obtain loans. The microfinance movement attempts to close this glitch, but according to Khawari [15] it might do more harm than good. Unwilling to invest in new technology, the poor fail to earn a greater return on the investment than the interest they must pay. Prahalad embraces the idea of the poor as entrepreneurs, but the fact is that most microcredit clients would prefer a factory job if it were available [16].

In many developing countries, laws are constantly being subjected to new regulations. These are enacted at such high speed that the system may be difficult for people to understand. As a result of chaotic legislations, corruption infiltrates all levels of bureaucracy. The consequences of the fast growing legislation of micro regulations can be just as bad as not having laws at all making an informal business sector emerge beyond reach of the chaotic world of laws, regulations and corruption. Another variant of the phenomenon is that the laws are underdeveloped giving bureaucrats the opportunity to interpret laws in their own favour [17] This situation does cause large firms to have an aversion to operate in markets at the base of the pyramid [6], but makes it complicated for local firms as well to engage in formal economical activity.

Sachs [7] argues that it is the poverty trap that explains the low economic growth in poor countries instead of corrupt governments. He argues that the poor are able to govern themselves responsibly and that any help they may receive is used for the benefit of the group, rather than pocketed by powerful individuals. Easterly [17] disagrees with Sachs and claims that there is a strong correlation between per capita income and corruption. While Sachs classifies countries as well-governed if their corruption is low for their level of income, Easterly argues that their level of income is low because of they are corrupt.

2.3 The poor as consumers: market opportunities

The other side of the coin learns that in spite of being challenged by income, resource, and informal economy constraints, BoP consumers are sophisticated and creative. Donaldson [18] discusses how BoP consumers are motivated not just by survival and physiological needs but seek to fulfil higher order needs either to build social capital, for cultural reasons or as a means to compensate for deficiencies in other areas of their lives. This is important to understand for those who want to operate on BoP markets. Building bonds with community and higher order needs such as self-esteem and self-fulfilment may be a key to success in BoP market initiatives. In BoP communities, social harmony, group loyalty and group recognition are so important that they even supersede physiological needs, providing a hierarchy of needs context different from Maslow's.

2.4 Telecommunication for development; the digital divide

The role of ICT in general and telecommunication in particular when considering effective development incentives is increasingly being discussed among scholars [19-21]. Considering the aforementioned challenges of poverty reduction, the lack of affordable access to relevant information and knowledge services is a major barrier for development, especially with the development of the global knowledge-based economy. The term digital divide refers to the gap between people with effective access to digital and information technology and those with very limited or no access at all. It includes the imbalance in physical access to technology as well as the imbalances in resources and skills needed to effectively participate as a digital citizen. With the developed world making huge knowledge and information leaps, continuously strengthening their competitive advantage, how will the underdeveloped world ever be able to keep up?

There are several reasons why telecommunication is considered the most appropriate technology when attempting to close the digital divide [22]. First, due to its unique characteristics, mobile technology is an especially good leapfrogger, eliminating the need to rely on physical infrastructure such as roads and phone wires, with base-stations powered using their own generators in places where there is no electrical grid. Second, mobile phones only require basic literacy, especially important in developing countries with high illiteracy levels. Finally, due to factors like increased private sector competition and innovative payment methods, mobile phones are increasingly affordable to the lower strata of the population and thereby can be used as a mechanism to ensure greater participation of these groups in the development process.

As mobile penetration rates increase rapidly in developing countries, there has also been an increase in the extent of research on telecommunication for development. A study by Deloitte [23] concludes that an overall increase in mobile subscribers by 10% increases BNP in developing countries by 1.2%. While scholars generally agree upon the value of telecommunications at the BoP, there is still a lack of evidence on how this mobile product service system works as a tool to solve development problems, due mainly to the difficulty in measuring their social and economic impacts [24]. A thematic research approach focused on the different developmental domains could assist in determining the sectors or areas where mobile phones can have the highest developmental impacts.

2.5 BOP and designers

Over the years, designers have played active roles in so-called poverty-alleviation and Base-of-the-Pyramid projects, supporting these and other strategies. Designers are experts in understanding needs, communicate between professions and combine these findings in product and service solutions. As cultural differences, affordability issues, scarce access to resources and in some cases unstable political systems are challenging factors when addressing product, system, or service-oriented solutions, the creative thinking and innovative experimentation embedded in designers' work methods have been found to support project goals considerably.

Design manuals for projects in developing countries

Whereas an abundance of sustainable design manuals exist, attention for design guidance in the specific context of developing countries has only emerged recently. Cooperation between Delft University of Technology and the United Nations Environmental Programme has been instrumental here. Crul and Diehl [25] point out that, whilst there is considerable experience accumulated in the field of product innovation in developed countries, much of this is not directly applicable to developing countries. Innovation climates in developing countries are, by nature, problematic, characterized by poor business and governance conditions, low educational levels, and mediocre infrastructure, challenging the promotion of innovation in these contexts. Most of the current available sustainable design manuals and tools are based upon European experiences. However, in developing economies needs are different and more immediate. Also the characteristics of the local companies and product innovation approaches differ because of specific local social, economical and industrial development aspects. Often micro, small and medium enterprises companies dominate the economy as well as the labour market. A structured product development process often is lacking.

These insights have led to the development of Design for Sustainability manual specifically targeted at developing economies [26], which was an adaption of the United Nations Environment Program (UNEP) Ecodesign manual [27], which was mainly based upon experiences in Europe and the United States. In a nutshell, the new manual is adapted to the context of developing economies in terms of an increased focus on internal drivers, higher priority to cost savings, educating in elementary product development principles and the inclusion of simple to understand tools that do not require extensive knowledge on underlying sustainability principles.

3 WIRELESS CARRIERS AT THE BOP

3.1 Telecom sector approaching the BoP

The BoP proposition considers the saturation of western markets one of the most important motivational factors among multinational corporations searching for future growth. In the case of the mobile telecommunication, with almost every western citizen already a mobile subscriber, the growth of new subscribers has seized. Developing countries on the other hand consists of billions of underserved customers, making them a major potential source for continuing growth. The requirements of a growth economy have led every major telecom player searching for the fortune at the base of the pyramid, and it appears they have been rather successful at it as well. There has been a rapid growth of mobile phone networks in developing countries, with the average number of mobile phones per inhabitant raised by 100-400 % in a span of just five years [28]. With other businesses struggling to generate profit at the BoP, how come the telecom industry appears to thrive in this market?

To better understand why the telecom sector is ideal for BoP ventures, the BoP market requirements proposed by Prahalad are drawn upon here. He states that the basic economics of the BoP market are based on small unit packages, low margin per unit, high volume and high return on capital employed. Mobile technology requires very little physical infrastructure, and once in place it has the potential to serve large volumes without generating significantly increased costs, this allowing them to further reduce service cost. Innovative payment methods such as prepaid solutions also make mobile services accessible to the poor. These elements have made many developing countries skip fixed wire communication, leapfrogging into the mobile world [24]. Currently mobile telephony is the predominant mode of communication in the developing world. While developing countries are still lagging behind high-income countries in overall ICT usage and applications, the mobile phone has been regarded as a more accessible and less expensive means to close the digital divide [29].

3.2 Missed calls; a challenge for product service system development

Traditional BoP literature emphasizes the need for radical innovation in order to create sustainable business ventures in developing countries. It has been discussed why mobile technology is especially suited for doing business at the BoP, and seen payment methods that assure affordability in low-income markets. But what about product service system innovation? It could be argued that the vast majority of all telecom products and services offered to the BoP are mere adjustments to the ones offered in western countries. Do the advantages of mobile technology make it ideal all over the world?

During the last few years, the widespread usage of SIM switching and intentional missed calls has received increasing attention among scholars and wireless carriers [22,30]. SIM switching implies that mobile users possess several SIM cards, and alternate between them to obtain the best possible service offering depending on the task to be performed.

Missed calls are placed to a number where the caller intentionally hangs up before the receiver answers the call. These calls often communicate simple, prearranged messages, but the phenomenon is increasingly evolving towards social networking and gaming. This development has placed enormous stress on the network capacity, with peak usage upwards of 70 % of total network traffic [5], causing network congestion while generating zero revenue for wireless carriers. This recent development could indicate that if product service systems are not specifically developed with the end user in mind, the BoP will make creative use of the available technology and develop free, easy to use ways of communicating.

The telecom industry is currently considering regulatory ways of reducing these intentional missed calls through charging for missed calls, or removing the caller ID from the missed calls log. While an obvious solution to the problem, there are a number of potential pitfalls that could severely damage brand identity and market acceptance. The challenge is therefore to develop solutions that not only benefit the telecom sector but also equally benefits other stakeholders, such as users, government and non-governmental organizations? In the next section it is considered how drawing on methodologies for product service system development may offer input to the described design challenge.

4 OPPORTUNITIES AND CHALLENGES FOR DESIGNING SERVICE BASED SOLUTIONS IN RESPONSE TO THE MISSED CALLS PHENOMENON

One of the early challenges in a design process targeting telecom services for the BoP is the selection of appropriate tools and methodology. Both BoP and PSS literature contribute with valuable insights that can be applied to service oriented design processes within the telecom sector aiming at emerging markets. The BoP protocols focus on the development of viable business concepts in cooperation with the poor, consider business models and local market knowledge. PSS literature focuses on identification of customer value, early involvement of the customer in the system, effective communication, information sharing, and continuous improvement. A key aspect in the fulfilment of customer needs is the addressing of perspectives, needs and activity cycles among all relevant stakeholders, which may result in non-conventional combinations of physical artefacts and services to fulfil those needs. PSS methodology also stresses the importance of a company having to move from ‘product thinking’ to ‘system thinking’, and having to break down the ‘business as usual’ attitude [31].

Both concepts share a sustainable ambition, although this ambition is more socially driven in the case of BOP, and more environmentally driven in the case of PSS. Combining these two perspectives could contribute significantly to an overall methodology for product service systems development targeting the BoP.

The next section summarizes a number of main elements from PSS and BOP methodologies that are considered meaningful input into the design brief for developing a solution to the missed calls phenomenon. They include stakeholder mapping, stakeholder involvement, focusing on user activity cycles, and avoiding business as usual.

4.1 Stakeholder mapping

Stakeholder mapping is a crucial part of PSS methodology in order to develop mutually beneficial services. Donaldson et al. [32] propose a tool named customer value chain analysis (CVCA), which enables design teams to comprehensively identify stakeholders, their relationships with each other, and their role in the product's life cycle. Similarly, BoP protocols emphasize the need for cooperation with partners familiar with, or preferably embedded in, local communities, to understand local priorities and to avoid mistrust. Operating in close proximity to, or within, the local communities at the same time enables mapping stakeholders relevant to the actual service development. Stakeholder needs are a fundamental element in general design methodology, implying that researchers and designers should engage with the cultures directly to avoid false or second-hand assumptions [33,34].

4.2 Understanding users and their activities

In addition to stakeholder mapping or network analysis, Sakao et al. identify value creation and focusing on the customer as a central aspect in all of the concepts within PSS [35]. One fundamental challenge when designing for the BoP is probably the term BoP in itself. Such a strong demographic label could lead designers to believe that the BoP is a homogenous group of customers, when it in fact is nothing but a label on the four billion people at the bottom of the economic pyramid. The dumbest mistake to make would be to generalize customer values, needs, abilities, customs and cultures across the BOP. With that being said, there are some general characteristics of the BoP that could prove valuable, especially in the initial stages of the design process.

Naturally, living at the bottom of the economic pyramid implies that the cost of telecommunication is of great importance. The missed calls phenomenon clearly shows the creativity of the BoP in order to reduce cost and take advantage of technology in more cost efficient ways. The task of competing with a free service is naturally a challenge, but the resulting increase in network capacity could be a sufficiently strong motivational factor for operators to support solutions that simply channel this behaviour in less network intensive ways.

With parallels to the early days of telecommunication in developed countries, missed calls were initially used for conveying short messages for free, and is still practiced to some extent today, like "I'm outside, open up", not necessarily due to cost efficiency, but for more practical reasons (quick and efficient). It is also common to exchange phone numbers through leaving a missed call on the phone of the person in question. In developing countries this behaviour has evolved towards a mobile language where missed calls are understood only in the context of the persons communicating, like a missed call in the morning could mean "I love you" if is from a boyfriend, "you're late for class" if it is from a classmate and "call me back" if it is from a younger sister.

Another important element of missed calls is the uniform appearance a missed call has. It has no meaning outside the context of the two persons communicating, and can therefore easily be explained as something less meaningful than it really is, like girls communicating with their boyfriends, or a random call intended for communicating with strangers, but with the ability to explain it as a wrong dial. The freedom of not having to compose a personal message is also mentioned as a major strength of missed calls.

In a Bangladesh case study [5], it was found that additional motivational factors (beyond missed calls being free) may range from practical motives (easy, fast), entertainment (missed call competitions, the other person tried to receive the call before the first hangs up), social and relational motives (missed calls providing a unique private space where socially forbidden behaviour can be practiced), or even the opposite: social control (indicating that all is well, or keeping a phone line busy to prevent others from calling).

Such analyses of customer needs and wants are crucial for designing an attractive substitute for missed calls; without a thorough understanding of the strengths and weaknesses of the communicative properties of this concept, possible alternatives may not be successful.

Customer value in the case of mobile phone services for the BOP may have to take into account the illiteracy aspects of prospective customers. Nokia suggests design solutions including iconic user interfaces, a speaking clock, an iconic phonebook and audio messaging [36].

Another aspect to consider, as it constitutes a general difference when comparing western telecom markets to that of the BoP is the percentage of phone owners. While a large majority of the BoP uses mobile communication on a regular basis, only a small percentage actually owns a phone. The concept of SIM-switching, allowing users to insert SIM-cards in community or friends' phones, is another consequence of non-ownership. Beyond accessing personal contact information, messages and the ability to leave missed calls from a number familiar to the receiver, it also implies an increasing market for services embedded in the SIM-card as this is the only true possession of the poor. Operators offering more SIM-based services are more likely to become what is known as the primary SIM, the SIM-card preferred by the user the majority of the time.

4.3 Stakeholder involvement

In order to develop successful projects at the BoP, apart from understanding the needs and capabilities of the poor, one of the key metrics is, according to the BoP literature, to co-create new business ventures with them that mutually benefit everyone involved. This correlates well with the evolution of PSS methodology towards a more user-involved design process. Reviewing the perceived benefits of such involvement in light of the BoP, it was found that user education, improved public relations and the creation of long-term relationships especially valuable [37]. With the poor involved in the actual shaping of a new service, less emphasis is needed on educating innovators and early adopters, creating market acceptance and maintaining a long-term commitment to the new service.

However, BOP literature suggests that the consideration of a range of other stakeholders is crucial as well.

For-profit stakeholders

Wireless carriers, terminal manufacturers and smart-card manufacturers work closely to develop product service systems. One of the current challenges between these players is the blurring of business boundaries. Increasingly, wireless carriers offer their customers SIM-based services developed in collaboration with smartcard manufacturers, thus interfering with the interface of the terminals. In response, terminal manufacturers hesitate to include the necessary tools enabling the SIM-card to communicate fully with the terminal. This development could in turn lead several wireless carriers to develop proper terminals in order to offer their customers a more seamless product service system [38]. This mix of agendas leads to considerable challenges when choosing appropriate platforms and developing appropriate technology for future telecom services.

Not-for-profit stakeholders

A community based organization, i.e. a non-governmental organization, could play a critical bridging role at the start of a project and help facilitate new relationships between designers and the community. They are often embedded in the local communities, with strong social ties to make both the introduction to the local communities and the selection of local resources run smoother [39].

Government and development initiatives

Several stakeholders could provide important contributions to the design of new services through their own agendas and potential use of telecommunication for governmental and developmental efforts. A growing discussion on the role of telecommunication for development could be a natural starting point in order to increase the perceived value of telecommunication among the poor.

- Rural livelihoods are almost by definition challenged by the lack of communication, both physical and digital. Without proper access to information, rural communities experience increased travel costs, less favourable market prices and lack of access to the latest agricultural information and technology.
- Women empowerment raises additional challenges in terms of development efforts. Women are believed to contribute considerably to the economic growth of a community, but without sufficient access to information they are unable to make deliberate decisions on their own.
- Other areas of interest are those of health and education. No country has been able to eradicate poverty without properly educating its people. At the BoP a wide range of not-for-profit and governmental organizations work closely on issues regarding education and health, especially in rural areas, providing interesting areas for further investigation.
- Finally, disaster prevention and intervention programs, both from governmental and not-for-profit organizations could provide valuable inputs on how telecommunication can assist in warning the population, distributing disaster relief and provide distant emergency assistance.

Working in close collaboration with government and not-for-profit organizations on these issues is an important step towards ensuring that the service concept becomes beneficial for all stakeholders involved, without compromising the triple bottom line.

4.4 No business as usual

It has also been observed that western designers take process shortcuts caused by the perceived lack of complexity in finding a solution at the BoP, which again stresses the importance of leaving behind the 'business as usual attitude' when designing solutions to the missed calls phenomenon. Without distancing themselves from existing services, while at the same time incorporating the strength of intentional missed calls in a way that significantly increase the perceived value of such a new service, designers are likely to fail.

5 TOWARDS A SUSTAINABLE SERVICE DESIGN IN RESPONSE TO THE MISSED CALLS PHENOMENON

This paper has intended to consider aspects of existing BOP and PSS methodologies as input to a process of formalizing specific requirements for a new service design in response to the missed calls phenomenon, SIM-switching and other forms of unintended use of mobile networks. The ultimate goal is to develop a service that would take into account the needs of prospective users as well as satisfy industrial requirements. PSS and BOP literature suggest a number of aspects to consider in this blueprinting process. This section aims to summarize the main elements for developing triple bottom line service solutions in response to the missed calls phenomenon, which will benefit all stakeholders involved. Table 1 provides an overview of these elements; they have been used as a starting point for a project at a major Norwegian telecom provider, and served as main input to the project and design brief.

Table 1: Project and design brief input based on BOP and PSS methodology review.

Stakeholder perspective	Required Elements
Provide customer value to the **end user**	▪ Free or minimal cost ▪ Easy to access and use ▪ Allow for use by illiterate customers ▪ Encompass existing communicative advantages of missed calls and SIM switching, including social networking ▪ Potential use for accessing beneficial information and services to improve social status and economic gain ▪ Reduce the gap between perceived benefit and cost of using the service ▪ Allow for gradual education of potential users through user-involvement and step-by-step implementation
Address **operator incentives** for an additional service	▪ Reduce necessary network capacity ▪ Reduce options and/or incentives for SIM-switching through strengthening of advantages resulting in a primary SIM position ▪ Include possibilities of alternative revenue streams, possibly from third party service providers ▪ Consider how a new service will complement existing services ▪ Improve brand acceptance in general through local involvement and commitment to sustainable thinking
Consider the position of **competing operators, terminal and smartcard manufacturers**	▪ Allow service to function on competing networks without compromising the competitive advantage of the client ▪ Involve terminal manufacturers to avoid tension while integrating product and service in a seamless way ▪ Involve smartcard manufacturers in order to design services without compromising security aspects of the SIM
Connect to **local institutions** to create leverage	▪ Allow local institutions to participate in the development process to improve the final proposal and thus future market acceptance ▪ Address local institutions potential use of a new service to strengthen development efforts

6 FUTURE RESEARCH

To what extent the criteria listed in the previous section might provide synergies, or might, on the other hand be mutually exclusive remains object of further study. This analysis has been the basis of a design project with a main Norwegian telecom provider aiming at considering the missed calls phenomenon an opportunity for strengthening their competitiveness as opposed to being a problem to be solved through economic sanctions and removal of features perceived valuable to the user.

While PSS literature contributes extensively to economic and environmental aspects of business, it demonstrates a missing social dimension that is becoming increasingly important for western companies in search of future growth. The BoP protocols on the other hand are very much targeting the potential profit of social sustainability, but environmental concerns are lagging behind. Further research on how these areas could join forces and contribute to improving the toolbox for sustainable thinking would be of great importance.

It would also appear that neither BoP nor PSS literature is optimal for developing innovative telecom services, implying that both fields could benefit from a more general focus on sustainable innovation.

Finally, when discussing motivational factors for western companies, the learning process when undertaking BoP projects is emphasized. Through developing concepts for poor and resource scarce environments, within the framework of PSS, companies could significantly expand their understanding on how to develop concepts suited for western markets as well. In this context it would be of great value for further reference to maintain a focus on western markets when innovating BoP specific services.

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8 REFERENCES

[1] Morelli, N.,2006. Developing new product service systems (PSS): methodologies and operational tools. Journal of Cleaner Production 14(17): 1495-1501

[2] Manzini, E. Vezzoli, C., 2003. A strategic design approach to develop sustainable product service systems: examples taken from the ‘environmentally friendly innovation’ Italian prize , Journal of Cleaner Production 11(8): 851-857

[3] Maxwell, D., van der Vorst, R., 2003. Developing sustainable products and services, Journal of Cleaner Production 11: 883–895

[4] Ness, D., 2007. Sustainable Product Service Systems: Potential to deliver business and social with less resource use. Seminar on greening the business and making environment a business opportunity, 5-7 June 2007, Bangkok, Thailand.

[5] Geirbo, H.C:, Helmersen, P., 2008. Turning Threats into Opportunities – the Social Dynamics of Missed Calls. Telektronikk, issue 2

[6] Prahalad, C.K., 2005. The Fortune at the Bottom of the Pyramid: Eradicating Poverty through Profits. Upper Saddle River, NJ: Wharton School Publishing

[7] Sachs, J., 2005. The End of Poverty. Penguin Books, London

[8] Karnani, A., 2007. The Mirage of Marketing to the Bottom of the Pyramid: How the Private Sector Can Help Alleviate Poverty. California Management Review, Vol. 4: 90-111.

[9] Oosterlaken, I., 2008. Product innovation for human development: A capability approach to designing for the Bottom of the Pyramid. Internal report for the 3TU Centre for Ethics and Technology

[10] Jaiswal, A.K., 2008. The Fortune at the Bottom or the Middle of the Pyramid? Innovations: Technology, Governance, Globalization.

[11] Walsh, J.P., Kress, J.C., Beyerchen K.W., 2005. Promises and Perils at the Bottom of the Pyramid. Administrative Science Qly, Vol. 3: 473-482.

[12] Hammond, A.L., Prahalad, C.K., 2004. Selling to the Poor. Foreign Policy. 142: 30-37.

[13] De Soto, H. 2000. The mystery of capital: Why capitalism triumphs in the West and fails everywhere else, London: Black Swan

[14] London, T, Hart, S.L., 2004. Reinventing Strategies for Emerging Markets: Beyond the Transnational Model. Jnl. of International Business Studies. 35: 350-370

[15] Khawari, A., 2004. Microfinance: Does it hold its promises? Hamburg Institute of International Economics. Discussion paper 276.

[16] Karnani, A., 2007. Microfinance Misses its Mark. Stanford Social Innovation Review. Summer: 34-40.

[17] Easterly, W.R., 2006. The White Man’s Burden: Why the West’s Efforts to Aid the Rest Have Done So Much Ill and So Little Good. Penguin Press

[18] Donaldson, K.M., 2006. Product design in less industrialized economies: constraints and opportunities in Kenya. Research in Engineering Design 3: 135-155.

[19] Marker, P., McNamara, K., Wallace, L., 2002. The significance of information and communication technologies for reducing poverty. Department for International Development (DFID).

[20] Rashid, A.T, Elder, L., 2009. Mobile Phones and Development: An Analysis of IDRC-Supported Projects. The Electronic Journal on Information Systems in Developing Countries.

[21] Bhavnani, A., Chiu, R.W., Janakiram, S., Silarszky, P., 2008. The Role of Mobile Phones in Sustainable Rural Poverty Reduction. ICT Policy Division – Global Information and Communications Department (GICD).

[22] Donner, J. 2007. The rules of beeping : Exchanging messages via intentional “missed calls” on mobile phones. Journal of Computer-Mediated Communication, 13 (1), article 1.

[23] Deloitte & Touche LLP, 2008. Economic impact of mobile communications in Serbia, Ukraine, Malaysia, Thailand Bangladesh and Pakistan: A report for Telenor ASA

[24] Rashid, A.T., Elder, L., 2009. Mobile phones and development: An analysis of IDRC-supported projects, Electronic Journal of Information

[25] Crul, M. and J. C. Diehl, 2008. Design for Sustainability (D4S): Manual and Tools for Developing Countries. Proceedings of the 7th Annual ASEE Global Colloquium on Engineering Education, Cape Town, 19-23 October 2008

[26] Crul, M. and J. C. Diehl, 2006. Design for Sustainability: A Practical Approach for Developing Economies Paris, United Nations Environment Program (UNEP).

[27] Brezet, J.C., van Hemel, C., 1997. Ecodesign, A Promising Approach to Sustainable Production and Consumption, UNEP IE, Paris

[28] Orbicom, 2007. Emerging Development Opportunities: The Making of Information Societies and ICT Markets. The Information and Communication Technology for Development (ICT4D) Program of the International Development Research Centre (IDRC).

[29] Wade, R.H., 2004. Bridging the Digital Divide: New Route to Development or New Form of Dependency, In The Social Study of Information and Communication Technology Innovation, Actors, and Contexts. Oxford University Press.

[30] Fjuk, A., Furberg, A,, Geirbo, H.C., Helmersen P., 2008. New artifacts – new practices: Putting mobile literacies into focus. Digital Kompetanse. No 1.

[31] Manzini, E., Vezzoli, C., Clark, G. (2001). Product servicesystems: using an existing concept as a new approach to sustainability. Journal of Design Research, 1(2).

[32] Donaldson, K.M., Ishii, K. and Sheppard, S.D., 2006. Customer value chain analysis, Research in Engineering Design, Vol. 16:174-83.

[33] Rodriguez, J., Diehl, J.C., Christiaans, H. 2006. Gaining insight into unfamiliar contexts: A design toolbox as input for using role-play techniques. Interacting with Computers 5 : 956-976

[34] Fathers, J., 2003. Peripheral Vision: An Interview with Gui Bonsiepe Charting a Lifetime of Commitment to Design Empowerment. Design Issues 4:44-56

[35] Sakao, T., Ölundh Sandström, G., Matzen, D., 2009. Framing research for service orientation of manufacturers through PSS approaches. Journal of Manufacturing Technology Management 20(5):754-778

[36] http://www.um.dk/NR/rdonlyres/165D8B21-A7DD-423E-B415-04B35216E559/0/NokiaDenmark.pdf

[37] Alam, I. 2002. An Exploratory Investigation of User Involvement in New Service Development. Journal of the Academy of Marketing Science, 30(3):250-261.

[38] Wooler, M., Murdoch, T., 2005. Can the operators kill the phone makers? Communications Engineer. February/March, pp. 26-27.

[39] Simanis, E., Hart, S., Duke, D., 2008. The Base of the Pyramid Protocol: Beyond “Basic Needs” Business Strategies. Innovations: Technology, Governance, Globalization 1: 57-84.

Implications of new institutional economy theory for PSS design

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Abstract

At the institute of product development a machine elements (pmd) of Technische Universität Darmstadt, Product Service Systems are researched as objects of design. In particular, the application of principles and methods of systematic engineering design to PSS design is examined. The aim is to contribute to effective PSS design by generating and evaluating design variants on different levels of concretization.

This paper focuses on, the interactions between customer and provider in a Business-to-Consumer scenario. An earlier idea of segmenting PSS into episodes of customer/provider interaction is expanded and an approach for applying selected methods of new institutional economics to the evaluation of design variants is presented.

Transaction cost and property rights distribution are proposed as evaluation criteria and suggestions for reducing the consequences of asymmetric information are given.

As an example, various alternatives for a PSS "laundry / cleaning clothes" are considered and the results are presented.

Keywords

PSS design, new institutional economy, variant design

1 INTRODUCTION

The roots of PSS research at pmd lie, as with other engineering institutes involved in the topic, in EcoDesign. Earlier work on the use phase of products has demonstrated that there is considerable influence of (sometimes erroneous) user behavior on the environmental performance of a product during use (e.g. [1]). Information on the actual future use processes of a product (as opposed to those envisioned in designing) is limited during the design process. Through the continued interaction between customer and service provider, the PSS concept offers better information on, and, depending on the particular type of PSS, control over these use processes. With the wider scope, a designer has the opportunity to purposefully redistribute responsibilities, risks, benefits, and costs in the system.

How this can be leveraged into enhanced customer value, opportunities for revenue for the provider, and a better environmental performance of the system compared to traditional manufacturing, sale, and use of products, is a subject of PSS design research.

2 RESEARCH BACKGROUND

Current research at pmd is focused on the question if and how concepts and procedures from product design may be adapted to benefit PSS design in achieving the aforementioned aims. It is assumed that some basic characteristics can be transferred: Design starts with an idea or a task to provide a particular benefit to a future customer. From then on, a solution space is explored and successively more concrete and detailed plans of the product are drawn up.

A particular trait of systematic engineering design is that it provides models of the object of design (the product) and of the process, which helps to segment the task into subtasks (cp. [2]). For these subtasks, solution variants can be found and evaluated: While it is often very hard to determine an absolute measure for the quality of a solution concept, particularly in the early stages of design, relative measures of multiple variants can often be compared to give an indication of the merits of certain solution ideas.

In order to facilitate a similar mode of working in PSS design, a set of models on a relatively low level of formalization has been devised, mostly adapted from existing models from product and service design [3]. Following Bullinger et al.'s concept [4] of services, considering a resource, process, and result dimension, they represent PSS in a series of successively more detailed process models, each entailing a transformation of resources into results. At the core is the segmentation of the PSS into "episodes" delimited by the arising of a need on the part of one of the actors and its fulfillment. In its current form, the model system comprises:

- A textual overview, providing the basic outline of the system with boundary conditions and functional unit
- An episodes overview, in essence a swimlane diagram, representing the causal and temporal relations between the episodes in the system
- An episode process model, describing the basic transformations occurring in an episode and based on the process model of [5]
- Blueprints of the episodes under development (see Figure 1) – Blueprinting is a method introduced to service design by [6]. It is modified here to include, besides the activities of the participants, the product and resource functions as cues for product design.

The purpose of these models is to provide a frame of reference for formulating solution variants and evaluating them against each other. In this paper, the focus is on the evaluation and on the role that theory and concepts from new institutional economics can play in it.

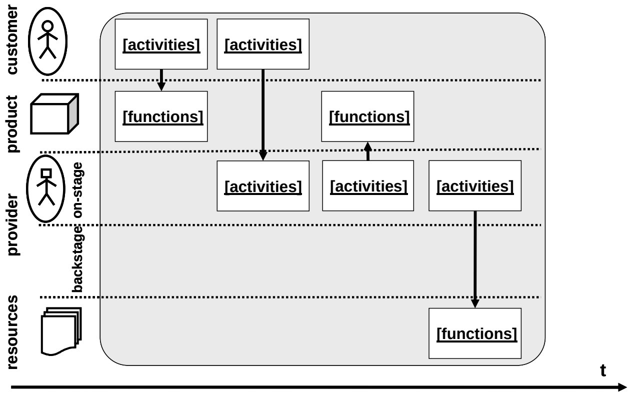

Figure 1: PSS blueprint schematic

3 APPROACH: NEW INSTITUTIONAL ECONOMY

New institutional economy is a sub-domain of economic research. It dismisses the assumptions of perfect rationality and utility maximization on the part of the economic actors. A more realistic view is provided instead, emphasizing problems concerning transactions and information. A number of theories developed in or attributed to the context of new institutional economy, are indispensable in modern economies. The well-known principal agent theory for example is essential for modern contract theory and therefore a basis in today's insurance business. The consideration of theories of new institutional economics to improve PSS is suggested by several authors (e.g. Scholl [7], Hockerts [8]).

In this paper, the focus is on determining the applicability of the theories of

- transaction costs
- and property rights

to the evaluation of PSS variants given in the models described above.

Furthermore, the influence of the assumptions of

- bounded rationality
- and asymmetric information

is investigated.

3.1 Transaction costs

At the center of the considerations of new institutional economy is the existence of transaction costs. [9] Transaction costs are a monetary representation of the effort involved in comparing or assessing different possible transactions [9].

New institutional economics know many types of transaction costs, like searching or information costs, costs for negotiation and decision making, as well as costs for supervising and monitoring. [9]

Due to these transaction costs, people usually settle for an acceptable solution to their needs, instead of the ideal solution (since the effort of seeking out the ideal solution would be excessive). With regard to PSS, the concept of transaction costs can help to elaborate benefits or drawbacks of different solution variants.

3.2 Property rights distribution

To improve the eco efficiency of PSS, Hockerts suggests a property rights centered approach and states "Why the Focus Should be on Property Rights Rather Than Services" [8]. He claims that PSS scholars stick to the service aspect, while trying to reduce the inefficiencies of PSS. The redistribution of property rights is proposed to induce efficient acting, as well on the producers as on the customer's side. Even if an occasion of opportunism presents itself and is characterized by bounded rationality and information asymmetries, this mechanism works.

In literature the number of property rights being differentiated varies from four to five. This paper follows the five types as used by Hockerts [8]:

1. the right to retain profits
2. the right to maintain and operate a product
3. the right to dispose of a product
4. the right to exclude others
5. the right to use a product

Hockerts claims that he first three rights cover important obligations as well :

1. the duty to cover losses
2. the obligation to maintain a product
3. the duty to pay for the disposal of a product.

3.3 Bounded rationality

This assumption shifts the view on the economic actor from the 'homo economicus', who was characterised as always rational and maximizing his utility, to people who are expected to make decisions which seem to be irrational and not driven by economic calculations. These assumptions are the key to a better understanding of the dynamics of economic behaviour, in ways which are relevant to PSS. Example: lots of people own cars, even if strictly calculated in economic ways –considering transaction costs and opportunity costs – the participation in car sharing would be the best solution. This can be traced back to an overestimation of the lack of comfort and availability as well as the resulting costs, supplemented with an underestimation of the total cost of car ownership. Addressing these factors is important when designing PSS with supposedly rational economic and engineering methods.

3.4 Asymmetric information

Asymmetric information is the reason for a number of economic problems and reducing the effects of asymmetric information is one goal of economic theories and mechanisms. The traditional approach of finding an optimal solution is restricted by the differences in the availability of information about the object of the contract. Usually for products the manufacturer has better information about the quality of the product. This information asymmetry is even more crucial if the tangible product is replaced or supplemented by a service. The problems of perceived quality and the impossibility of an assessment of the services quality previous to participation or making use of the service is discussed in literature (e.g. [10]).

Overcoming the problems of asymmetric information is a challenge for PSS design. Different approaches are made in new institutional economy with methods like signalling and screening. For the purpose of this paper, however, the focus is on the effects of property rights distribution on reducing consequences of asymmetric information. Moreover, the problem of transaction costs due to the problem of asymmetric information is discussed.

4 EXAMPLE CASE: „WASHING CLOTHES "

"Cleaning dirty clothes" is used as an example here for several reasons:

- It is readily accessible to readers, since the vast majority of people is, at some point, faced with the necessity of getting their clothes cleaned
- The availability of data and general information on user behavior and market situation of the solutions is good

- Some of the solutions in the market constitute nicely integrated PSS (laundry, coin-operated laundromats)
- The example has been the subject of PSS research several times before [11], which allows for a comparison between the different suggested representations of the topic.

The presented cases are considered as PSS cases because they are developed as a combination of both, the product and the service, to satisfy the customer needs.

4.1 Scope of solution variants

In keeping with the aim of supporting a „top-down“ design process, three fundamentally different variants of systems for washing clothes are presented below. (In a real design process, decisions on the more general levels would have narrowed the solution space before blueprinting would start, but the examples here are selected to demonstrate the possible range of variants which can be compared.) The PSS variants are described later on in a short abstract and in the following sections in detail.

To get an outline on the actual 'common situation', which is used as reference case, there is a description of the usual condition. The market saturation in consumer washing machines being well over 90% in many European countries, "washing at home with a user-owned machine" is considered the reference case here.

The washing machine is normally sold with a warranty. However, since the service life of the machines is usually considerably longer than the warranty period, it is assumed here that the owner is in charge for the maintenance and has to pay for repairs if necessary. The decisions about the dosage of detergent and the choice of washing program are made by the user.

The first episode to consider here is plainly "washing clothes". To compare the cases **a typical episode** is chosen: **cleaning laundry**. All related activities are enclosed in it; the need is for the clothes to be clean and the fulfilment is achieved when the clothes are taken out of the machine. This may seem trivial, but other solution variants may comprise more episodes with opportunities for designing in added customer values.

This episode, and later on others, is evaluated for 3 different PSS variants:

- **The reference case**:
  This case consists of the situation described above with privately owned washing machines in private households. The customer is in charge of every action and decision.
- **Case 'rented machine with full technical support'**
  In this case the customer only rents the machine from the provider, who is still the owner. The customer uses the machine as if it was his one, but has the provider as regular maintenance service and in case of damage as repair service. If the machine is not working, the provider is obliged to repair the broken machine or to exchange it with a working one.
- **Case 'laundry service'**
  In this case the customer just hands his laundry in and every machine interaction and the whole cleaning process happens at the providers place.

The customers utility 'getting clean cloth' is gained in all of the different PSS. Therefore it is possible to compare the PSS, and especially the episode cleaning cloth.

4.2 The reference case

The reference case, which is characterized above, is now presented in a blueprint for evaluation. The blueprints can be interpreted as follows:

The blueprint as described above is a structured description of activities and functions. The blueprint enables the designer to point out the aspects that are important in the phase of development he is in and with the knowledge about the customer he has at that point. With the knowledge about transactions costs and property rights, the content of the blueprint can be evaluated as it is demonstrated in the following.

In the tables about transaction costs and property rights, there is a third column, called assessment (AM). This column indicates the effect on the overall assessment of the PSS utility. The background is the consideration of an average customer, that is able to wash on his own, but willing to pay for convenience as well.

The most remarkable aspects of transaction costs are marked with a TC and the ownership as type of property right is marked as well.

For the blueprint, the reader is referred to Figure 2 at the end of the paper.

The steps of the **reference case** look like this: Taking the laundry to the washing machine (WM), deciding about pre-treatment of staining, the amount and type of detergent and apply it; starting the WM.

Actor	Type of transaction costs	AM
customer	• Information costs for how to treat the laundry	-
provider	Is not participating in the PSS at that point, therefore no transaction costs	

Actor	Type of property right or duty	AM
customer	• The ownership of the machine assigns all rights and duties to the owner • This includes, that the owner is fully responsible if something goes wrong in the episode	+ -
provider	Is not participating in the PSS at that point, therefore no rights or duties	

Another episode, that is usually interesting to look at in PSS, is payment. For this standard case example there is the payment for the washing machine, when it is bought and a regular payment for resources (water, electricity). It is possible to design variations for the payment episode, but this case is supposed to be reduced to the regular situation in usual households.

4.3 Case 'rented machine with full technical support'

The blueprint of the episode 'washing' looks exactly like in the standard case. While using the machine without technical problems no difference of an owned machine and a rented one is experienced. The Episodes with the obvious differences are the 'technical problem', 'buying' and 'disposal'.

For this case the **payment episode** provides multiple options for variation. The payment can be instantly for each usage, or in a monthly pattern but usage bound. There could also be a fixed price model independent from the intensity of usage as well as a get money back model for not calling for the service in a year. As well as the amount and frequency, it is possible to vary the co-contractor. The machine could be provided from the same service provider who is partner for water and electricity and be a content of the contract.

Actor	Type of transaction costs	AM
customer	• Information costs for how to treat the laundry (e.g. temperature, program, detergent and drying method). But due to the nature of repeating this episode regularly with the same or similar clothes, this costs are little determinant for the PSS decision. • no transaction costs for booking the machine or alike come up, and the machine is free and ready to use whenever needed.	- ++
provider	• costs for assuring availability for problem reports • costs for searching the damage/reason for damage	- -

Actor	Type of property rights or duty	AM
customer	• the right to exclude others • the right to use the product • The right to maintain and operate the product in terms of regular careful usage including cleaning	+ + +
provider	• The right to retain profits • The right to maintain and operate the product in terms of technical maintenance	+ +

4.4 Case 'laundry service'

For the blueprint, the reader is referred to Figure 3 at the end of the paper.

Actor	Type of transaction costs	AM
customer	• costs for finding out when to bring the laundry and pick the laundry up • costs for the transportation	- - -
provider	• costs for the decision about how to treat the laundry - due to experience, they are supposed to be much smaller on the provider side, then on the customer side • costs for arranging optimal utilisation of the washing machines to get all the laundry done in time	+ -

Actor	Type of property rights or duty	AM
customer	• no rights or duties concerning the washing machine at all. Just the right to get the machine used for his aim.	+
provider	• the provider is owner of the machine and owns all direct rights or duties	++

For the case 'laundry service', the episode payment is a source for variation too. Payment can be per piece, per usage, per monthly or dependent on weight and dirt. The latter is an example for reducing transaction costs. If the payment is monthly by debit, the customer only needs to make sure that there is enough money or overdraft value to pay. In a 'pay each time you use' variation, that could be even worse by only accepting cash, the customer has transaction costs for checking and securing his liquidity every time.

Conclusion of the case description:

All described PSS variants fulfil the same utility 'cleaning cloth' but with different levels of customer interaction

4.5 Trouble episode 'broken machine'

After the description of the episode 'cleaning laundry' a second episode is examined for the three types of PSS. To be able to compare PSS relating to their overall utility, it is important to consider the typical episodes of usage as well as episodes of anticipatory problems. Often there is a significant difference between the PSS types in these episodes.

Thus an episode of handling a broken machine, that doesn't work anymore, e.g. due to a broken part inside, is presented as well.

Broken machine in the 'regular owned machine' case

The customer will be the one who discovers that the machine does not work. Supposed that the warranty is already expired, the customer has to order a repair service of his choice. Usually this requires getting information about who is qualified, which prices need to be paid and if there is a service with good reputation. The customer must enable the repair service to reach the machine for repairing – on his own or by an authorised other person, and pay the bill afterwards.

Actor	Type of transaction costs	AM
customer	• costs for gathering information about qualified repair service and deciding who to order • costs for organising and supervising the repair service	- +
provider	Is not participating in the PSS at that point, therefore has no rights or duties.	

Actor	Type of property rights or duty	AM
customer	• All rights… • …and duties belong to the customer	+ -
provider	Is not participating in the PSS at that point, therefore has no rights or duties.	

Broken machine in the case 'rented machine with full technical support'

Depending on the type of damage and the technical equipment, the damage can be detected by the customer or the electronic system of the machine. In the first situation, the customer calls the provider and makes an appointment for the repair service. In the second situation the customer is contacted by the provider.

Actor	Type of transaction costs	AM
customer	• Little costs for finding out what is to be done	++
provider	• Costs for evaluating what damage needs to be repaired • Costs for organising a backup machine	- -

Actor	Type of property rights or duty	AM
customer	• the right to exclude others • the right to use the product • The right to maintain and operate the product in terms of regular careful usage including cleaning	++ ++ +
provider	• The right to retain profits • The right to maintain and operate the product in terms of technical maintenance	+ +

Broken machine in the case 'laundry service'

If there is one of the laundry services' machines is broken, usually the customer does not even know if something alike happens.

Actor	Type of transaction costs	AM
customer	No cost due to the "broken machine"	++
provider	• costs for arranging repairing • costs for arranging a new utilisation of the washing machines to get all the laundry done in time	- -

Actor	Type of property rights or duty	AM
customer	• no rights or duties concerning the washing machine at all. Just the right to get the machine used for his aim.	+
provider	• the provider is owner of the machine and owns all direct rights or duties, therefore especially the duty to for maintenance in this case	+

5 EVALUATION OF VARIANTS

Evaluation of the cleaning episode in the variants

In the cleaning episodes there is a reduction of work to be done and decisions to be made from the first two examples to the third and a rising inflexibility in the usage. The reduction of work is paid for in terms of losing flexibility in the process. Depending on the needs of the customer, the assessment of flexibility and less work will be different, but with the variants it is possible to meet different types of customers.

	Customers effort in the process	Dependence on the provider
Reference case	++	- -
Rented machine with full service	++	- -
Laundry service	-	++

These results seem to indicate, that the more property rights the customer has, the higher is his flexibility in handling the system.

Due to the systematic variation of the property rights distribution, it is possible to design variants of the same PSS utility that all match the core benefit, cleaning laundry in our example, but also special extra utilities of different types of customers.

Evaluation of the effects of the broken machine on the customer

In the different variants of the PSS there is a significant difference in the effects of a broken machine on the customer. The two ways in which the damage can affect the customer:

1 concerning his ability to get clean clothes

2 concerning his responsibility to change the situation and get the machine working again

In the **reference case** the customer is not able to get clean clothes with the PSS until the machine is repaired. Furthermore he has the full responsibility for the process. This leads to maximum lack of the utility of the PSS for the customer. With a bad reparation service situation, or a damage that can't be fixed, the loss is for a longer time up to a final loss of utility of the PSS.

In the case of a **rented machine** with full technical service, the customer only needs to report the damage and enable the service to get to the machine. The lack of utility only lasts for the duration of the defined maximum time span for repairing. If the repair service is unable to fix the machine, a working replacement will be supplied. The effort the customer has to make is small in this case and the time he can't use the PSS in the supposed way is limited.

In the **laundry service case**, the customer will not even notice if one of the machines is broken. It is the provider who has to arrange how to get the machine working again and how to reschedule the laundry jobs on the other machines. Therefore the customer has no lack of utility at all.

In the selected PSS cases a systematic reduction of property rights is performed. Starting with full ownership up to the right to make someone use the product for the customers utility. From the description above it is perceptible, that the less property rights and duties the customer has, the less he is in charge when problems come up.

Evaluation of the utility of developing and comparing episodes

The presented examples show, that it is easy to compare aspects of a PSS, when there is just a part of the PSS in a defined and therefore contrastable extent. The chosen way to define episodes of action appears to be a good choice.

It hast to be pointed out, that the presented blueprints can be illustrating the final result of a development process. But they can also be the base to which further modification can be applied.

6 CONCLUSION

For systematic variation it seems to be helpful to include property rights as variable. But even if it is not used for designing variants, it is important to consider the existence of transaction costs and the opportunities of different types of property rights, as well as the problem of asymmetric information. With the knowledge about the theories of new institutional economy, the customers needs have to be focused. Only the maximizing of the customer value can change a good PSS into a better PSS, not the blind application of theories and concepts.

The knowledge about asymmetric information and transaction costs implies that it is more effective to design a good PSS that covers customer needs as well as the ability and willingness to pay the recommended price, than designing the best ever PSS that needs too much designing effort and is not affordable for the customers.

Designing the PSS in episodes and comparing the designed variants with focus on the episodes that are most important, looks like an appropriate way to get to a best matching solution. The information how to assess the episodes can be taken from customer surveys, interviews or other marketing instruments.

7 REFERENCES

[1] Oberender, C., Birkhofer, H., 2003, Estimating Environmental Impacts: The Use-Phase-Analysis-Matrix – A Use Phase Centered Approach, International Conference on Engineering Design ICED 03, Stockholm, Sweden, 19-21 August

[2] Pahl, G., Beitz, W., Feldhusen, J., Grote, K.-H., 2007, Engineering Design - A Systematic Approach, Third edition, Springer, London

[3] Schendel, C., Spahl, T., Birkhofer, H., 2008, Considerations towards Systematic Engineering of Product Service Systems, NordDesign 2008, Tallin, Estonia, 21-23 August

[4] Bullinger, H.-J., Fähnrich, K. P., Meiren,T., 2003, Service Engineering - Methodical Development of New Service Products, Int. Journal of Production Economics (85): 275-287

[5] Heidemann, B., 2001, Trennende Verknüpfung – Ein Prozessmodell als Quelle für Produktideen, Doctoral Thesis, Fortschritt-Berichte VDI, Reihe 1, Nr. 351, VDI Verlag, Düsseldorf, Germany

[6] Shostack, G. L., 1982, How to Design a Service, European Journal of Marketing 16(1): 49-63.

[7] Scholl, G., 2008, Product Service Systems - Taking a Functional and a Symbolic Perspective on Usership, In: Tukker, A. (Ed.), Perspectives on radical changes to sustainable consumption and production, Greenleaf, Sheffield, UK: 269–284

[8] Hockerts, K., 2008, Property Rights as a Predicator for the Eco-Efficiency of Product-Service Systems, CBS Working Paper Series, Working Paper No. 2-2008

[9] Richter, R., Furubotn, E. G., Streissler, M., 2003, Neue Institutionenökonomik - Eine Einführung und kritische Würdigung, 3.Edition, Mohr Siebeck (Neue ökonomische Grundrisse), Tübingen, Germany

[10] Zeithaml, V., 2000, Service Quality, Profitability, and the Economic Worth of Customers: What We Know and What We Need to Learn, Journal of the Academy of Marketing Science (67): 67-85

[11] Hirschl, B., Konrad, W., Scholl, G., Zundel, St., 2001, Nachhaltige Produktnutzung, edition sigma, Berlin

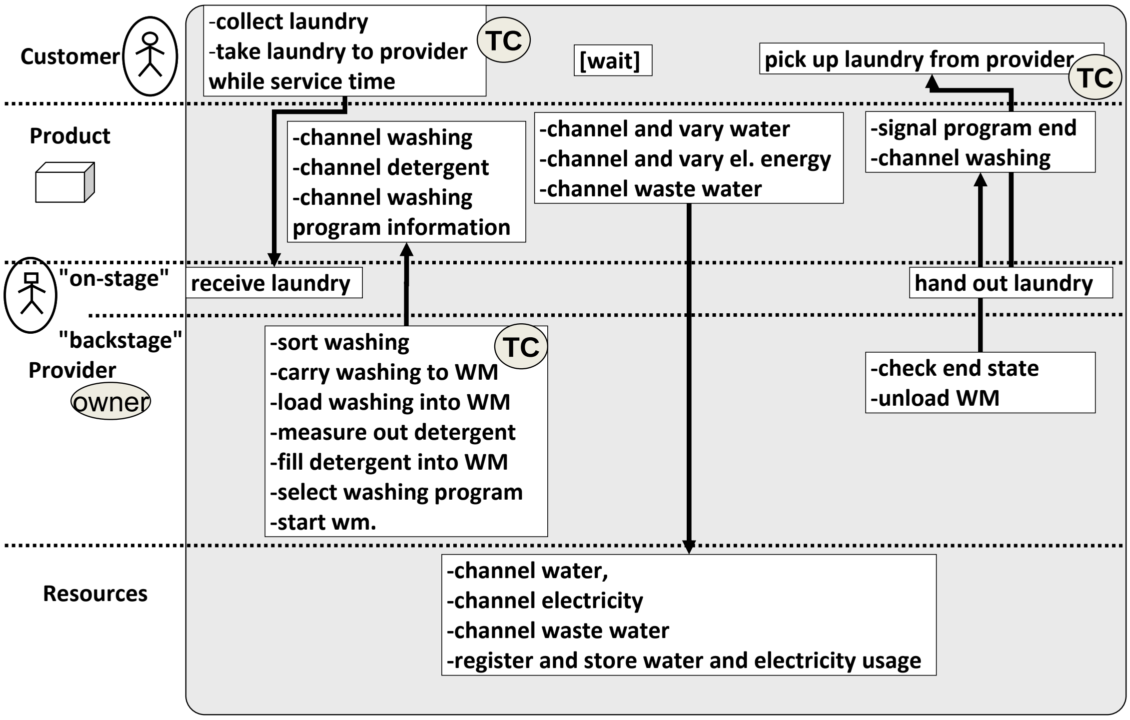

Figure 1: Case 'laundry service'

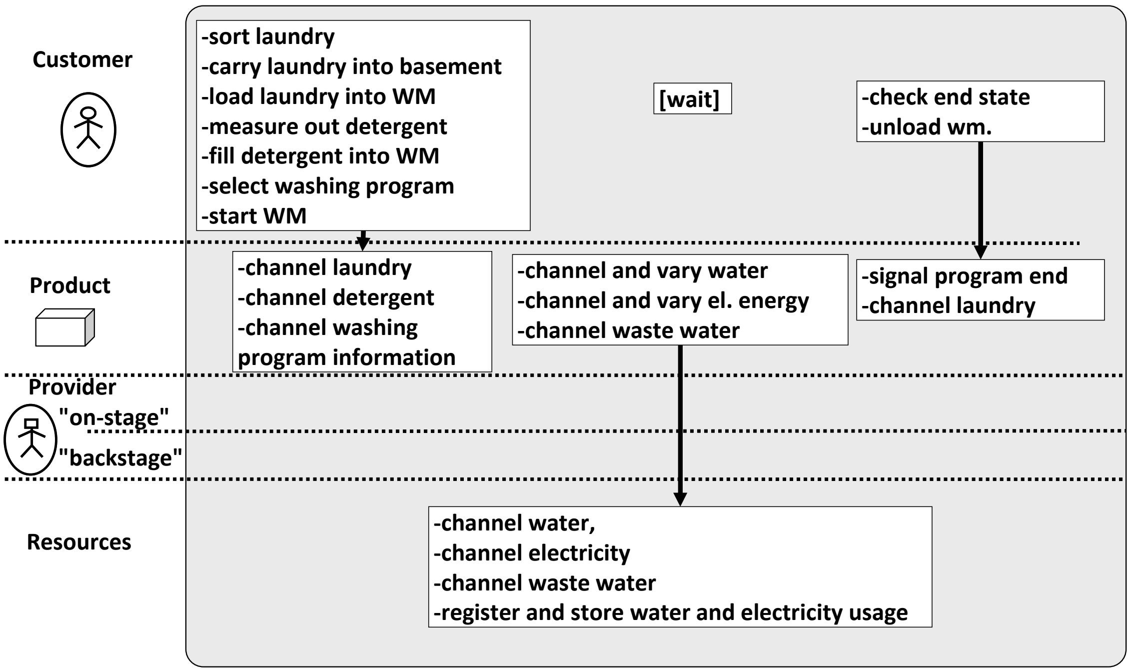

Figure 2: Reference case

Energy services in industry – an interdisciplinary approach with engineering and social science aspects

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Abstract

A large potential for energy efficiency exists in industry but the adoption of energy efficiency measures is often inhibited by various barriers. Different means to overcome these barriers and promote energy efficiency in industry exist, one of the most promising being energy services. Earlier research shows that while many barriers could be overcome by energy services, the industry's ranking and adoption of energy services are very low. By applying an interdisciplinary approach using barrier theory, socio-technical regimes, and IPSE (Integrated Product Service Engineering) to energy services in industry, the aim of this paper is to i) theoretically explain why there is a considerable discrepancy between the potential for energy services in industry and their adoption, and ii), partly based on i) and by applying an interdisciplinary approach, attempt to explore ways of reaching a satisfactory level of energy services in industry.

Keywords

Energy efficiency, services in manufacturing industry, barrier theory

1 INTRODUCTION

One of the major means of reducing emissions of greenhouse gases (GHG) is to increase industrial energy efficiency. A recent report by the IEA (International Energy Agency) stated that even from the most "technology-optimistic" perspective, industrial energy use will increase over the next 50 years [1]. The European Union, working proactively to increase energy efficiency and reduce GHG emissions, states in a directive on energy efficiency that the Member States shall aim to reduce their use of energy within the coming nine years by nine percent through eliminating barriers to energy efficiency [2].

Saving energy is at the same time often a part of customer value. Energy services have the potential to contribute to decrease energy use and thus add customer value. The above-mentioned EU directive indeed states that the EU, through each Member State, should develop the energy services markets and investigate, for example, third party financing. Tackling energy saving can be a practical research issue within research on Industrial Product Service Systems (IPS^2), which are defined as "an integrated industrial product and service offering that delivers value in use" [3].

By applying an interdisciplinary approach using barrier theory, socio-technical regimes, and IPSE (Integrated Product Service Engineering) [4] to energy services in industry, the aim of this paper is to i) theoretically explain why there is a considerable discrepancy between the potential for energy services in industry and their adoption, and ii), partly based on i) and by applying an interdisciplinary approach, attempt to explore means to reach a satisfactory level of energy services in industry. The paper's scope is energy services in the non energy-intensive and small and medium-sized manufacturing industry, i.e. it does not address energy services in energy-intensive industry. The paper is unique in the sense that it explores the timing topic – increased industrial energy efficiency through the adoption of energy services – applying an interdisciplinary approach.

The primary method applied in this paper is literature analysis. Section 2 reveals the current status of energy services including the fact that the degree of energy service adoption in Swedish small- and medium-sized and non-energy-intensive industry is considerably low [5, 6]. Section 3 introduces existing theoretical insights, and Section 4 derives some results of the literature analysis. Section 5 provides discussion pointing out the need of empirical research.

2 STATUS QUO OF ENERGY SERVICES

Recent research on barriers to energy efficiency in Swedish industry has found that lack of access to capital and lack of budget funding were among the top-ranked barriers [7]. Third party financing and energy performance contracting are means to enhance energy efficiency and overcome, for example, financial barriers [8].

Unlike energy-intensive industries, where energy efficiency measures mainly concern the production processes, energy efficiency measures in non-energy-intensive and small and medium-sized manufacturing industries are related mainly to support processes [7]. HVAC, compressed air, lighting and tap hot water are normally categorized among the support processes [9]. ESCOs mainly orient their businesses towards the support processes and thus seem to be suitable when it comes to overcoming barriers to energy efficiency in the non-energy-intensive manufacturing industry.

Evaluations of Swedish industrial energy programmes have revealed that the support processes contribute to about half of the cost-effective energy savings undertaken by energy-intensive industries, and close to 90% among non-energy-intensive and small and medium-sized industries [10]. According to [11], on average only 15% of the measures that are profitable for property owners are implemented, a picture that is repeated in the industrial and transport sectors. Consequently, if energy services for Swedish industry are to be developed further, there is great potential not only for reduced emissions of CO2 and reduced industrial energy use but also new business opportunities.

Increased industrial energy efficiency through energy services has a positive impact on the reduction of GHG. The scarcity of the use and development of, and research on energy services in industry, and the great potential for energy efficiency through energy services calls for research in this area. The Swedish Government Bill for example states a potential annual energy saving figure of 2-3 TWh through more efficient use of energy in small and medium-sized industries [12]. Other figures state a 20% energy efficiency potential in small and medium-sized industries and non-energy-intensive industry in the EU [13]. The Swedish ESCO market has hitherto primarily involved customers in the public sector focusing on control systems, ventilation and heat recovery [14] while the ESCO market for industry is considerably underdeveloped. Geissler et al. [15], for example, estimate the energy-saving potential through ESCOs to be around 15% of the present Swedish energy demand.

It is an intricate matter to give a potential figure of how much energy can be saved in such an early stage of business model development. However, based on related research such as [9] one may conclude that the potential is vast. Moreover, the stated potential of 2-3 TWh annually, relates to measures available with strict investment criteria. Energy performance contracting and third party financing enable investments with much longer payoff-periods, which means that the potential for energy services is far greater. From an annual energy usage of about 40-45 TWh among Swedish small and medium-sized industries and non-energy-intensive manufacturing industries, a simple calculation reveals that if energy services were to achieve only 10% of the energy efficiency potential of 15% according to [15], annual savings of 600 GWh per year or more would be reached.

However, while energy services are an important means to reduce barriers to energy efficiency, it has not been extensively studied among Swedish industries. Also, traditional industrial energy efficiency research has emphasised technical matters – such as, for example, the energy efficiency potential from implementing specific technologies [9]. The use and adoption of energy services still very much needs to be further explored. While the lack of industrial energy efficiency research related to energy services in a Swedish and an international context remains, the environment demands fast action. Moreover, Swedish industry has been faced with substantial energy price increases in recent years, creating problems in particular for energy-intensive industries as many Swedish industries use more electricity than their European competitors. Furthermore, the current economic turbulence requires Swedish industry to spot potential areas for cost reductions in order to survive. Research related to energy services demands an interdisciplinary approach, involving both technical and social science issues, calling for an interdisciplinary study on the issue. Although the earlier activities directed towards the public sector in Sweden have brought progress in the field [14], great potential still exists to increase energy efficiency in industry [15]. Consequently, if energy services for Swedish industry are to be further developed, there is potential not only for reduced energy efficiency and lower emissions of GHG but also increased business activity.

3 THEORETICAL APPROACH

3.1 Barriers to and driving forces for energy efficiency

Energy efficient technologies are not always adopted, which is explained by various barriers to energy efficiency. This discrepancy between energy efficiency potential and actual implementation results is called the energy efficiency gap. A barrier is defined as ‘a postulated mechanism that inhibits investments in technologies that are both energy-efficient and economically efficient’ [16]. A driving force may be defined as the opposite of a barrier, i.e. a factor which promotes investments in technologies that are both energy-efficient and cost-effective [17]. The most often cited barriers include heterogeneity, lack of access to capital, hidden costs, risk, and imperfect and asymmetric information [18]. Empirical studies on barriers to and driving forces for energy efficiency in industry show a considerable discrepancy between the barriers identified and the driving forces. Thollander [7] and Thollander et al. [19] show that while many of the barriers, for example lack of time and other priorities and lack of access to capital, could be overcome by various energy services such as energy performance contracting, third party financing etc., the industry does not in fact rank such means particularly high.

The energy efficiency gap is based upon the hypothesis that there exists a technology, method or process that leads to reduced use of energy in industry, but due to the existence of various barriers to energy efficiency, this technology or method is not implemented. If the actors were to act in a rational way this energy efficiency gap would not exist. In reality, however, it does exist and different kinds of barriers to energy efficiency have been identified to explain it. The barriers are many and include risk and lack of information, knowledge, time or access to capital. One criticism of this barrier approach, however, is that it leads to reductionism in research (compare [20]. Taking an STS (Science, Technology & Society) approach, the energy efficiency gap can be understood better in a social and institutional context, which will be discussed next.

3.2 Energy efficiency in the perspective of socio-technical regimes

The paper is interested in how socio-technical changes occur in industries and how and why energy efficient solutions are - or are not - implemented. Several approaches deal with these issues from different perspectives and starting points. The transition management approach aims to support the emergence of sustainable technological alternatives by analyzing social, infrastructural and institutional systems as driving forces for or barriers to technological change [21]. Many studies rely on terms of technological regimes [22] that they use to explain regularities in technical change. A technical regime is all the formal and informal rules that are embedded in a technology or mode of manufacturing, that structure the activities of engineers and the policies that are developed [23]. Geels [24] has developed this model and introduced the term ‘socio-technical regimes’, because a regime includes more actors than just the engineers. But it is on the socio-technical regime that the search must focus to explain changes to or the preservation of existing routines and why new technologies are implemented or not. A regime is relatively stable with incremental changes. Thoresson and Glad [25] have discussed socio-technical regimes in housing companies and concluded that different regimes can exist at different levels in the same company: on the board, in the planning unit and on the operational level.

Focusing energy efficient technology development in industry in the perspective of competing socio-technical regimes could throw new light on why energy efficient technology is not implemented, even if it seems both economically and technologically rational for the industry to do so. If one follows traditional STS science such as [26] and [27], Shove [28] then points out that decisions concerning how we use energy and energy efficiency measures are made in social contexts. According to Shove, practitioners identify and make energy-related decisions within different networks and different contexts: what qualifies as a reliable, cost effective, worthwhile energy saving measure in one socio-cultural domain might count for nothing in another [28]. In this perspective, energy efficiency is also dependent on social relations and discussion, negotiations and agreements developed within regimes. Experience, routines and habits established and negotiated in a regime will then decide what energy efficiency measures will be implemented. These negotiated agreements can then constitute both possibilities for and constraints to future development in each sector [29].

If we add that an industrial company can include different regimes with slightly different problem definitions, goals, routines, values and so on, then the discussion on barriers to energy efficiency and the adoption of energy services can be developed further. We have seen in earlier research that an investment which an energy manager at a company is willing to do, can be stopped by the financial administration because they have different value systems and perhaps require strict investment criteria. From interviews it has been found that the possibilities to receive approval for an energy efficiency measure are higher at the beginning of the year than at the end and the reason is not always obvious to the people in charge of energy efficiency [30].

If one looks at this in terms of socio-technical regimes, then some regimes are embedded more robustly than others, and enjoy greater institutional support and have stronger financial significance and broader legitimacy in the company. This could be an important explanation of why energy efficiency measures, known and profitable to the company, are not implemented. Studying energy services could thus benefit from in-depth studies in industry to see how employees talk about energy efficiency, and how they relate this to economic and environmental aspects. Moreover, such a study could also determine whether there are different regimes at the company and power relations between different regimes and how they influence energy efficiency and the adoption of energy services.

Identifying and addressing powerful socio-technical regimes provides an opportunity to develop new business ideas. In this perspective, a new procedure for how energy service processes should be adopted in industries is needed, where for example different regimes might need to be targeted slightly differently, even if the mission is kept unchanged.

3.3 IPSE

Energy efficiency in general is determined primarily by a used technology and a physical product implementing the technology. However, there are two other main factors with a broadened perspective. One is how the machine is operated. This is influenced by services from product suppliers or third party service providers, as well as by operation by the users themselves. Energy service is closely related to in-house energy management. Either energy management is carried out by the company or, e.g. the management of the energy issue is outsourced to a third party. Research on energy management states that savings in the magnitude of 40 % or more can be achieved [31].,This is done by a combination of

Table 1: Implications for designing energy services based on the barrier theory
(See [16] for an outline of barrier theory.)

Perspective	**Barrier**	**Implication for energy services**
Economic	Heterogeneity	- This barrier may be effectively avoided by having successfully adopted cases to rely upon and skilled ESCO staff.
	Hidden costs	- Having an ESCO involved in the initial phase of an energy efficiency investment may greatly reduce hidden costs as the ESCO staff are specialists in their field and know where to find information etc.
	Access to capital	- An ESCO providing third party financing enables this barrier to be fully eliminated.
	Risk	- The industry's risk may be considerably reduced by having "specialists" involved, which greatly enhances the investment's stability. The industry's risk of entering into a business agreement with the ESCO and vice versa, however, is not as easily reduced, calling for a complex agreement to be set up which in turn may increase the magnitude of the hidden cost barriers.
	Imperfect information	- Service opportunities exist where the information for customers/users is imperfect. - Providing information of energy consumption for economically efficient decisions may contribute to service provision. - Keeping information on how to increase energy efficiency within a provider may turn out to be a source of services.
	Asymmetric information	- Building up an agent responsible for both costs and benefits may be a key to introduce energy efficient solutions (Split incentives).
		- Visualizing and guaranteeing quality of products/services may lead to purchase of better solutions (Adverse selection).
		- Transferring (and/or translating) the information at the agent level up to the principal level may be effective (Principal-agent relationships).
Behavioural	Bounded rationality	- Routines and everyday activities do not support energy efficiency. Establish routines that contribute to 'right' decisions being embedded in everyday practices.
	Form of information	- Different regimes within a company need different kinds of information and information packages that relate to their needs and demands.
	Credibility and trust	- The industry's perception of ESCOs needs to be strong as regards their credibility and trust if an energy service is to be carried out.
	Values and Inertia	- Different value systems can exist in a company. Promote and support value systems that benefit energy efficiency.
Organisation theory	Power	- Identify different power arenas in a company to know where to target different kinds of information and measures.
	Culture	- Embedded knowledge and routines need to be identified to initiate reflection on how to change and improve them.

technology and management (services), where the latter can be addressed by IPSE and be related to the socio-technical regime as introduced in the previous section.

The reason why this type of service is valid is that the information about products is asymmetrical between users and service providers (original manufacturers or service providers). When users purchase services, they actually find it rational to pay money for benefiting from a kind of knowledge that they otherwise would not gain. This type of knowledge originates with manufacturers. Manufacturers can make use of their own knowledge to package an IPSO (Integrated Product Service Offering) [4]. In addition, other companies independent of original manufacturers can provide such services (ESCOs in this case). Thus, the issue of energy service is a good practical target in the IPSE research.

4 RESULTS FROM ANALYSES

4.1 The barrier approach

Heterogeneity, lack of access to capital and hidden costs refer to a technology involved in an energy service contract and its associated costs. From an energy efficiency perspective, there are a wide range of energy efficiency measures available with fairly low pay-off periods. However, in some cases a technology may not be able to fit into a specific production-condition due to constraints in the technology. It is either fit or not fit. No major "maybe" cases exist. In empiric research on barriers to energy efficiency, the heterogeneity barrier has been shown to be of minor importance [16], indicating that the heterogeneity barriers do not give a plausible explanation for the low adoption of energy services in industry. As regards lack of access to capital and hidden costs, these barriers may also be categorized as existent or not: either the company has access to capital or it does not. Sometimes this is self-imposed from restrictions on lending money etc. However, it may not be argued to be non-existent if the industry states that this is a barrier. The lack of access to capital barrier has been shown to be of major importance in some sectors [10, 17, 32]. The costs (hidden) associated with investments in a certain energy efficient technology may also be considered real. The hidden cost barrier has also been shown to differ between sectors [10, 17, 32]. However, applying socio-technical-regimes on the lack of access to capital and hidden cost barriers may reveal new insight on the issue and problematize how and why actors in negotiations in decision processes do not prioritize energy efficient investments even if it would be beneficial in the long run.

Risk, imperfect and asymmetric information etc. are barriers which refer to information involved in the transaction when investing in an energy efficient technology. Unlike the previously outlined barriers, these barriers also concern the actors, i.e. socio-technical regimes involved in the investment and the actor's perception of the information regarding the investment, the information type, etc. These barriers are not related solely to technological facts, but do also include how actors perceive risks, for example associated with an investment. Various types of risk exist, for example risk of production disruption, hassle and inconvenience – a high-ranked barrier in many empiric studies on barriers. How the actors perceive the risks is connected to tradition, values and experience from past decisions and this needs to be investigated further to understand its impact on risk calculations made. Previous research has found that in some cases values, culture and power are factors which may influence decisions on energy efficiency in a positive way [6]. The credibility of and trust in a third party, such as an energy auditor, have also been shown to be crucial in the uptake (or not) of information on energy efficiency opportunities [5].

4.2 Promotion of energy services

Table 1 shows findings from the analysis of energy services using barrier theory. They include implications for energy services based on an extensive review of barriers to energy efficiency by [16]. Based on this extensive review, it is theoretically possible to derive various kinds of measures to tackle the barriers.

Apart from the outlined means in Table 1, concerning the industry and the ESCO, one may also consider promoting energy services activity by adopting public policy instruments such as risk-free state loans. Such a policy would considerably reduce the risk to both parties from entering into a business agreement. The risk barrier may also need market guidelines and principles to be set up by the Government, for example, standardized guidelines for how agreements should be set up. Such guideline would also contribute to lower the hidden cost and credibility and trust barriers and possibly also imperfect and asymmetric information barriers, as both parties would be fully informed of how an agreement should be formulated. Moreover, it is suggested that the Swedish Energy Agency sets up a separate homepage regarding energy services in industry presenting, among other things, successful examples of energy service adoption in industry. A homepage regarding energy services in industry would enable a reduction in magnitude of basically all barriers to energy efficiency in industry outlined in Table 1.

5 CONCLUDING DISCUSSION

Applying an interdisciplinary approach to the adoption of energy services is a unique research approach. This paper emphasizes that one of the main reasons for the considerable discrepancy between the potential for energy services in industry and their adoption is the existence of various socio-technical regimes in organisations. Moreover, the paper shows that the ESCO-market would benefit from leaving traditional regimes and moving into non-traditional ones. A number of promising means for reaching a satisfactory level of energy services in industry is outlined in this paper. If these findings were to be successfully adopted, this may lead to greater energy efficiency in industry, strengthen the ESCO businesses, contribute to lower production costs and increase the industries' competitiveness. The paper is unique in the sense that it explores the topic of industrial energy efficiency and energy services using an interdisciplinary approach. By doing so, it carries the issue further than solely conducting research based on one theoretical framework, see for example [33], and actually contributes to new knowledge, which has not been possible to achieve using a non-interdisciplinary approach. The potential for energy services in terms of increased energy efficiency may be stated to be very large, based on a pessimistic assumption in the range of 600 GWh per year on a Swedish national scale.

From earlier research, knowledge exists of *which* barriers that exists, but the understanding of *how and why* barriers appear in a company needs to be deepened. By including an empirical analysis of socio-technical regimes and their negotiations and power relations, future research can contribute to the understanding of the existence of barriers and how they can be resolved. This calls for future empirical studies on the subject involving both ESCOs and manufacturing industry.

In conclusion, and even though much remains to be done as far as research and business model development are concerned, this paper has contributed to reduce the scarcity of research in the field of energy services in industry. Future research is suggested in the area, not least empirical research. The future will show whether energy services in industry, using insights from the interdisciplinary perspectives addressed in this paper, are not just a potential approach but as stated in this paper a key to the closure – or at least a major reduction of – the energy efficiency gap in industry.

6 REFERENCES

[1] D. Gielen, M. Taylor, 2007, Modelling industrial energy use: The IEA Energy Technology Perspectives, Energy Economics, 29: 889-912.

[2] EC, Directive 2006/32/EC of the European Parliament and of the Council of 5 April 2006 on energy end-use efficiency and energy services and repealing. Brussels: Council Directive 93/76/EEC, 2006.

[3] R. Roy, E. Shehab, eds. Proceedings of the 1st CIRP IPS2 Conference 2009. 2009, Cranfield University.

[4] M. Lindahl, G. Ö. Sandström, E. Sundin, A. Ö. Rönnbäck, J. Östlin, 2008, Learning networks: a method for Integrated Product and Service Engineering – experience from the IPSE project, In: Manufacturing Systems and Technologies for the New Frontier - Proceedings for The 41st CIRP Conference on Manufacturing Systems, Mitsuishi, Ueda, and Kimura, Editors. Springer: Tokyo. 495-500.

[5] P. Thollander, P. Solding, M. Söderström, Energy Management in Industrial SMEs, in Proceedings of the 5th European conference on economics and management of energy in industry (ECEMEI-5). 2009: Portugal.

[6] P. Rohdin, P. Thollander, 2006, Barriers to and driving forces for energy efficiency in the non-energy-intensive manufacturing industry in Sweden, Energy, 31: 1836-1844.

[7] P. Thollander, Towards increased energy efficiency in Swedish industry – barriers, driving forces and policies. 2008, Ph. D. thesis, Linköping University: Linköping.

[8] P. Bertoldi, B. Boze-Kiss, S. Rezessy, Latest Development of Energy Service Companies across Europe – A European ESCO Update. Ispra: JRC, European Comission, 2007.

[9] L. Trygg, Swedish industrial and energy supply measures in a European Perspective. 2006, Ph. D. thesis, Linköping University: Linköping.

[10] P. Thollander, P. Rohdin, M. Danestig, 2007, Energy policies for increased industrial energy efficiency: Evaluation of a local energy programme for manufacturing SMEs, Energy Policy, 35 5774-5783.

[11] SEEI (Swedish Energy Efficiency Inquiry), Vägen till ett energieffektivare Sverige (The road towards a more energy efficient Sweden). Stockholm: SOU (Statens offentliga utredningar), 2008.

[12] EEC (Energy Efficiency Committee), Vägen till ett energieffektivare Sverige (The road to a more energy efficient Sweden). Stockholm, 2008.

[13] P. Bertoldi, 1999, The use of long term agreements to improve energy efficiency in the industrial sector: overview of the European experiences and proposals for common framework. In the 1999 SAVE conference "For An Energy Efficient Millennium", Session III, 1-10.

[14] A. Forsberg, C. Lopes, E. Öfverholm, 2007, How to kick start a market for EPC Lessons learned from a mix of measures in Sweden. In ECEEE 2007 Summer Study - Saving Energy - Just Do It!, 211-218.

[15] M. Geissler, A. Waldmann, R. Goldman, 2006, Market Development for Energy Services in Europe. In ACEEE Summer Study.

[16] S. Sorrell, J. Schleich, S. Scott, E. O'Malley, F. Trace, E. Boede, K. Ostertag, P. Radgen, Reducing Barriers to Energy Efficiency in Public and Private Organizations. 2000, SPRU (Science and Technology Policy Research).

[17] P. Thollander, M. Ottosson, 2008, An energy-efficient Swedish pulp and paper industry – exploring barriers to and driving forces for cost-effective energy efficiency investments, Energy Efficiency, 1: 21-34.

[18] A. B. Jaffe, R. N. Stavins, 1994, The energy efficiency gap: what does it mean?, Energy Policy, 22: 60-71.

[19] P. Thollander, M. Söderström, P. Solding, 2009, Energy Management in Industrial SMEs. In 5th European conference on economics and management of energy in industry (ECEMEI-5). Portugal.

[20] J. Palm, 2009, Placing barriers to industrial energy efficiency in a social context: a discussion of lifestyle categorisation, Energy Efficiency, 2: 263-270.

[21] R. Kemp, D. Loorbach, 2006, Transition management: a reflexive governance approach, In: Reflexive Governance for Sustainable Development, Voss, Bauknecht, and Kemp, Editors. Edward Elgar. 104-130.

[22] R. R. Nelson, S. G. Winter, 1977, In search of useful theory of innovation, Research Policy, 6: 36–76.

[23] J. Ende, R. Kemp, 1999, Technological transformations in history: how the computer regime grew out of existing computing regimes, Research Policy, 28: 833-851.

[24] F. W. Geels, 2005, Technological Transitions and System Innovations: a co-evolutionary and socio-technial analysis. Edward Elgar, Camberley

[25] Thoresson Glad, Working Paper, in Tema Technology and social Change. 2009, Linköping university.

[26] M. Callon, 1991, Techno-economic networks and irreversibility, In: A Sociology of Monsters: Essays on Power, Technology and Domination, Sociological Review Monograph, Law, Editor. Routledge and Kegan Paul: London.

[27] W. Bijker, 1995, Sociohistorical Technology Studies, In: Handbook of Science and Technology Studies, al., Editor. Sage Publications: CA, USA.

[28] E. Shove, 1998, Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings, Energy Policy, 26: 1105-1112.

[29] J. Palm, P. Thollander, 2009, Applying an interdisciplinary perspective on industrial energy efficiency. In the Scientific Conference on Energy and IT at Alvsjo fair, 97-110.

[30] A. Gebremedhin, J. Palm, Energianalys Borås. Eskilstuna: Swedish Energy Agency, 2005.

[31] C. Caffal, Energy management in industry. Analysis Series 17. Sittard, The Netherlands: Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), 1995.

[32] P. Rohdin, P. Thollander, P. Solding, 2007, Barriers to and drivers for energy efficiency in the Swedish foundry industry, Energy Policy, 35: 672-677.

[33] M. Bergmasth, M. Strid, Energitjänster på en avreglerad marknad - för en effektivare energianvändning? (Energy Services in a deregulated market – for a more efficient use of energy?), in School of Economics and Commercial Law. 2004, Gothenburg University: Gothenburg.

Session 1B:
Sustainability

Is the Industrial Product-Service System really sustainable?

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Abstract

As the product-service system has shifted from its original concept to the Industrial PSS, its scope has expanded to include industrial products. Furthermore, the overall goal of reducing environmental impacts has been left behind. Despite the PSS's potential as a business model for a more sustainable production and consumption system, the mere addition of services to conventional products does not necessarily lead to a reduction of environmental impacts. This paper aims to discuss the concepts related to PSS, the need for considering environmental impact reduction as a critical issue for sustainability, and the role of ecodesign practices in the development of PSS.

Keywords

Product-Service System (PSS), Industrial Product-Service System (IPS^2), environmental sustainability, ecodesign

1 INTRODUCTION

According to the World Commission on Environment and Development (WCED) [1], sustainable development is defined as the 'development that meets the needs of the present without compromising the ability of the future generations to meet their own needs'. This definition, known as the Brundtland definition for sustainable development, is a rather general statement and leaves much scope for different interpretations among individual organizations [2]. Cowell et al. [3] state that 'although there is no consensus on the meaning of sustainable development or sustainability, there is common acceptance that it involves the consideration of economic, environmental and social aspects'. Thus, it can be deduced that sustainability requires a balance between economic, social and environmental aspects. Within this context, this paper explores the environmental sustainability of product-service systems (PSS).

The ever growing consumption of products is the origin of most of the pollution and depletion of resources caused by our society [4]. Because most existing environmental impacts are product-related, a significant decrease in materials and energy flows is required in order to achieve sustainability.

Traditional approaches to environmental management have evolved from pollution control and end-of-pipe treatments to preventive or cleaner production technologies, defined as the continuous redesign of industrial processes and products to prevent the generation of pollutants and waste at their sources and to minimize risks to humans and the environment. This approach was applied initially to industrial processes (hence cleaner technologies) and then, to make it more inclusive, to the industrial products themselves (hence cleaner products) since the environmental impacts observed throughout the life cycle of a product are, to a large extent, determined in its development phase [5].

Long-term economic growth combined with reduced pressure on the environment requires changes in production and consumption systems and the firm commitment of all actors in society. Therefore, the solution to environmental issues must be put into the context of the entire society, considered as a complex system with several main actors: government, manufacturers, recyclers and consumers. Since it is the interaction between these actors that finally determines the environmental performance of a product over its entire life cycle, the development of the issues raised must be accompanied by an in-depth study of the mechanisms of the entire complex system [6].

The need to consider environmental issues during new product development (NPD) gave rise to two research lines: the field of ecodesign, which deals with the integration of the environmental dimension into the initial stages of NPD, and the field of product-service systems (PSS), which involves the development of products and services systems and which is perceived as having a much higher potential to achieve environmental sustainability than ecodesign.

In this context, the Product-Service System (PSS) emerges as a promising approach for a more sustainable society. The concept of PSS implies a shift in business thinking from selling products to providing service solutions to customer needs. The introduction of new ownership patterns, such as leasing focused on extending a product's lifespan, increases manufacturers' interest in designing for durability and enables the reuse and remanufacturing of products prior to recycling, making possible the dematerialization of products.

This paper discusses the various concepts related to PSS, the need to consider environmental impact reduction as a critical issue towards sustainability, and the role of ecodesign practices in PSS development.

The 'Introduction' section described the context of this paper. The next section, 'Methodology', explains the methodology adopted in writing the paper. This is followed by the 'Product-Service Systems' section, which presents the most relevant PSS concepts available in the literature and the types into which they are usually classified. The 'PSS and environmental sustainability' section then addresses opportunities for increasing environmental sustainability by means of PSS, followed by the section on 'Ecodesign practices for PSS development', which describes ecodesign practices that can be used in the development of PSS with improved environmental performance. The subsequent section then discusses the 'Role of Ecodesign in PSS sustainability'. The last section presents the authors' 'Final Remarks', discussing the conclusions of the paper, which are followed by the 'Acknowledgments' and the 'References' cited herein.

2 METHODOLOGY

The main methodology employed in this study was the systematic literature review, a specific research methodology, which involves collecting and evaluating the available studies on a subject by means of a defined and strict sequence of three methodological steps: (1) problem formulation, (2) database definition and data collection, and (3) data analysis and evaluation [7].

Systematic literature reviews enable the researcher to map all the existing knowledge and initiatives currently and previously developed in a specific field. In addition to a preview of discoveries, techniques, ideas and exploratory modes for the topic, systematic reviews allow for an evaluation of the relevance of the information to the issue in question.

In this sense, a systematic literature review was made to collect and interpret available data on Product-Service Systems and Ecodesign. The PSS literature was studied to determine the concepts different authors put forward to define PSS and the context in which they were developed. In addition, a study was made of the potential reduction in environmental impacts provided by the different types of PSS. This review revealed the answer to the main question of this paper, namely, "Is PSS really sustainable?"

The literature on ecodesign was also examined to determine if it could contribute to increase the environmental performance of product and PSS development, contributing to its sustainability. Finally, an analysis was made of the possibility of applying ecodesign practices in the development of PSS, and a proposal was drawn up to integrate the two concepts, PSS and ecodesign, in order to achieve environmental sustainability.

3 PRODUCT-SERVICE SYSTEMS (PSS)

The traditional industrial economy in which value is attributed to material products that are exchanged has shifted towards the new service economy, in which value is more closely related to the performance and real utilization of the products integrated in a system [8].

Business-to-business and business-to-customer markets have a tendency to offer a combination of products and services, which are sold in one package to meet the customer's needs. These combinations of products and services are called product-service systems (PSS) or industrial product-service systems (IPS^2), in the case of industrial applications [9].

The services that are of interest in the field of sustainable development are known by many different names: eco-services, eco-efficient services, sustainable services, product-service systems (PSS), sustainable service systems, and sustainable product-service systems [10]. These terms, mainly "Product-service" and "product-service systems", are rarely used in the mainstream business literature, where the terms functional sales, experiences and/or satisfaction and integrated solutions are quite common [11]. The following sections present the definitions of PSS and also the categories into which it is classified.

3.1 Definitions of PSS

Since the concept of Product-Service System (PSS) emerged in northern Europe in the late 1990s, many definitions have been proposed to clarify the composition of this new business model. First, Goedkoop and his collaborators [12] defined PSS as 'a marketable set of products and services capable of jointly fulfilling a user's need'.

According to Baines et al. [13], a PSS can be seen as a new market proposal that extends the traditional functionalities of a product through the incorporation of additional services. Instead of centering on 'traditional' forms of sale, ownership, consumption and disposal of products, a PSS focuses on the delivery of a 'function' to the customer. In practice, this may mean the provision of combinations of products and services that are capable of 'jointly fulfilling users' needs' [12 apud 14].

Brezet et al. [15] defines eco-efficient services as 'systems of products and services that are developed to cause less environmental impact than traditional business models'.

Manzini and Vezzoli [16] present PSS as the result of an innovation strategy, shifting the business focus from designing and selling physical products only, to selling a system of products and services that can jointly meet clients' specific demands.

Mont [17] states that, in a PSS, the traditional forms of manufacturing and product use are replaced by the possibility of meeting consumers' needs by providing services that are more intangible, which are associated with changes in ownership structure and that target environmental improvements. According to this author, PSS can be defined as 'a system of products, services, networks of actors and supporting infrastructure that continuously strives to be competitive, satisfy customer needs, and cause a lower environmental impact than traditional business models'.

In the context of the SusProNet project that aimed to exchange, analyze, complete and make easily available information on best practice of PSS, in 2006 Tukker and Tischner [11] developed the following definition of PSS: 'the product-service including the value network, technological infrastructure and governance structure (or revenue model) that produces a product-service – a value proposition that consists of a mix of tangible products and intangible service designed and combined so that jointly they are capable of fulfilling final customer needs'.

Industrial Product-Service Systems (IPS^2) can be characterized as a combination of tangible products and intangible services, providing a value to the customer via the complete life cycle [18]. An IPS^2 is defined as 'an integrated industrial product and service offering that delivers value in use' and represents a change in the competitive strategy for manufacturing companies, enabling innovative function, availability and results-oriented business models [19].

3.2 Types of PSS

The distinction between products and services can be difficult to define. In practice, there is a continuum of products and services, in which the total offer is a product-service mix [10].

The product/service ratio in this set may vary, either in terms of function fulfillment or of economic value [12].

PSS can be classified in different ways, as can be seen in [12], [17] and [20], but it is most commonly divided into three categories: (1) product-oriented, (2) use-oriented, and (3) result-oriented, as presented in [11]. In summary, the categories differ basically in the importance ascribed to the product (physical part) and to ownership patterns.

In product-oriented PSS, the customer owns the product and relevant services are offered to ensure the product's functionality and durability, such as after-sales services (installation, maintenance, repair, upgrading and recycling, and helping customers optimize the application of a product through training and consulting) [13].

Use-oriented PSS comprises product rental, leasing, sharing and pooling. In this category, the product still plays the central role in the system, but its ownership remains under the manufacturers' responsibility. The consumer pays a fee only to use a specific product.

In the last category, result-oriented PSS, a given function is agreed upon between the provider and the customer. The product, which is seen simply as a tool to attain the desired result, is chosen by the supplier. Outsourcing activities and pay per service units are well known examples.

According to Tukker and Tischner [11], the potential of moving PSS to greater sustainability is directly proportional to radical changes made in the system. Furthermore, whether the available potential is achieved depends on a focused effort to design PSS to be as sustainable as possible, preferably stimulated by the right framework conditions and suitable tools. Hence, sustainability is not an automatic mechanism built into the PSS concept but depends on many conditions.

4 PSS AND ENVIRONMENTAL SUSTAINABILITY

To date, the shift from selling products to providing services has not been driven by environmental concerns but instead by business motivations. These include increasing competitiveness, reducing costs, serving a market's need for speed, providing customer convenience and flexibility, improving corporate identity, or responding to a discrete business opportunity [10].

The generic eco-drivers for the adoption of PSS are [21]:

For companies:

- Threat of legislation;
- Response to client's wishes;
- Increased employment;
- Provide jobs for local markets;
- Move towards green purchasing by authorities;
- Fewer waste management concerns from the domestic and manufacturing sector;
- Companies considering themselves environmentally and socially responsible;
- More sustainable economy based on higher levels of services.

For consumers:

- Lower costs and fewer problems associated with the purchase, use, maintenance, and eventual replacement of products;
- The service provider is stimulated to use and maintain equipment properly, increasing both efficiency and effectiveness.

However, the global footprint forces research and industry to engage in activities aimed at improving sustainability. IPS² could have a positive influence on the sustainability issues as the changing market environment gives rise to new customer demands. The contribution of IPS^2 to sustainability is based on four different types of motivation [19]:

- Economic: there is little profit in selling machines, but more profit in delivering services;
- Technical: the equal focus on product and service development enables innovation;
- Social: integration of product and service engineering enables high-income countries to protect and build up employment; while countries with low technical qualifications improve their performance levels;
- Ecological: IPS2 reduce the consumption of resources.

Thus, according to Manzini and Vezzoli [16], PSS (and IPS^2) is a feasible and promising business strategy potentially able to help achieve the leap that is needed to move to a more sustainable society, and can be seen as a strategic innovation that companies may choose in order to:

- Separate resource consumption from its traditional link to profit and standard of living improvements;
- Find new profit centers,
- Compete and generate value and social quality while decreasing (directly or indirectly) total resource consumption.

According to Tukker and Tischner [11], the potential environment benefits of PSS are:

- Lower materials and energy consumption during the phases of production and use of services compared with products;
- Lower stock of products in manufacturing, since it encourages leaner manufacturing because products are more valuable;
- Potential for environmental benefits through economies of scale;
- Extension of the manufacturer's responsibility for the product, making it more palatable to the consumer, manufacturer and environment;
- More durable products, diminishing the total stock of product required in the cycle to meet a specific need at any given time;
- Renting potentially opens up the possibility for more intensive use of the product, with the same environmentally beneficial outcome;
- Manufactures may take more professional care of the product over the use phase, thus ensuring a higher quality end-stock and less downcycling;
- Manufacturers, which are also the main operators of the PSS, will have no incentive to sell excess material, will be in a better position to optimize the products to their true function, and will have far better knowledge about the true requirements and characteristics of the equipment.
- Collection of end-of-life products will be significantly easier, thus increasing the rate of utilization of end-of-life products;
- Development of better end-of-life disposal processes, since there will be clear pressure to design for this stage of the product life-cycle, starting from the concept generation phase onwards;
- Manufacturers encouraged to develop innovative uses for end-of-life products;
- Easier upgrading to more eco-efficient technologies.

Comparing the PSS types, Tukker [22] states that they can contribute differently to the environment (Figure 1). According to this author:

- Product-related service, advice and consultancy, and product lease have probably marginal environmental benefits, since at best mainly incremental change such as better maintenance etc. can be expected. Cases of product leases may even have negative environmental effects if the lessee feels encouraged to use the product less carefully than if he owned it;

- Renting, sharing or pooling can have major environmental benefits if the burden is related to the production of the artifact, since the same product is shared and used more intensively. However, if, in the case of product renting or sharing, the use phase dominates and does not lead to a low use behavior there is little positive outcome. In such cases, pooling leads to lower impacts since more people make use of the product at the same time;
- Activity management/outsourcing PSS will lead to lower environmental impacts if (monetary) efficiency gains are related particularly to materials and artifacts, and not to human time inputs;
- The pay per unit use overcomes the split incentive between production costs of a product and costs incurred in the use phase. It is likely that at least incremental gains will be realized, but since the technological system in principle does not change radically, no significant improvements can be expected.
- In theory, functional result PSSs have the highest potential since the provider offers a result closer to a final client's needs and therefore has greater freedom to design a low-impact system.

The shift from buying products to buying services provided by the result-oriented PSS therefore has a major potential to minimize environmental impacts [23].

In this context, it can be concluded that the development of PSS is not intrinsically sustainable, and there are also cases in which the environmental impacts are higher than in a traditional system (leasing, for instance) [11].

5 ECODESIGN PRACTICES IN PSS DEVELOPMENT

It is essential that considerations of environmental sustainability be integrated into all the steps of a PSS development and design process, that its market launch is carefully prepared to ensure success, and that the solution on the market is reviewed in terms of economic, environmental and social impacts [11].

A paramount goal of product–service systems should be to minimize the environmental impact of consumption by [17]:

- Closing material cycles;
- Reducing consumption through alternative scenarios of product use;
- Increasing overall resource productivity and dematerialization of PSSs;
- Providing system solutions aimed at perfecting the system's integrating elements while simultaneously improving the resource and functional efficiency of each element.

Ecodesign can be defined as a strategic design activity whose purpose is to conceive and develop sustainable solutions. It generates sets of products, services and knowledge that enable consumers to achieve sustainable results. Ecodesign can also be seen as a proactive management approach that guides product development towards the reduction of environmental impacts throughout a product's life cycle, without compromising other criteria such as performance, functionality, aesthetics, quality and cost [24-30].

The development of PSS is the highest level of innovation in ecodesign. According to Charter and Tischner [21], there are four levels of environmental considerations in the product development process. The fourth level is described as the level where the functionality concepts are conceived to be compatible in a sustainable society. Brezet and van Hemel [31] define system innovation as the last level of innovation in ecodesign, corresponding to new products and services that require changes in infrastructure and in the systems involved in the use of the product. Finally, the last intervention level is defined by Vezzoli and Manzini [32] as the creation of new scenarios for a sustainable way of life.

In a PSS, the physical product is responsible for the majority of environmental impacts caused by the PSS because the flows of materials and energy are related mainly to the physical product along its whole life cycle, from the extraction of raw materials to its end-of-life disposal (Figure 2).

Due to its great potential, therefore, design is one of the most influential factors in the development of sustainable production systems and products [6].

A variety of ecodesign practices have been developed to evaluate environmental impacts resulting from the product's life cycle, bringing to light potential problems/conflicts and facilitating the choice among possible product aspects. Ecodesign methods and tools can be defined as any systematic means to deal with environmental issues during the product development process [33, 34], while guidelines are general rules that can guide designers and engineers during the product development process.

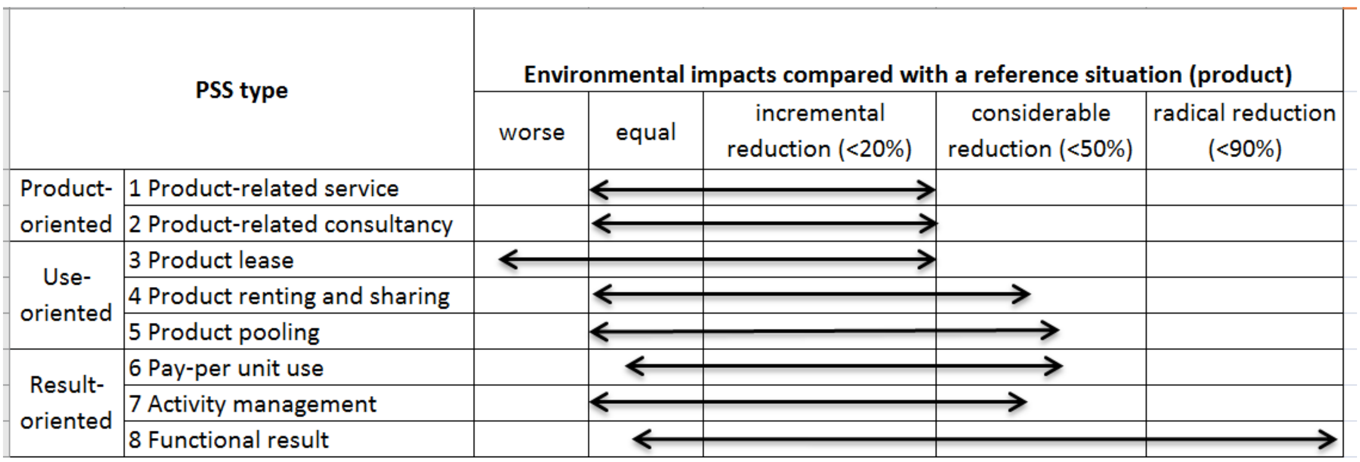

Figure 1: Environmental impacts according to PSS types (adapted from [11])

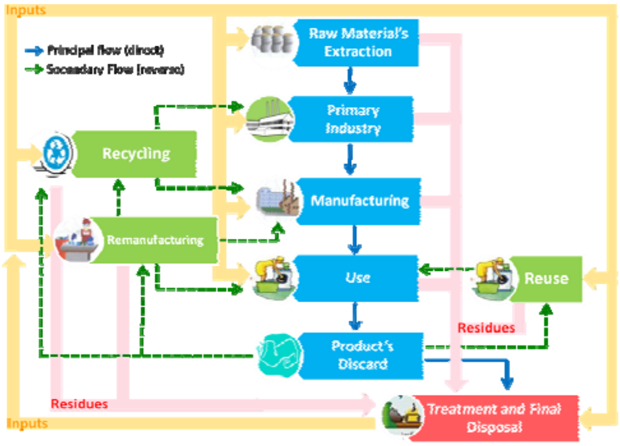

Figure 2: Material Life Cycle

The main ecodesign strategies to increase the environmental performance of products, according to Vezzoli and Manzini [32], are:

Minimizing material consumption:

- Minimize material content;
- Minimize scraps and discards;
- Minimize or avoid packaging;
- Engage more consumption-efficient systems;
- Engage systems of flexible materials consumption;
- Minimize materials consumption during the product development phase.

Minimizing Energy Consumption

- Minimize energy consumption during pre-production and production;
- Minimize energy consumption during transportation and storage;
- Select systems with energy-efficient operation stage;
- Engage dynamic consumption of energy;
- Minimize energy consumption during product development.

Minimizing Toxic Emissions

- Select nontoxic and harmless materials;
- Select nontoxic and harmless energy sources.

Renewable and Biocompatible Resources

- Select renewable and biocompatible materials;
- Select renewable and biocompatible energy sources.

Optimization of Product Lifespan

- Design appropriate lifespan;
- Design for reliability;
- Facilitate upgrading and adaptability;
- Facilitate maintenance;
- Facilitate repairs;
- Facilitate reuse;
- Facilitate remanufacture.

Improve Lifespan of Materials

- Adopt the cascade approach;
- Select materials with the most efficient recycling technologies;
- Facilitate end-of-life collection and transportation;
- Material identification;
- Minimize the number of different incompatible materials;
- Facilitate cleaning;
- Facilitate composting;
- Facilitate combustion.

Design for Disassembly

- Overall architecture;
- Shape of components and parts;
- Shape and accessibility of joints;
- Engage reversible joining systems;
- Engage easily collapsible permanent joining systems;
- Co-design special technologies and features for crushing separation.

According to Bhamra and Lofthouse [10], products for PSS will need to be more durable than those that exist today and may have different features that reflect the need of the service. In this sense, the strategies 'Optimization of product lifespan' and 'Design for Disassembly' are of considerable importance.

6 ROLE OF ECODESIGN IN PSS SUSTAINABILITY

Once the company has strategically decided to develop a product-service system (PSS), the whole development process must be adjusted to the new intrinsic PSS requirements, such as design for disassembly, increase of product's durability, and design for maintainability, among others.

It is extremely important to include ecodesign practices (methods, tools, guidelines, software) in the PSS design and development in order to minimize its environmental impact, contributing to achieve the PSS sustainability potential that is currently being disregarded by companies worldwide.

All the ecodesign practices presented above can be applied successfully during the PSS development in order to ensure the product's improved environmental performance, which contributes to increase the sustainability of the entire system. The focus of the PSS, however, should be on the "Optimization of Product Lifespan" and also on the "Design for Disassembly" strategies.

Ecodesign strategies can also be addressed during the development of the service, focusing on the reduction of the system's overall environmental impacts.

Compared to Ecodesign cases, the transition towards PSS will often entail an important process of change by the company towards new thinking on how it should create value, produce, distribute and approach its clients.

7 FINAL REMARKS

Although it did not do so explicitly, the first PSS concept developed by Goedkoop et al. [12] embraced the concern of decreasing impacts on the environment. Albeit recognized as an important part of the PSS concept, Tukker and Tischner [11] believe that 'a (PSS) term should not implicitly include the normative notion of sustainability but, if relevant, that this should be indicated specifically'.

The authors of this paper believe that PSS/IPS^2 definitions that fail to consider sustainability as a central issue of the PSS concept represent a regression in the concept's development and application worldwide, which may result in little achievement of the sustainability potential through PSS.

PSS does not follow the tendency of reducing the environmental burdens associated with products along its whole life cycle, which is the concept that underpins the Integrated Product Policy (IPP). The Green Paper on Integrated Product Policy (IPP) launched a broad debate on how to achieve a new growth paradigm through wealth creation and competitiveness on the basis of green products, and proposed strategies intended to reinforce environmental policies, with the aim of integrating environmental requirements into product standards [6].

As presented by Tukker and Tischner [11], the development of PSS is not intrinsically sustainable, and there are also cases in which PSS causes higher environmental impacts than a traditional system (leasing, for instance).

It is argued that a PSS can only be considered a "true" PSS if it was designed to minimize environmental and social impacts throughout its whole life cycle. In this sense, the consideration of environmental concerns must be intrinsic to the PSS concept. Higher environmental performance ought to result when ecodesign practices are addressed in PSS design and development.

As McAloone and Andreasen [35] state, there is a need to readdress the way in which we develop and provide products to users and consumers, so that leap-changes can be made in the environmental profile of products, rather than merely minor incremental improvements. In other words, we need to shift from focusing on the design and development of the simple artifact to the innovation of a whole PSS, in which the traditional manufacturer-vendor-user relationship is rearranged, allowing for the delivery of environmental, social and economic benefits.

8 ACKNOWLEDGMENTS

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9 REFERENCES

[1] Brundtland, G. (ed.), 1987, Our Common Future: the World Commission on Environment and Development. Oxford University Press.

[2] Paramanathan, S., Farrukh, C., Phaal, R., Probert, D., 2004, Implementing industrial sustainability: the research issues in technology management. In: R&D Management, 34: 527-537.

[3] Cowell, S.J., Wehrmeyer, W., Argustb, P.W., Robertson, J.G.S., 1999, Sustainability and the primary extraction industries: theories and practice. In: Resources Policy, 25: 277–286.

[4] Green paper on integrated product policy, 2001. Available at: <http://eur-lex.europa.eu/LexUriServ/site/en/com/2001/com2001_0068en01.pdf>. Accessed on Jan. 15, 2007.

[5] Graedel, E., Allenby, R., 1995, Industrial Ecology. Prentice Hall.

[6] Giudice, F., Rosa, G. la, Risitano, A., 2006, Product Design for the Environment: a life cycle approach. Taylor & Francys.

[7] Biolchini, J. et al., 2005, Systematic Review in Software Engineering. Technical Report RT – ES 679/05. Rio de Janeiro: Systems Engineering and Computer Science Department, Universidade Federal do Rio de Janeiro.

[8] Giarini, O., Stahel, W.R., 1993, The Limits to Certainty: facing risks in the new service economy. Kluwer Academic Publishers.

[9] Seliger, G., Gegusch, R., Müller, P., Blessing, L., 2008, Knowledge Generation as a Means to Improve Development Processes of industrial Product-Service Systems. In: Annals of the 41st CIRP Conference on Manufacturing Systems.

[10] Bhamra, T., Lofthouse, V., 2007, Design for Sustainability: a practical approach. Gower Publising Limited.

[11] Tukker, A., Tischner, U., 2006, New Business for Old Europe: Product-Service Development, Competitiveness and Sustainability. Greenleaf Publishing.

[12] Goedkoop, M., van Halen, C., te Riele, H., Rommens, P., 1999, Product Service Systems, Ecological and Economic Basis. Available at: <http://www.pre.nl/pss/default.htm>. Accessed on Nov. 18, 2008.

[13] Baines, T. et al., 2007, State-of-the-art in product-service systems. In: Proc. IMechE Part B: J. Engineering Manufacture, 221: 1543-1552.

[14] Williams, A., 2007, Product service systems in the automobile industry: contribution to system innovation? In: Journal of Cleaner Production, 15: 1093-1103.

[15] Brezet, J.C., Bijma, A.S., Ehrenfeld, J., Silvester, S., 2001, The design of eco-efficient services. TU Delft for the Dutch Ministry of Environment.

[16] Manzini, E., Vezzoli, C., 2002, Product-service systems and sustainability. Available at: <http://www.unep.fr/scp/design/pdf/pss-imp-7.pdf>. Accessed on Aug. 20, 2008.

[17] Mont, O., 2002, Clarifying the concept of product-service system. In: Journal of Cleaner Production, 10: 237-245.

[18] Meier, H., Uhlmann, E., Krug, C., Völker, O., Geisert, C., Stelzer, C., 2009, Dynamic IPS²-Networks and -Operations Based on Software Agents. In: Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS2) Conference, Cranfield University, 1-2 April 2009.

[19] CIRP Working Group IPS2, 2009. What is an Industrial Product Service System? Available at: < http://www.Ips.rub.de/schwerpunkt/cirp/>. Accessed on Sep. 15, 2009.

[20] Behrendt, S., C. Jasch, et al., 2003, Eco-Service Development: Reinventing Supply and Demand in the European Union. Greenleaf Publishing.

[21] Charter, M.; Tischner, U., 2001, Sustainable Solutions: Developing Products and Services for the Future. Greenleaf Publishing.

[22] Tukker, A., 2004, Eight types of product-service system: eight ways to sustainability? In: Business Strategy and the Environment, 13: 246–260.

[23] Yang, X., Moore, P., Pu, J-S., Wong, C-B., 2009, A practical methodology for realizing product service systems for consumer products. In: Computers & Industrial Engineering, 56: 224-235.

[24] Sundin, E., Bras, B., 2005, Making functional sales environmentally and economically beneficial through product remanufacturing. In: Journal of Cleaner Production, 13: 913-925.

[25] Kerr, W., Ryan, C., 2003, Eco-efficiency gains from remanufacturing: A case study of photocopier remanufacturing at Fuji Xerox Australia. In: Journal of Cleaner Production, 9: 75–81.

[26] Spicer, A., Wang, M., 1997, Environmental Design Industrial Template (EDIT) a software tool for analysis of product retirement. In: Journal of Cleaner Production, 5: 193-198.

[27] Yu, S.Y., Zhang, H-C., Ertas, A., 1999, Environmental Conscious Design an Introduction to EDST. In: Journal of Integrated Design and Process Science, 3: 27-38.

[28] Sun, J., Han, B., Ekwaro-Osire, S., Zhang, H-C., 2003, Design for Environment: Methodologies, Tools and Implementation. In: Journal of Integrated Design and Process Science, 7: 59-75.

[29] Johansson, G., 2002, Success Factors for Integration of ecodesign in product development: a review of state of the art. In: Environmental Management and Health, 13: 98-107.

[30] Weenen, J.C.V., 1995, Towards sustainable product development. In: Journal of Cleaner Production, 3: 95-100.

[31] Brezet, J. C., Van Hemel, C., 1997, Ecodesign: A Promising Approach. UNEP Working Group on Sustainable Product Development. Paris: [s.n.].

[32] Vezzoli, C., Manzini, E., 2008, Design for Environmental Sustainability. Springer.

[33] Baumann, H., Boons, F., Bragd, A., 2002, Mapping the green product development field: engineering, policy and business perspectives. In: Journal of Cleaner Production, 10: 409-425.

[34] Byggeth, S., Hochschorner, E., 2006, Handling trade-offs in Ecodesign tools for sustainable product development and procurement. In: Journal of Cleaner Production, 14: 1420-1430.

[35] McAloone, T., Andreasen, M. Defining Product Service Systems. Available at: http://www.aaben.dtu.dk/upload/centre/cipu/pss/031-0210-fertigung.pdf. Accessed on: Nov. 10 2009.

Assessment of the Sustainability Effects of Product-Service Systems

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Abstract

The concept of Product-Service Systems (PSS) as a means to realize sustainable business models is a vividly discussed topic in management literature. Most approaches to evaluate the impacts of PSS focus on the economic as well as the ecological dimension of sustainability, whereas social implications are hardly analyzed. However, a more comprehensive evaluation of potential effects of all three dimensions of sustainability is indispensable to foster the diffusion of PSS. Therefore, this article offers an integrative assessment of the sustainability impacts of PSS based on expert interviews in the B2B as well as B2C sector.

Keywords

Product-Service Systems, Sustainability, Empirical Results, Manufacturing Sector, Wastewater Treatment

1 INTRODUCTION

Recently, it has been possible to observe a shift in many manufacturing industries from traditional product-oriented business models towards service-oriented business models [1]. Instead of simply selling physical products, the functionality of the product is sold to customers [2]. Characteristic for these new business models is the bundling of products and value-added service to offer customer solutions instead of mere products [3, 4].

There are many different terms used in literature to name service-oriented business models, i.e. functional sales [5], performance–based contracting [6] or high value integrated solutions [7]. The business concepts outlined hereunder aim to fully satisfy customer needs and at the same time offer advantages like higher profits, strengthened customer ties and generating benefits in mature markets [8]. Within the research arena dedicated to sustainability issues, these innovative business relations between equipment suppliers and their customers are discussed predominantly under the term "product service systems" (PSS) [9]. With focus on sustainability this strain of PSS research stresses the opportunity of decoupling material consumption from generating profit through integrating services and by this means reducing the environmental impact in production systems [10].

Although the potential of PSS to realize economic as well as ecological goals are approved by both research groups the implemented business models often emphasize mainly one perspective. While the economic sustainability of concepts like for example Total Cost of Ownership (TCO) is explicitly pursued, the ecological sustainability effects of such models remains unclear. In other models, for instance contracting in the energy sector, the ecological and economic motivations are more closely interrelated. Occasionally service models are promoted as beneficial to the environment, without their social-economic viability having been proven.

However, some approaches to investigate the effects of PSS on sustainability have been made in the past. An attempt to assess the economic and ecological impact of PSS was made by Tukker [10]. He estimated the environmental impacts of eight different types of PSS in comparison to the reference product on a scale from "Worse [than the reference product]" to "radical reduction". Implications of service orientation (product-, use- and result-oriented) on job creation and ecological effects were analyzed by Scholl [11]. Furthermore Maxwell and van der Vorst [12] in conjunction with practitioners from industry developed a procedural method that supports value chain partners in developing sustainable products and/or services under consideration of economic, ecological as well as social aspects.

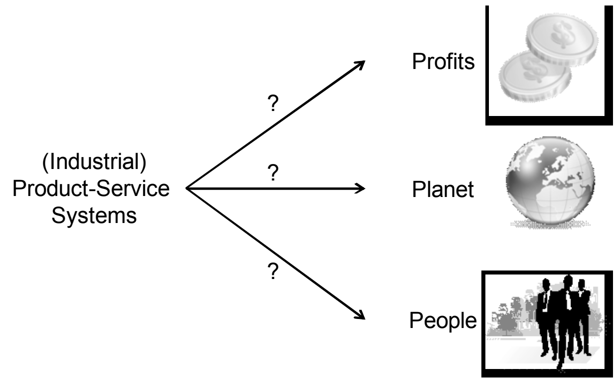

Figure 1: Dimensions of Sustainability.

Although in turbulent times like these the economic aspect is ranked first, the importance of a holistic assessment of economic, ecological and social aspects of sustainability can not be overemphasized. Dyllick and Hockerts [13] express it as follows: "*A single-minded focus on economic sustainability can succeed in the short run; however, in the long run sustainability requires all three dimensions to be satisfied simultaneously.*

However, in order to assess the contribution of PSS concepts to sustainability a comprehensive assessment of potential effects of all three dimensions of sustainability is indispensable (see Figure 1). A holistic approach allows the identification of cause-and-effect chains to set up a framework of generally admitted interdependencies over different types of PSS and different industry sectors.

Therefore, a literature review was performed with the aim of identifying the state-of-the-art in this field of research. As no consistent Product-Service Systems theory exists up to now giving theoretical explanations on the why and how value added can be created neither in an economic, ecological or social sense the review process was used to look for first contributions to fill this gap. At the end of this process New Institutional Economics especially Property Rights Theory indicated by Hockerts [14], Transaction Cost Economics indicated by Toffel [15] and also incorporating considerations from Principal Agent Theory were identified. These are expanded by the interrelation of services and the Resource-based View of the firm implied by Burr [16] and insights from services science [17]. These approaches have been chosen to serve as theoretical backbone to derive hypotheses on possible cause-effect chains.

In this paper three key hypotheses out of the identified 15 on sustainability impacts of PSS are presented. Furthermore, a preliminary qualitative assessment of these hypotheses based on interviews with different stakeholders of PSS, e. g. industry associations, labor unions, policy-makers and also scientists withholding expertise with PSS is given.

Our research contributes to the existing research on the sustainability potential of PSS and will detect correlations and divergences over different manufacturing sectors. In the following section the applied research method is described in detail.

2 RESEARCH METHOD

The aim of the research described in this paper is to determine and evaluate the sustainability effects of PSS. For this purpose, a qualitative approach has been chosen, which is depicted in Figure 2. Although the research questions were deduced from already existing theory, a qualitative approach was chosen for the following reasons. Up to now no explicit theory on Product-Service Systems exists. Therefore, although hypotheses could be deduced from business management and economic theory, testing these hypotheses via a quantitative survey would not reveal interrelationships that are not yet covered by theory. Furthermore, the aim of this research was not only to validate the underlying assumptions, but also to identify conditions under which the cause-effect chains are true. Therefore, following a qualitative approach in a first step, the general research question was defined. In doing so, the research gap underlying the project was tapped and additionally a focus was set to avoid getting lost in the volume of information [18]. The overall research question was defined as:

- RQ: What are the sustainability effects of PSS?

On this basis a comprehensive literature review was conducted. Previous studies and publications on PSS and sustainability were the focus of this literature review and served as a foundation for both development of hypotheses and selection of potential interviewees. Against this background a set of hypotheses was established, bolstered by the literature findings on possible correlations of PSS on economic, ecological and social impacts. The three dimensions of sustainability must not be regarded as independent. However, as the sustainability effects of PSS are difficult to measure and to analyze, in the chosen approach the hypotheses only refer to one dimension. Furthermore this approach allows it to measure different shades of the impact level of the individual dimension. Nevertheless the concept of PSS resembles the node which all of the three aspects are tied to.

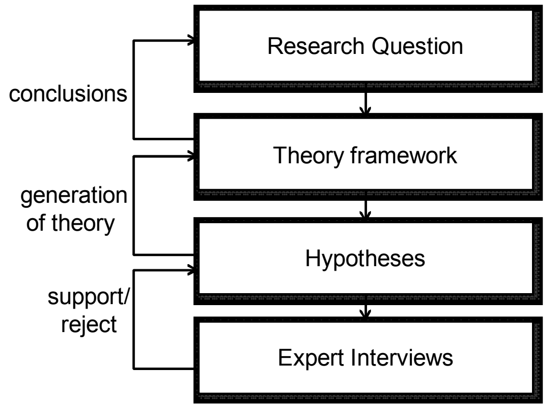

Figure 2: Research method.

Next, an interview guideline was elaborated, where the hypotheses were split up into one to three questions to disperse a complex interrelation into linear traceable relationships in order to capture most of the experts' knowledge, experience and thoughts on PSS.

This interview guideline also served as an orientation for the interviewers to cover all aspects, but allows going into more detail, especially in certain fields of the interviewee´s expertise [19]. In section three, it will be shown how the hypotheses were derived from literature and how they were operationalized in the interview guidelines. The results of the expert interviews can be found in section 4. The experts were identified on the basis of the literature review: persons from research, but also from industrial associations, companies and labor unions who had contributed to the PSS-sustainability debate during the last years were selected and were invited to give insights into their expertise. To shed light on possible differences caused whether the product-service system is delivered in a business-to-business or business-to-customer context experts from fields were interviewed. Thus, the focus was on two sectors: manufacturing and wastewater treatment.

For the manufacturing sector, a total of ten experts were interviewed. Of these, three experts were researchers, four employees of industrial associations and three from others, i.e. companies, consulting agencies and labor unions. As the manufacturing sector consists of several subsectors, two experts came from the machine tool industry, two from the compressors industry, one each from the assembly industry and the energy systems industry and four were experts on the manufacturing sector in general. (See Table 1) The experts came from several European countries.

Sector:	**Research**	**Association**	**Others**	**Total**
Machine Tool Industry	1	1		*2*
Compressed Air		1	1	*2*
Assembly Systems			1	*1*
Energy Systems			1	*1*
Manufacturing Sector (general)	2	2		*4*
Manufacturing Sector total	**3**	**4**	**3**	***10***
Wastewater Treatment	**1**	**2**	**2**	***5***

Table 1: Interviewees.

Six interviews were conducted overall for wastewater treatment. One of the wastewater experts came from research, one from an industrial association, one from a company offering PSS and three experts came from platforms dealing with different aspects of wastewater management.

Expert interviews were conducted from April 2009 to November 2009. They took between one and two hours and were done either face-to-face or via telephone. Two interviewers participated in the interview, one to lead the discussion and the other one to take written notes of the interview [18]. Afterwards the protocols of the interviews were sent back to the interviewee for revision.

After finishing the interviews, the interview reports were analyzed by three researchers independently to guarantee profound results. If there was a deflation concerning the interpretation of certain information this special issue was discussed again within the group of researchers. The interviews were evaluated by means of a content analysis.

Given the limited scope of this paper, we will discuss only 3 hypotheses in detail, one for each of the three dimensions of sustainability. The content analysis allows going away from the written interview text and tries to systematically reduce the volume of information as well as to structure the information according to pursued research question [19]. To extract the key information from the interviews, an evaluation matrix was developed. This was extremely important as experts from two different industrial sectors with individual peculiarities were evaluated. The matrix design contributed under these circumstances to a structured and consistent procedure of extracting information to assess the hypotheses. By doing so, the answers given during the interviews could be used to either support or reject the hypotheses. The results of these interviews can be found in section 4 of this paper. These finding will be used to contribute to the generation of theory on the sustainability effects of PSS. Before the results are presented the analyzed hypotheses and their theoretical roots are to be presented. Corresponding to the quality criteria of this qualitative research approach the operational steps of the study were previously defined to guarantee a structured execution of the study [20]. The sequential steps of the content analysis are depicted in Figure 3. To answer traditional criteria of reliability of the results the analyses of the answers was carried out by multiple researchers. Furthermore addressing newly established quality criteria of qualitative research, the procedural manner has been carefully documented and the evaluation of the hypotheses is embedded into a written argumentation. Contributing to the traditional criteria of validity the questions included in the guided interview are based on the hypotheses derived from theory that draw on a combination of well established organizational and management theories [20, 21].

3 FRAMEWORK OF RESEARCH HYPOTHESES

For the purpose of deriving hypotheses on the sustainability effects of PSS, at the beginning of this research project a literature review focused on the effects on sustainability was conducted and existing approaches of a theoretical derivation of the value added through these business concepts were scanned. Thereby, initial works were identified. Toffel [15] refers to the term servicizing that "involves suppliers providing functionality rather than products" and picks up the peculiarities of these models and their influence on the governance structure using transaction cost economics. Hockerts [14] draws on the property rights theory to explain why PSS are supposed to be superior market solutions in comparison to the traditional way of doing business. Transaction cost economics and property rights theory seem to be promising theoretical approaches, due to the fact that in PSS, compared to the traditional sale of equipment, changes in the mode of transaction are implied, as PSS providers retain some or all property rights of the physical good used in PSS and hence stay responsible for it. From a resource-based point of view, Product-Service Systems unfold their benefits due to the specialized knowledge of the provider. These capabilities in terms of PSS are based on, for example, certain engineering competencies, capabilities in process design or established long-term relationships with customers. These internally existing competencies enable the provider to perform activities in a better way than its customer and thus build the basis to achieve a value added through the PSS offer.

When analyzing PSS in this paper it is referred to Tukker´s [10] widely acknowledged categorization scheme, which differentiates into the following subcategories:

- Product-oriented services: sale of product including

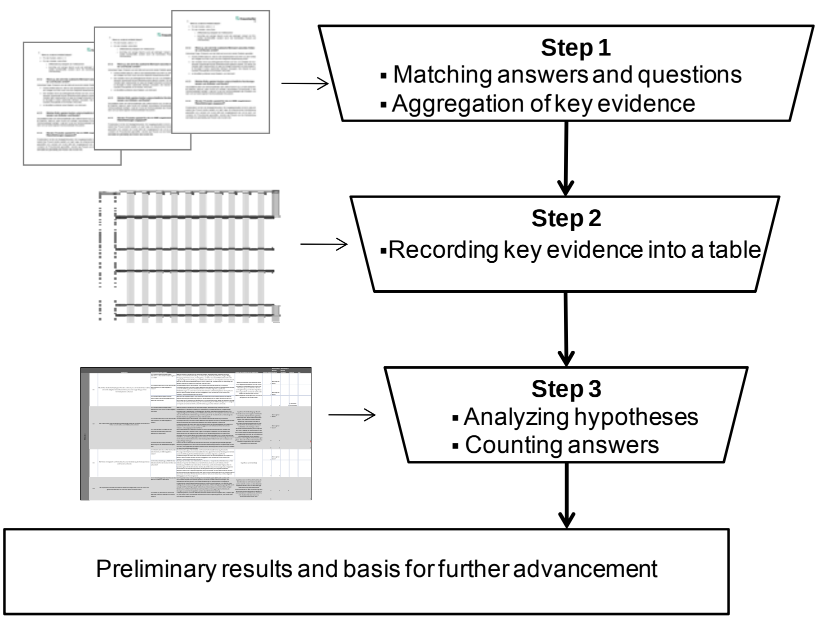

Figure 3: Procedural steps of qualitative content analysis.

add-on services

- Use-oriented services: selling use or availability of a product
- Result-oriented services: selling result or capability instead of a product [23]

Economic Sustainability

One underlying assumption of New Institution Economies is that behavior is motivated by maximizing individual wealth, referred to as opportunistic behavior. Especially in situations where one party has an information advantage over another [15], this behavior has to be anticipated. Information asymmetry is a crucial point in new business models as information asymmetries can result when one actor is not able to evaluate the conclusion of a contract before (adverse selection) or after (moral hazard). Also due to the fact that no contract can cover all possibilities that might come up during the transaction, both actors are subject to opportunism, especially if one actor made specific investments (hold-up) [24]. For example, due to its expert information on machine behavior, durability of spare parts, or time span of maintenance, the provider has an advantage over the customer, especially if the machine or product incorporates innovative technology. The problem of information asymmetries could apply also vice versa, as characteristic for services is the co-operation or co-creation of value [25] of the customer.

Information asymmetry exists when information on accidents or monitoring data of the product is withheld by the customer. If mechanisms of opportunistic behavior come into force, leading to a one-sided absorption of the value added, a persistent return on investment for one party might be not guaranteed. These considerations lead to the following hypotheses:

H 1: An unbalanced power structure in a PSS entails a one-sided absorption of the value added.

To test this hypothesis in the expert interviews, several questions in the interview guideline were dedicated to it. First, the interviewee was asked if PSS in the examined sector created an added value compared to the traditional business model at all. If the expert gave an affirmative answer to this question, the distribution of the value added was asked for.

Ecological Sustainability

According to Property Rights Theory [26], an efficient assignment of resources could be realized transferring the rights to these resources to the party that maximizes their value. Due to specialized knowledge of the provider for instance, in maintaining a good, its performance contributes at a higher degree to the value of the machine than the maintenance performed by the customer´s own department. Also holding the property rights of operating a resource e.g. a machine, could set incentives for the provider to pay more attention to the energy and material efficiency of the physical good. As with PSS, the product is no longer sold alone, the profit originates not from the sale price but from the input of resources to deliver the promised functionality to the customer. To assess if environmental benefits are achieved and how that is linked to provider´s expertise the following hypothesis was formulated:

H 2: The provider’s know-how entails a more efficient use of material and energy during the use phase, resulting in less emissions and waste.

Also this hypothesis was split up for a better assessment. The question was posed if savings in energy and material consumption can be realized through PSS compared to the traditional business model.

Social Sustainability

As mentioned before, the impact on social aspects of PSS have so far been underrepresented in the academic literature. To detect correlations of PSS and the social life, the literature on services science in general was consulted. In doing so, different scenarios could be identified. Customer integration in the value creation process of service activities especially for use- and result-oriented services could not only lead to a rise of customer interfaces, but the interaction is often more labor-intensive. Additionally concepts for reducing environmental impact, for example extension of durability or offering new services targeting the end of the product´s life time, like recycling, could imply a rise in employment. Another line of argumentation could be that, through processing experiences gained in the industrial service business, learning curve effects can be realized and through advances in information technologies the need for human personnel could be reduced [11]. Often at first glance the transfer of activities from customer to provider could entail a shift of jobs, curtailed at the customer side and created at the provider side. The total effect on the number of jobs would be neutral. Dissecting social implications in terms of job creation led to the following hypothesis:

H3: PSS have a positive impact on the number of jobs on the provider side and equally a negative impact on the customer side.

The three hypotheses presented above were tested in the conducted expert interviews. Preliminary results from the qualitative content analysis are outlined in section 4.

4 QUALITATIVE ANALYSIS OF EXPERT INTERVIEWS

In the following section, the results of the qualitative analysis of the expert interviews will be presented. They are divided into the manufacturing sector and wastewater treatment.

4.1 Manufacturing Industry

Background

Ever since Wise and Baumgartner advised manufacturing firms to “go downstream” [27], the servitization of manufacturing has been discussed with increasing intensity [28-30]. The growing competitiveness on the market, especially based on the global rise of low-cost manufacturers [1], makes it impossible for manufacturers to merely rely on the innovativeness of their products. They have to move up the value chain, include services into their offers and cleverly combine their products with service components into product-service systems.

Whilst basic services like maintenance, training and spare-part management, referred to in the literature as product-oriented services [10], are widespread in the manufacturing sector, use-oriented, like leasing and renting services, and result-oriented services, like pay-on-production services, have only been offered reluctantly up to now. For example, in 2003, only 4% of the German machine tool builders have offered pay on production concepts to their customers [31], although these business models which focus on the sale of use or of results rather than the equipment itself have been promoted in the literature as leading to higher margins [27] and additionally foster ecological benefits [32].

Yet, what still needs to be investigated and proved are the often mentioned positive effects that offering product-service systems are supposed to imply for manufacturing companies. Therefore, experts from manufacturing industry in general but also from its subsectors were interviewed with the aim of verifying or rejecting the three hypotheses developed above.

Results

Hypothesis No. 1 was partially supported by the interviewees. Eight of the ten interviewees gave an affirmative answer to the question whether PSS contribute to added value creation, while two experts did not comment on this at all. When asked what causes the additional value derived from a PSS, the experts specified the following:

- a higher level of equipment availability,
- a higher degree of capacity utilization of the equipment employed,
- access to customer process know-how,
- extended equipment life-time,
- qualified partner for machinery design and maintenance services
- reduction of Total Cost of Ownership (TCO),
- energy efficiency and material savings,
- reuse of parts or components,
- increase in planning reliability and
- increase in flexibility.

Though various value added potentials were named by the interviewees, it was also marked that value generation through PSS is not automatic.

When confirming the creation of additional value, the experts were asked to give their position on how the value added was distributed between the provider and the customer of PSS. Four of the respondents consider the added value as shared between both, customer and provider of PSS. Three experts think that only the customers benefit from PSS whereas one interviewee states that all the value added remains with the supplier. Furthermore, it was also pointed out that especially the flexibility gained by the customer through PSS is borne by a shift of risks towards the provider.

In the course of the interview, three experts stated that the power structure in PSS was unbalanced and in favor of the customers. The customers used their power to force providers of machinery into offering PSS and hence fostered their diffusion. Furthermore, they considerably influence the contract negotiations for their own benefits and to the disadvantage of the providers so that contracts were “oppressive”. One expert stated that the providers of PSS also have power in the business relationship, however, according to this respondent, this only applies to major machine and plant suppliers, as these “have the power to implement their ideas in their relationship with OEMs”.

Summing up the experts’ answers, it can be concluded that PSS in the manufacturing sector contribute to creating added value in various ways. However, in this business transaction, power and risk are not balanced. More interviewees see advantages on the customers’ side and disadvantages on the suppliers’ side than vice versa. Yet, most experts consider the added value as divided between customer and supplier, but the majority of those respondents who point out that the value added is not shared but retained by one party see the customers as the profiteers.

Hypothesis No. 2 was only partially supported by the experts. They confirmed that PSS implies energy and material savings, yet they attributed this fact less to the suppliers’ superior know-how than to the stakeholders’ interests.

The question if product-service systems have an influence on the consumption of energy and material compared to the traditional business model was answered in the affirmative by eight experts. One interviewee did not see any influence on the consumption of either energy or material, whereas one further expert did not comment on this question. Three experts limited their affirmative answers, as in their opinion and experience material and energy savings were only possible for some cases, depending on the explicit conditions of the PSS contract. One of the experts claimed that up to 30% of energy could be saved by PSS in field of compressed air. Furthermore, one respondent specified that material savings were implied by PSS, but if reused components were assembled into the machinery used, the consumption of energy would increase.

The experts, who confirmed that PSS implied a decreased consumption of energy, material or both, were asked to point out the reasons for this relation. The interviewees argued that reusing machinery after their first use phase in PSS with other customers or reusing components in newly assembly equipment implies that resources are saved. Furthermore, they claimed that the life span of equipment used in PSS was longer, compared to equipment used in the traditional business model. They state that hence less equipment needs to be manufactured and material as well as energy would be saved. The accounting mode agreed upon in a PSS contract which would automatically make the customers save material and energy was mentioned as well. It was also stated that saving resources was in the essential interest of suppliers in PSS contracts and that they consequently designed the equipment used in PSS so that the components were power-saving and reusable. Technological progress was mentioned as well as it involved novel equipment which could be automatically adapted to capacities employed.

The remark was made that the possible savings to a large degree depend on the level of cooperation between customer and provider. Only if they established a close collaboration, could the entire potential be tapped. It was also stated that some obstacles persisted to tapping these potentials but that PSS contracts were contributing to overcome these constraints.

The third hypothesis was supported by the interviewed experts. They either stated that offering PSS would increase the number of job positions on the supply side while it stayed the same on the customer side, or they assumed that the overall number of job positions would stay the same, but that they were redistributed between PSS providers and PSS customers. It was pointed out that over time the job content of people involved in PSS would change with the consequence that different competences and an increase in flexibility would be required and hence further training of the employees would become necessary.

4.2 Wastewater treatment

Background

Up to now, in Germany about 3.75 million private households are not connected to a central wastewater treatment plant [33]. Most of these households are located in rural areas, where decentralized small-scale wastewater treatment can be considered as a competitive alternative to centralized water treatment. As new regulations, such as the EU Water Framework Directive, prescribe the adoption of the best available technology in wastewater treatment, new technologies and business models for decentralized wastewater treatment are increasingly catching the attention of researchers [21], public water associations and private water utilities. Within the decentralized setting, the homeowners themselves are in charge of the operation of the wastewater treatment plant. However, many homeowners face severe difficulties in dealing with the technical, financial, legal and administrative issues associated with the operation of a wastewater treatment plant. As planning and operating errors can lead to the pollution of water bodies, decentralized wastewater treatment facilities were suspected of not meeting the high quality standards of centralized wastewater treatment plants. Against this backdrop, Product-Service-Systems initiated by public water associations or private water utilities can be considered as a viable alternative which allows for a centralized operation of decentralized wastewater treatment plants.

The Lippe River Association, a large German water association, recently established a small pilot project in a rural residential area near the city of Selm (North Rhine-Westphalia), where it offers a comprehensive service package comprising the planning, procurement, construction, operation and maintenance of private wastewater treatment plants. The homeowners pay a fixed monthly fee for wastewater services, which also covers the investment cost. Besides the Lippe River Association, other public and private water utilities plan to introduce similar business models, so the study could draw on representatives from public and private water utilities as well as public research institutes to answer the questionnaire.

Results

Hypothesis No. 1 relates to the value added created by the PSS. The respondents found the question difficult to answer because the new business model is still in an experimental stage. However, some respondents hinted at possible sources of value added created by the PSS. As the service provider is a public utility, the value added does not necessarily lead to higher profits, but may result in a greater efficacy of the organization. First of all, the public utility gains more administrative control over decentralized wastewater treatment plants, because the plants can be equipped with remote monitoring. Thus, the water association can immediately discover a malfunctioning plant and send out service personnel to fix the problem. If the homeowner is solely responsible for the operation of the plant, technical disruptions of the plant might happen unnoticed, leading to a pollution of recipient water bodies. This might be the case if too much cleaning agent ends up in the wastewater treatment plant and leads to a destruction of the biochemical reactor. Additionally, remote monitoring would allow for a rationalization of the administrative processes associated with decentralized wastewater plants. On the clients' side, there might be a substantial increase in the value added because the homeowner can utilize the competencies of the water utility. During the planning stage, the provider will make sure that the wastewater treatment plant matches the needs of the individual household. Due to economies of scale the provider is also able to negotiate favorable prices and financing conditions for wastewater treatment plants. Furthermore, the homeowner is relieved from most of the technical and administrative tasks associated with the operation of the plant. Obviously, this increase in utility on the suppliers and customers side has to outweigh the additional costs associated with the PSS in order to create added value.

The first part of hypothesis No. 2 relates to the reduction of energy and materials consumption. The respondents largely confirmed this hypothesis, although the effects were assumed to be of a marginal nature. Minor energy and materials savings might result from the fact that the provider will operate the wastewater treatment plant in a more professional manner, thus avoiding frequently made mistakes which result in a high consumption of energy and raw materials. The second part of hypothesis No. 2 concerns the reduction of emissions and waste. This hypothesis was confirmed by all respondents because the provider has the technological capabilities to ensure the compliance with high environmental standards.

Although during the set-up period new jobs will be created at the provider, eventually these positive effects will be counteracted by job losses once the new business model has reached maturity. Thus, the first part of hypothesis No. 3 was rejected. The second part of hypothesis No. 3 is not applicable in this context because the clients are households not companies. Initially, administrative and technical tasks which were performed by the households are performed by the provider. This substitution of homework by professional work creates new jobs and, in the short term leads to a positive impact on the number of jobs on the provider side. Subsequently, the provider will invest in remote monitoring and remote control devices in order to economize on personnel costs. Thus, the long-term impact of the PSS on jobs is expected to be neutral, not positive. However, one interviewee suggested that a successful PSS might generate additional jobs in Germany if the business model can be exported to other countries.

Concerning the impact of regulation on PSS in the wastewater sector the results were ambiguous. A strong positive regulatory impact results from the conversion of the European Water Framework into national law, which will trigger huge investments in new decentralized wastewater treatment plants and provides impetus for the concept of PSS. Additionally, there are new public funding schemes at a federal level to facilitate private investment in new wastewater technologies. A barrier stemming from regulation was mentioned by a representative from a river association: The German law of corporate union currently impinges on economic activities of river associations such as PSS.

5 CONCLUSIONS AND NEED FOR FURTHER RESEARCH

This paper contributes to PSS research by exploring the sustainability effects of PSS in two traditional industrial sectors: manufacturing industry and the wastewater treatment sector.

Three main hypotheses with regard to the sustainability effects of PSS were described and tested in 15 interviews with experts from each sector. By comparing the outcomes of the expert interviews in the two sectors, it seems that the sustainability effects of PSS in these sectors differ slightly. One reason can definitely be seen in the fact that wastewater treatment deals with business-to-customer transactions whereas the PSS in the manufacturing industry are based on business-to-business transactions.

The first hypothesis, which describes the effects of an unbalanced power structure in a PSS on the absorption of the value added by one actor, was accepted by the experts in both sectors. However, whereas most of the experts in the manufacturing sector stated that in their sector the customer usually has more power than the provider, the expert in the wastewater treatment sector claimed a reverse situation for their sector. For future research it would be interesting to examine how the less powerful actor, either the customer or the provider in the

PSS, could improve his position of power to increase the fairness of the relationships in the considered business concept.

The second hypothesis relates to the positive ecological effects of PSS based on the provider´s superior knowledge of the efficient use of materials and energy during the usage phase of the equipment. This hypothesis is only partially supported by the experts in both sectors. The knowledge of how to decrease material and energy consumption is indeed mentioned as an important factor, but if there is no corresponding incentive specified in the PSS contract, or related legal environmental requirements like in the wastewater treatment sector, resource efficiency potentials will not be fully realized.

The third hypothesis was accepted by the experts in both sectors. They concluded that PSS would lead merely to a redistribution of jobs between PSS provider and PSS customers. Even if they expect no increase in the number of jobs through PSS, they suggested that there will be a change in the job content of people involved. As a next step, it would be fruitful to examine if these changes would be advantageous or detrimental for the job quality of these workers.

Since the research field of the sustainability effects of PSS has not been explored exhaustively, there is still need for further analysis. Further research activities should encompass in-depth case studies with companies as well as a quantitative survey with regard to the diffusion of PSS and its effect on cost and resource efficiency.

6 ACKNOWLEDGEMENT

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7 REFERENCES

[1] Neely, A., 2007, The Servitization of Manufacturing: an Analysis of Global Trends, 14th European Operations Management Association (EUROMA) Conference, Ankara, Turkey, 17-20 June 2007:1-10.

[2] Oliva, R., Kallenberg, R., 2003, Managing the transition from products to services, International Journal of Service Industry Management, 14: 160-172.

[3] Lay, G., Schröter, M., Biege, S., 2009, Service-based business concepts: A typology for business-to-business markets, European Management Journal, 27: 442-455.

[4] Lindahl, M., Ölundh, G., 2001, The Meaning of Functional Sales, Proceedings of the 8th International CIRP Seminar on Life Cycle Engineering, Varna, Bulgaria, 18-20 June 2001, 211-220.

[5] Stremersch, S., Wuyts, S., Frambach, R. T., 2001, The Purchasing of Full-service Contracts: An Exploratory Study within the Industrial Maintenance Market, Industrial Marketing Management, 30: 1–12

[6] Kim, S.-H., Cohen, M. A., Netessine, S., 2007, Performance Contracting in After-Sales Service Supply Chains, Management Science, 53: 1843-1858.

[7] Davis, A., 2004, Moving Base into High-Value Integrated Solutions: A Value Stream Approach, Industrial and Corporate Change, 13: 727-756.

[8] Brax, S., 2005, A manufacturer becoming service provider challenges and a paradox, Managing Service Quality, 15:142-155.

[9] Goedkoop, M. J., van Halen, C. J. G., te Riele, H. R. M., Rommens, P. J. M., 1999, Product Service Systems: Ecological and Economic Basics, Amersfoort, The Netherlands: PR´e Consultants.

[10] Tukker, A., 2004, Eight Types of Product-Service System: Eight ways to sustainability? Experiences from Suspronet, Business Strategy and the Environment, 13:246–260.

[11] Scholl, G. U., 2000, Beschäftigungsimplikationen und ökologische Wirkungen einer Verlängerung und Intensivierung der Produktnutzung, Papers 00-522, Veröffentlichungsreihe der Querschnittsgruppe Arbeit & Ökologie beim Präsidenten des Wissenschaftszentrum Berlin für Sozialforschung.

[12] Maxwell, D., van der Vorst, R., 2003, Developing sustainable products and services, Journal of Cleaner Production, 11:883-895.

[13] Dyllick, T., Hockerts, K., 2002, Beyond the business case for corporate sustainability, Business Strategy and the Environment, 11:130-141.

[14] Hockerts, K., 2008, Property rights as a predictor for the eco-efficiency of product-service systems. Working Paper No. 02- 2008, CBS Center for Corporate Social Responsibility, Frederiksberg.

[15] Toffel, M. W., 2002, Contracting for Servicizing. Harvard Business School Technology & Operations Mgt. Unit Research Paper, No. 08-063.

[16] Burr, W., 2002, Service Engineering bei technischen Dienstleistungen, Deutscher Universitäts-Verlag GmbH, Wiesbaden.

[17] Spring, M., Araujo, L., 2009, Service, services and products: rethinking operations strategy, International Journal of Operations and Production Management, 29: 444-47.

[18] Eisenhardt, K. M., 1989, Building Theories from Case Study Research, Academy of Management Review, 14: 532-550.

[19] Perry, C.,1998, Processes of a case study methodology for postgraduate research, European Journal of Marketing, 32: 785–802.

[20] Mayring, P., 2003, Qualitative Inhaltsanalyse, Beltz Verlag, Weinheim, Basel.

[21] De Ruyer, K.; Scholl, N., 1998, Positioning Qualitative Market Research: Reflections from Theory and Practice, Journal of Marketing, 59: 58-70.

[22] Gläser, J., Laudel, G., 2006, Experteninterviews und qualitative Inhaltsanalyse, VS Verlag, Wiesbaden, Germany.

[23] Baines, T. S, Lightfoot, H.W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J. R., Angus, J. P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Micheli, P., Tranfield, D., Walton, I. M., Wilson, H., 2007, State-of-the-art in product-service systems. Proceedings of the Institution of Mechanical Engineers, Journal of Engineering Manufacture - Part B, 221: 1543-1552.

[24] Picot, A., Dietl, H., Franck, E., 2008, Organisation, Schäffer-Poeschl Verlag, Stuttgart, Germany.

[25] Vargo, S.L., Maglio, P.P. and Akaka, M.A. 2008, On value and value co-creation: A service systems and service logic perspective, European Management Journal, 26: 145-152.

[26] Ulrich, F., 2004, Verdünnte Verfügungsrechte, Deutscher Universitäts-Verlag, Wiesbaden.

[27] Wise, R., Baumgartner, P., 1999, Go Downstream – The New Profit Imperative in manufacturing, Harvard Business Review, 77: 133-141.

[28] Baines, T.S., Lightfoot, H., Benedettini, O., Kay, J.M., 2009, The Servizitation of Manufacturing – A Review of Literature and Reflections on Future Challenges, International Journal of Manufacturing Technology Management, 20: 547-567.

[29] Gebauer, H., 2008, Identifying Service Strategies in Product Manufacturing Companies by Exploring Environment–Strategy Configurations, Industrial Marketing Management, 37: 278-291.

[30] Azarenko, A., Roy, R., Shehab, E.; Tiwari, A., 2009, Technical Product-Service Systems. Some Implications for the Machine Tool Industry, 20: 700-722.

[31] Copani, G., Molinari Tosatti, L., Lay, G., Schröter, M., Bueno, R., 2007, New Business Models Diffusion and Trends in European Machine Tool Industry, Proceedings of the 40th CIRP International Manufacturing Systems Seminar, Liverpool, Great Britain, 30 May – 1 June 2007:1-8.

[32] Mont, O., 2002, Clarifying the Concept of Product-Service System, Journal of Cleaner Production, 10: 237–245.

[33] Statistisches Bundesamt, 2006, Öffentliche Wasserversorgung und Abwasserbeseitigung, Fachserie 19, Reihe 2.1 – 2004, Wiesbaden, Germany.

[34] Hiessl, H., Toussaint, D., Becker, M., Dyrbusch, A., Geisler, S., Herbst, H.,Prager, J. U., 2003, Alternativen kommunaler Wasserversorgung und Abwasserentsorgungssysteme AKWA 2100, Physica Verlag, Heidelberg, Germany.

Environmental Evaluation of Machine-to-Machine Services: the case of Glass Waste Collection

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Abstract

Product-Service Systems (PSS) based on Machine-to-Machine (M2M) technologies show high potential to help solve environmental issues. Such technologies resort to electronic equipment and telecommunication infrastructures.

This paper presents a methodology for assessing environmental impacts of M2M PSS, and a case study of Glass Waste Collection. Life Cycle Analysis (LCA) has been performed taking into account the complete M2M infrastructure, starting from electronic sensors through gateways to the telecommunication network and service platform and down to the end user. Results are compared with traditional glass collection and can provide insight for design choices in the M2M service.

Keywords

Life Cycle Analysis, Machine-To-Machine service

1 INTRODUCTION

Today, Information and Communication Technologies (ICT) play a key role in our lives and the number of users is growing. Perception of its scope is broadening at the same time. Telecommunications not only mean people communicating with one another, but also include the machines around us. Machines can “contact” one another through the network. This is called Machine-To-Machine (M2M) Communication. It covers a large number of machines throughout the world, from home appliances to industrial machines. M2M systems allow machines to communicate with one another, or systems to monitor machines and, in this way, help them accomplish their tasks. With M2M, machines can not only “sense” information from the physical world (machine as a sensor of temperature, pressure, humidity, …) but also take action based on information received (machine as a controller or an actuator in traffic lights, air conditioners, switches, …) Lawton [1] clearly reviewed the growth of M2M systems and their great potentials resulting from the networking of a growing number of machines. In our understanding, M2M systems can be assimilated to Product-Service Systems (PSS): M2M networks together equipments, considered as a system of products that deliver values in the form of new services.

Despite M2M’s promising growth, the technology used in M2M systems still faces several significant challenges in terms of wireless technology, communication protocol, energy consumption, etc. Beside these technological challenges, sustainable development has to be considered. Deployment of such systems must take account of environmental impacts during their full life cycle. Life-Cycle Analysis (LCA) can be used to evaluate these environmental impacts for a product or a system.

For ICT services, too, LCA has been used. However, analysis is generally incomplete, and does not always consider all the aspects from electronic devices and other components to ICT infrastructure and service deployment. This paper presents a new, complete methodology for applying LCA to M2M services.

This paper presents an overview of methodology in section 2 that includes a literature review of LCA for ICT services, as well as the proposed methodology. Section 3 presents a case study that is one example of an M2M based PSS. The next section shows the results of the case study. These results are discussed and used to validate our methodology. The last section is the conclusion.

2 OVERVIEW OF METHODOLOGY

2.1 LCA methodology for service: literature analysis

It is shown in literature that LCA is a useful, powerful tool to evaluate the environmental impacts of a product [2-4]. Furthermore, LCA has also been used for ICT services [5-9]. For example, in 2001, Taiariol [5] presents the impact on Energy for centralized and home answering machine systems in Italy. The impact of the Internet structure used in the University of Switzerland were analysed in 2003, based on Global Warming Potential (GWP) indicator [6]. In 2004, the impact of a video conference was analyzed by summing individual impacts of elementary devices necessary to provide the service [7]. It was compared with the alternative scenario of face-to-face meetings taking into account transport for the participants. However, in this study, only the GWP indicator was used. The same method was also applied in the case of E-paper that compared the GWP indicators for printed, web-based and e-paper newspapers [8]. Most studies use only one indicator, either energy consumption or GWP indicator emissions. A study on an intelligent lightening system, done adopted a multi-criteria approach using indicators of Acidification, Ecotoxicity, Eutrophication, Fossil fuel depletion, Global warming, Carcinogenicity, Non-carcinogenicity, Ozone-depletion and Photochemical smog [9]. Most of the studies presented comparisons with alternative scenarios.

One common point of these studies is that in order to use LCA methodology, they divide the service into elementary parts. In this way, LCA is first applied to individual electronic equipments and the result for the complete service is obtained by summing up individual impacts.

Service / Application, Date	Environmental criteria	Comparison with an alternative scenario?	ICT infrastructure considered?
Centralized and home answering Machine systems, Italy [5], 2001	Energy consumption	Yes: Centralised vs. Home	No
Internet structure in a university, Switzerland [6], 2003	Global warming	No	No
Video conference in Japan [7], 2004	Global warming	Yes: Conventional conference (transport)	No
E-paper [8], 2007	Global warming	Yes: Printed newspaper, web-services	No
Intelligent Lighting System [9], 2004	Multi-criteria: Acidification, Ecotoxicity, Eutrophication, Fossil fuel depletion, Global warming, Carcinogenicity, Non-carcinogenicity, Ozone-depletion, Photochemical smog	Yes: Traditional lighting system	No
Energy consumption of ICT in France [11], 2008	Energy consumption	No	Yes

Table 1: LCA Literature review for service

None of these studies take account of the infrastructure of the service; neither do they clearly explain why they do not. The analysis of these case-studies is summarised in Table 1.

ICT energy consumption is big: one seventh of global electrical consumption is estimated to be necessary for ICT use phases in 2020 [10]. Souchon [11] studied the energy consumption of ICTs in France. This work takes into account the telecommunication infrastructure, including the energy necessary to send data via the network, the energy for network operation and the energy to run the data centres, buildings, and other facilities. Using telephones with different technologies was also studied. The results (Table 2) show that energy used by the infrastructure is greater than the devices themselves and must not be ignored. For instance, when considering a mobile phone with an optimized mobile charger, the network can count for up to 75% of total energy.

	Communication technology		
	GSM (optimized charger)	GSM	Stationary phone
2 telephones	25%	49%	39%
Network Infrastructure	75%	51%	61%

Table 2: Energy share: telephones and network [11].

For M2M services, we did not identify any study taking into account the complete system, including electronic devices, other components and network infrastructure, using a multi-criteria impact evaluation. The later issue is problematic considering that ISO 14042 recommends using a multi-criteria approach during the characterization of Life Cycle Impact Assessment. The methodology proposed in this paper applies multi-criteria LCA to assess the impact of the complete M2M system including the telecommunication infrastructure.

To validate methodology, the case of Glass Waste Collection is studied. The study includes the complete M2M service and compares it to the conventional service.

2.2 Methodology for an M2M system

As stated in section 1, an M2M system allows machines to communicate with other machines, or other systems, through a communication network. To help understand our methodology for M2M systems, a typical system is shown in Figure 1. The system sends information from the first machine to the telecom network via a gateway, using the Global System for Mobile Communication (GSM) cellular technology. In the telecom network the information is converted into an internet protocol, such as TCP/IP, and can be fed to a back-end server. From the server, the data is sent to the monitoring facility of the second machine. In that way, a Machine-to-Machine system is created.

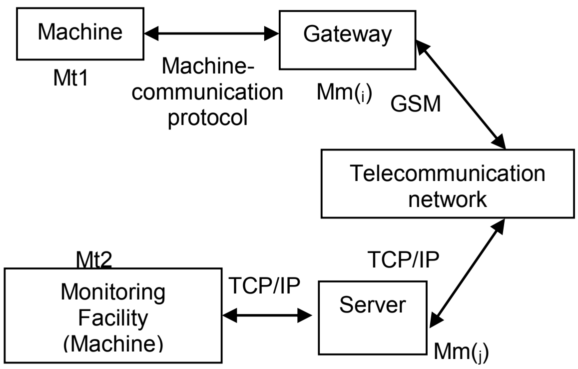

Figure 1: A typical M2M system.

To calculate the environmental impact (EI) of the M2M system, two important contributions must be determined: “equipment” and “communication”.

“Equipment”

This contribution refers to the equipments used by the system. It includes the beginning-machine that could be a sensor or an actuator, the end-machine that could be a desktop or a mobile phone, and the equipment used between the two machines. Material contribution to the environmental impact is determined by summing the impacts of individual equipments as follows:

$$EI_{equipment} = EI_{Mt1} + \sum EI_{Mm(i)} + EI_{Mt2} \quad (1)$$

With:

- $EI_{equipment}$: equipment contribution to the environmental impact

- EI_{Mt1} and EI_{Mt2}: respectively, the impacts of the beginning- and end-machines
- $EI_{Mm(i)}$: the impact of intermediary equipment i.

"Communication"

Communication covers the communication networks between the machines and the other equipments. It can be divided into two sub-parts.

One sub-part concerns the need for communication directly between machines. A variety of technologies can be used like IEEE wireless, Bluetooth, ZigBee, Wavenis, etc. Concerning environmental issues, this part is related directly to the energy needed to transmit the information. The machines need a power supply that could be the main lines or a battery when access to electric power supplies is not feasible. The environmental impact due to communication directly between the machines is given by:

$$EI_{DCM} = EI_{elec} + EI_{battery} \quad (2)$$

With:

- EI_{DCM}: the impact of Direct Communication between Machines
- EI_{elec}: the impact of electrical energy used to transmit information depends on the wireless technology, the number of times the information is sent each day and the quantity of data
- $EI_{battery}$: the impact of the battery depends on the battery weight, type and life-cycle.

The battery life-cycle is determined by the transmission protocol, the number of daily emissions, the quantity of data and its capacity. It is derived from initial capacity, self-discharge and daily energy consumption. Initial capacity and self-discharge depend on the technology used. Technologies like Nickel-cadmium, Nickel-metal-hydride, Lead-acid or Lithium-ion are often found in similar applications. These considerations are out of the scope of this paper. The daily energy consumption depends on the wireless technology, the number of daily emissions and the quantity of data. The life cycle of battery is determined by:

$$L_{battery} = \frac{L_{init} \times L_{discharge} \times SF}{E_{normal} + N \times E_{comm}} \quad (3)$$

With:

- $L_{battery}$: the Life span of the battery (days)
- L_{init}: the initial capacity of the battery
- $L_{discharge}$: the natural self-discharge factor
- SF: Safety Factor
- E_{normal}: the energy consumption during normal use
- N: the number of daily emissions
- E_{comm}: the energy consumption for each emission

The second sub-part is related to communication assumed by the telecom operator. This usually includes GSM, TCP/IP, etc. The contribution to the impact is given by:

$$EI_{OC} = EI_{send} + EI_{subscriber} \quad (4)$$

With:

- EI_{OC}: the impact of energy in Operator Communication
- EI_{send}: the impact of energy used to transmit data. This depends on the number of daily emissions, and the quantity of data per emission
- $EI_{subscriber}$: to calculate the energy contribution of the M2M system for running the telecommunication infrastructure facilities, we assimilate the system to a typical telecommunication subscriber. In the same way that each subscriber is responsible for a fraction of total energy required to run the facilities, we can deduct the share of energy for the M2M system. In that way, $EI_{subscriber}$ depends on network energy requirements and the number of subscribers. This energy includes energy for data centres, buildings and other facilities.

It should be underlined that Equation (4) is an important contribution of the paper as environmental impacts of infrastructures are not taken into account in previous studies (see Section 2.1).

To summarise, we suggest that the impact of the M2M service be determined as follows:

$$EI_{M2M} = EI_{equipment} + \{ EI_{DCM} + EI_{OC} \} \quad (5)$$

$EI_{equipment}$, EI_{DCM} and EI_{OC} are determined by (1), (2) and (4).

3 CASE STUDY: SERVICE, SCOPE AND MODEL

3.1 Context

Why add a M2M-based PSS to glass waste collection?

A Collection of Glass Waste from bottle banks using PSS based on M2M wireless sensor networks had been tested in 2006 by Orange Labs in Voiron, close to Grenoble, France [12]. The area concerned covers urban and sub-urban sites and serves a population of around 42,000 inhabitants.

Before the introduction of the new PSS, the truck driver of the local waste collection centre had to systematically go to each waste bank, stop the truck and check the level of glass in each container before deciding whether to empty the container or not.

With M2M, sensors are placed inside the containers and measure the level of waste glass. This data can then be used to calculate an optimal collect plan so that the truck driver only goes to and empties the containers that are necessary. Analysis of the PSS by Orange Labs identified possible societal benefits: diminished fuel consumption for the truck; time-saving; noise-reduction; population satisfaction and improvement of traffic circulation.

Supply energy considerations

Glass waste banks are situated on the kerb where there is no access to electric power supplies, furthermore the containers have to be moved every time they are emptied and wired supplies are not possible. Therefore a battery supply is used. In order to insure a sufficient life-span for the battery, power consumption has to be kept low. Since most of the power is used for communication with the gateway, the choice of the communication technology is important. Wavenis Wireless Technology [13] was chosen for its ultra-low-power consumption; high link budget and capacity for long-range connection. Wavenis Wireless is a 2-way wireless connectivity platform dedicated to M2M applications. The PSS model is presented in Figure 2.

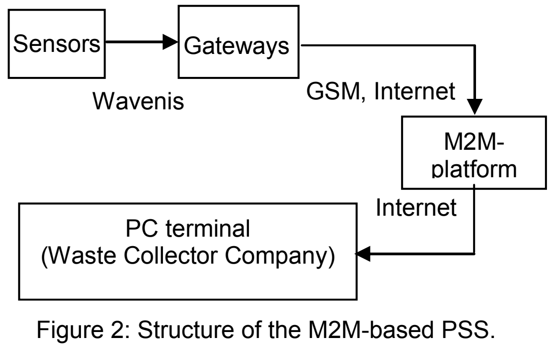

Figure 2: Structure of the M2M-based PSS.

3.2 Scope of the LCA

Since a reduced environmental impact could be a major commercial argument for services, an in-depth environmental impact study has been initiated. LCA methodology is used to answer the questions "Is the proposed M2M service more environment-friendly than the conventional service?" and "What are the major hot spots of the service and how can we improve them?"

The functional unit used for the LCA is: "collect glass waste in the Voiron district during ten years."

The study uses data from the M2M experimentation conducted between June and September 2006 and comparison with conventional waste collection.

The LCA includes a cradle-to-grave analysis of life-cycle stages: from raw material extraction and acquisition, material processing, product manufacturing, transportation, product use to end-of-life disposal. The environmental impact of the installation of the service is also included. A summary of the elements taken into account is presented in Table 3.

- Sensor and gateway: Electronic components, printed circuit board and processes, casing, etc.
- Wavenis: Communication between the sensor and the gateway. The sensor battery supplies the energy needed for this communication and there is no extra energy needed.
- Mobile and internet networks: Communication between the gateway and the M2M platform. Only data for energy in the network was available from Orange. It includes energy used to transmit the information, EI_{send}, and energy used to run the operator facilities, $EI_{subscriber}$.
- M2M platform: Server, supporting rack and air cooling. Energy for air cooling is supposed to be the same as for the use of the server. Due to lack of data, only energy in the fabrication and use phases is accounted for [14]. The server in the M2M platform is taken to be HP ProLiant ML350 [15].
- Internet: Energy used to send the information from the M2M platform to the waste collect company via the IP network. It includes energy used to transmit information, EI_{send}, and energy used to run the facilities, $EI_{subscriber}$.
- PC terminal: As with the server used in the M2M platform. Only energy in the fabrication and use phases is accounted for [16].
- Transportation: Sensors, gateways, servers and PC terminals. They require transport from their respective manufacturing sites to the installation site. This includes transoceanic freight transport from China to the harbour in the south of France, followed by overland transport by trucks to Voiron.
- Installation: Includes transport to Voiron to study where to place the gateways, and the installation of the sensors and gateways. It does not include the energy and material for installation, due to the unavailability of data.

4 RESULTS

4.1 Choice of impact categories

The case study adopted a multi-criteria approach as recommended by ISO 14042. LCA was performed using EIME LCA software. All the indicators of the Life Cycle Impact categories in the software were accounted for: Natural Resources Depletion (RMD), Energy Depletion (ED), Water Depletion (WD), Global Warming Potential (GWP), Stratospheric Ozone Depletion Potential (ODP), Air Toxicity Indicator (AT), Water Toxicity (WT),

Element	Description	Reference flows considered in the Life Cycle Inventory [Unit Process]	Life Cycle Stages
Sensor	Sensors are installed inside waste containers to measure the glass filling level	Electronic components, battery, printed circuit board and processes, casing, etc [Equipment and Energy]	Transportation, fabrication, use
Wavenis	Communication	Null (Energy is supplied by battery in the sensors and gateways)	No effect
Gateway	Gateways are installed on telephone poles, electricity poles, walls of public buildings	Electronic components, battery, photovoltaic panel, printed circuit board and processing, casing, etc [Equipment and Energy]	Transportation, fabrication, use
Mobile network (GSM)	GSM is used for communication between gateway and M2M platform	Communication, Infrastructure facilities [Energy]	Use + Infrastructure
Internet network	IP network is used to transfer the information on glass filling level of each sensor from M2M platform to waste collection company	Communication, Infrastructure facilities [Energy]	Use + Infrastructure
M2M platform	Server, air conditioning for the server, and material to support the server	Server and air cooling [Energy] Supporting rack [Equipment]	Transportation, fabrication, use
Internet network	The IP network is used to transfer the information on glass level from each sensor from the M2M platform to the waste collect company	Communication, Infrastructure facilities [Energy]	Use + Infrastructure
PC terminal	At the waste company, the middle manager uses a PC to connect to the IP network. With the information from the sensors, he is able to optimize the collect rounds	PC [Energy]	Transportation, fabrication, use
Service installation	The provider is based in Montpelier (France) and must go to Voiron to install the system	Transport, investigation and installation of sensors and gateways [Fuel]	Transportation, for study and installation

Table 3: Elements of the system used in LCA.

Photochemical Ozone Creation (POC), Air Acidification Potential (AA), Water Eutrophication (WE) and Hazardous Waste Production (HWP) [17]. However, it is not easy to discuss LCA results considering eleven indicators. In this paper, results are presented for a limited number of indicators, chosen according to Orange Labs' policy and their relevance in the context of M2M services, namely:

- ED (expressed in MJ): represents energy contents in materials and the consumption of energy. It is important for running services. Furthermore, as stated before, the only data available on the server, PC terminal and telecommunication networks are expressed only in terms of electrical power consumption.
- GW (expressed in g eq. CO2): that represents global warming expressed as the equivalent CO2 contribution to the greenhouse effect. This is a very important global issue today and could not be omitted.
- AT (expressed m3) and WT (expressed dm3): that represent toxicity in air and water; they correspond to the air/water volumes necessary to dilute contaminated air/water, respectively. They were chosen because they represent toxicity in a human environment. This is especially important for services deployed in the city.
- RMD (expressed in year-1): that is the depletion of natural resources, for which gold, silver and copper are major contributors. These rare materials are used a lot in electronic devices which are major components of the M2M system.

These impact categories are typical for LCA of electr(on)ic devices. Sanitary impacts of electromagnetic waves are not considered in this study.

4.2 Major contributors to environmental impacts

The study considers environmental impacts of the following life cycle stages: material extraction; manufacturing; distribution; and use. Performances of end-of-life treatment are not covered.

Figure 3 shows the relative contribution for each component of the service using the 5 preselected indicators.

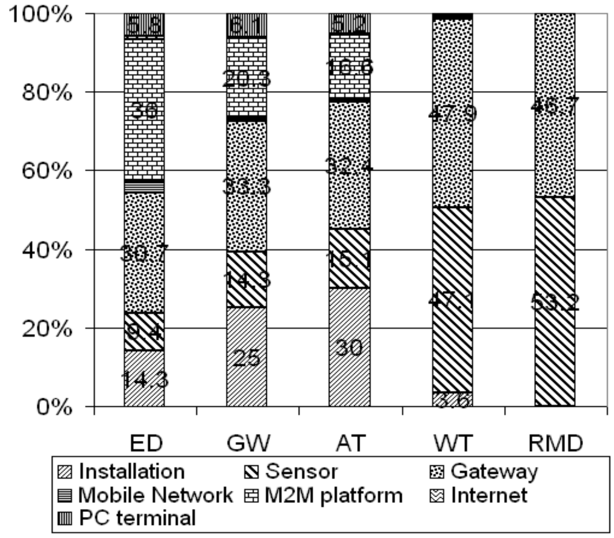

Figure 3: Comparative impacts of each component for five environmental criteria.

The comparison calls for some remarks:

- The gateway is the major contributor to most of the impacts. This appears for all the indicators: GW (33.3%), AT (32.4%), WT (47.9%) and RMD (46.7%). For ED, gateway represents the second impact (30.7%). This results from the use of electronic components, the battery and the photovoltaic panel and a relatively large casing. The share of the different components of the gateway is shown in Figure 4.

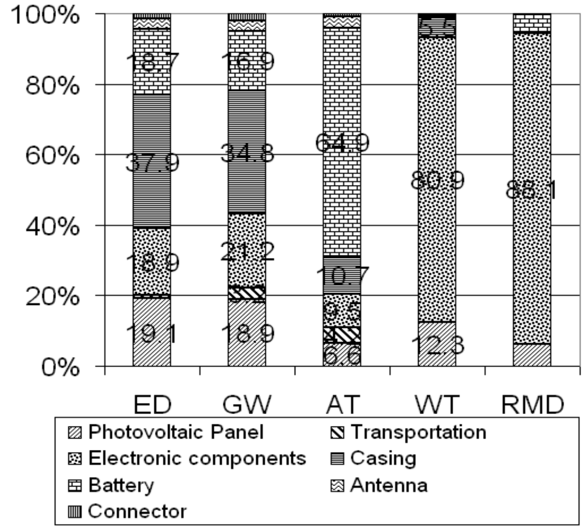

Figure 4: Comparative impacts of each part in gateway.

- The M2M platform is the highest contributor for ED and is important for GW and AT, but disappears for the other indicators. This is due to the fact that only energy for the server fabrication is taken into account. It is probable that taking into account all reference flows (including materials and processes) would increase the importance of its contribution to the other indicators. This remark is also true for the PC terminal.
- Two indicators of WT and RMD are most affected by the gateway and the sensor. This is caused by the electronic components. Material for fabricating and processing electronic components and printed circuit boards, for instance, gold, silver and copper are major contributors for WT and RMD. As explained above, although the M2M platform and PC terminal contain a lot of electronic components they do not affect these indicators because only the energy for fabrication and use was taken into account.
- It can be noted that an analysis based on just one criterion is not sufficient to interpret the results and multi-criteria reveals some important points. Leaving aside the components for which only energy was inventoried (M2M, telecommunication …), a comparison between the gateway and the sensor is interesting. The gateway is the most impacting factor for ED, GW and AT, whereas the results change significantly for the other two indicators. This point is due to the type of power supply in the two cases. The sensor is battery-run while the gateway resorts to solar energy and photovoltaic cells. Different technologies behave differently from an environmental point of view.
- Installation plays a key role in ED, GW and AT due to the fuel consumption for transport.
- For the mobile network and internet infrastructures, the remarks concerning ED and the other impacts for the M2M platform remains true, contributions appear in ED, GW and AT, but disappear in WT and RMD because only energy is taken into account and the electronic devices of the network are not accounted for. In addition, even for ED their contributions can be ignored due to their relatively small values. This is because the quantity of information sent to the service platform is very small, only 120 bytes per message are

necessary. Furthermore the information is sent only once a day. However their relative impacts could well change if the number of daily emissions is increased. This new hypothesis merits to be studied in more detail.

4.3 Influence of the number of daily emissions

This section will study what will happen if the number of emissions is increased to 24 times per day. Although such a hypothesis is quite unrealistic for waste collection (unless the municipal council could require that the levels be measured once an hour to avoid overfilling), such frequencies are quite possible for other M2M services. However, in this case, care must be taken to anticipate the technological modifications to the system in order to do so. The important changes are studied as follows.

Sensor Battery

For the sensor, as the energy consumed during the emissions is increased, the life cycle of its battery is reduced. The life span of the battery is determined by the daily energy consumption of the sensor. Table 4 presents the energy consumption in the normal and communication modes.

Mode	Consumption (mAs per day)
Normal mode	
Standby	260
Inquiry mode	80
Micro-processor	10
Total for normal mode	350
Communication mode	
Emission	110
Micro-processor	10
Other protocols	80
Total for communication mode	200

Table 4: Energy required for sending data.

According to formula (3), the life span of the battery is dependant on the communication protocol and the number of daily emissions.

Number of daily emissions	Consumption (mAs per day)	Life cycle of battery (year)
1	550	17
12	2800	4.9
24	5100	2.6

Table 5: Battery life span.

The battery used in the sensor is a Li-SoCl2 battery rated as 2250 MAh. The self-discharge of battery is dependent on factors like the type of battery, humidity, temperature, etc. In this case, the self-discharge is estimated as 40%. A safety factor of 70% is taken to calculate battery life. The resulting life span is shown in Table 5 for different numbers of daily emissions.

Although the estimated life span of the battery with one emission per day is 17 years, for practical reasons usage is limited to 10 years. Beyond this limit, operation may not be insured under harsh conditions of humidity, temperature and mechanical vibrations. In the case of 24 emissions per day, the life cycle of battery is 2.6 years, and four batteries must be used to attain the functional unit. Due to the greater number of batteries, the casing of the sensor must be larger, and its weight recalculated: it is now considered 30% larger than the original one. Modifications to the transportation of the sensor are taken into account in this case.

Gateway battery and photovoltaic panel

A photovoltaic panel and a rechargeable battery are used for power supply. Energy from the photovoltaic panel and its environmental impacts are reviewed in [18-19]. For the new system, to ensure sufficient power supply in the gateway, the sizes of the photovoltaic panel and the rechargeable battery must be increased. To calculate the required sizes, the daily energy consumption of the gateway must be determined. This energy includes two parts, communication with the sensor and GSM-communication with the telecommunication infrastructure. The first part is has similar energy-consumption to the sensor presented in Table 4, because the electronics is the same. The energy used for GSM-communication is presented in Table 6. This table takes into account that an emission requires connection, sending information, and de-connection.

Mode	Consumption (mA.s per day)
Standby	110000
Connection	600
De-connection	300
Emission	700
Total	110000

Table 6: Energy requirements for GSM.

The daily consumption of the gateway depends on the number of emissions and is shown in Table 7. The third column of the table shows the ratio of the photovoltaic panel and battery sizes for moving from 1 emission per day to N emissions per day. For the new scenario of 24 emissions per day, the sizes of the photovoltaic panel and the battery are increased by a factor of 1.4. The size of gateway casing and transport parameters must be changed accordingly.

Number of daily emissions (N)	Consumption (mAs) per day	Energy ratio: N emissions/day to 1 emission/day
1	110000	1
12	130000	1.2
24	150000	1.4

Table 7: Ratio of energy consumption.

Mobile network

The impact for operator communication is changed as follows:

$$EI_{OC} = 24 \times EI_{send} + EI_{subscriber} \quad (6)$$

This equation is true for the mobile network and for the internet.

Result

The result of the relative environmental impacts of each component is presented in Figure 5.

The impacts of the mobile network and internet increase for ED, GW, and AT when compared with one emission per day. Even though the casings, batteries, photovoltaic panel and transport increase for the gateways and sensors, the relative increases in energy for the two networks are much larger. This means that in LCA for M2M services the impact of the infrastructure must indeed be taken into account.

4.4 Comparison between the M2M service and the conventional service

As stated in section 3, using the M2M service for the glass waste collection can provide important gains in fuel consumption for the truck.

Gains were estimated during the experimentation over a 12 month period. Observation of glass waste collection trips with the truck driver enabled an estimation of the time and distance gains for each round trip. The driver can avoid containers are filled to less than 60% of their volume. The distance gains in city areas are estimated to be between 20%-37% and in small villages between 25%-32%. If the critical level of glass is set of 70% instead of 60%, the distance gains can attain 22%-41% in the city and 25%-32% in small villages. In this section, a critical level of 60% is considered. Average distance gains in the city are 28% and in small villages, 28%.

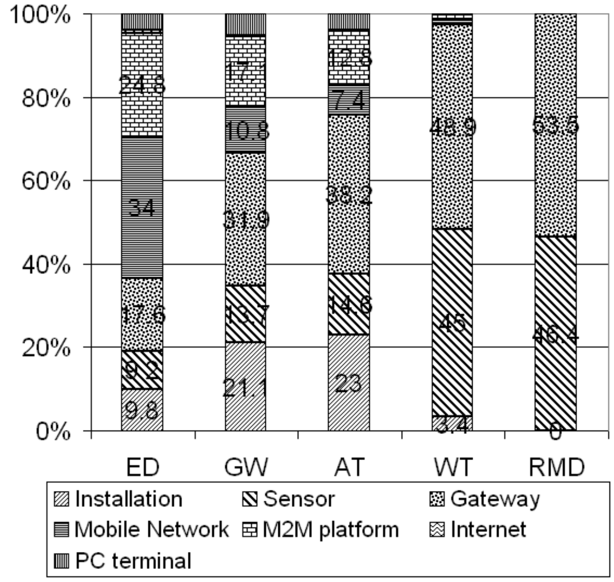

Figure 5: Environmental impact of components with 24 emissions per day.

The comparison of environmental burdens of the M2M and conventional services is made by comparing the burdens of the M2M service to the truck gains using this service. Figure 6 presents the results.

For RMD, WD, WT, WE, and HWP, the M2M service shows a greater impact than the conventional service, and improves the other indicators (ED, GW, AT, OD, POC and AA). In order to deploy and sell the M2M service, the service must be improved and the incriminated environmental impacts reduced. Section 4.2 shows that to do this efficiently, efforts should be concentrated on the gateway and the sensors, and in particular, their energy supplies must be improved.

5 CONCLUSION

This paper presents a life-cycle assessment (LCA) of an M2M-based PSS. To access the environmental impact of the PSS, a proposed methodology that takes into account a complete system is presented. This methodology is applied for the case study of a service deployed and tested by Orange Labs in Voiron, France. The LCA shows that using the M2M service for Glass Waste Collection applications has the potential to achieve environmental benefits in comparison to conventional glass waste collection services. It reveals the weak points. Our proposed methodology and results for the case study show that the ICT infrastructure must be taken into account. Multi-criteria approach must be used to identify the major contributors of the service. This will show where design efforts should be concentrated.

Future work should include a full inventory of the servers and PCs including the material to show their effects on the RMD and WT indicators. Influence of the size of the messages and the types of battery could also be studied.

6 ACKNOWLEDGEMENTS

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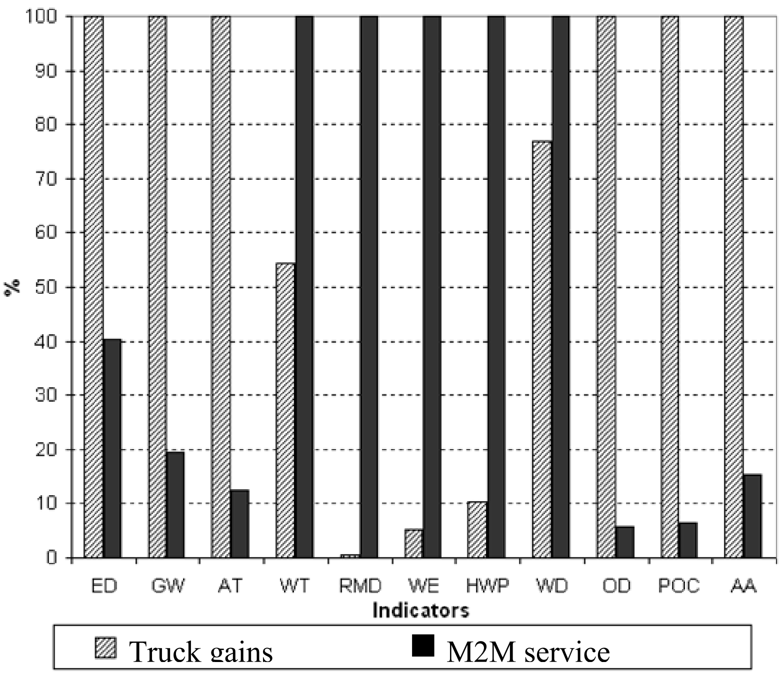

Figure 6: Comparison of environmental impacts of the M2M service and the truck gains (normalized indicators).

Madhusudan Giyyarpuram for his valuable discussions on M2M systems.

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7 REFERENCE

[1] Sandborn, P., Mauro, F. and Knox, R., 2007, A data mining based approach to electronic part obsolescence forecasting, IEEE Transactions on Components and Packaging Technologies, 30; 3; 397-401.

[2] Singh, P. and Sandborn, P., 2006, Obsolescence Driven Design Refresh Planning for Sustainment-Dominated Systems, The Engineering Economist, 51; 2; 115-139.

[3] Madisetti, V., Jung, Y., Khan, M., Kim, J. and Finnessy, T., 2000. On upgrading legacy electronics systems: methodology, enabling technologies and tools, VHDL International Users Forum Fall Workshop, 2000. Proceedings, Orlando, FL, USA, 18-20 Oct.: 7-14.

[4] Singh, P., Sandborn, P., Lorenson, D. and Geiser, T., 2002, Determining Optimum Redesign Plans for Avionics Based on Electronic Part Obsolescence Forecasts, Proceedings World Aviation Congress, November 2002, Phoenix, AZ, SAE International.

[5] Meyer, A., Pretorius, L., Pretorius, J. H. C., 2004. A model to manage electronic component obsolescence for complex or long life systems. Engineering Management Conference, 2004 Proceedings IEEE International, 3; 1303-1309.

[6] Pecht, M. G. and Das, D., 2000. Electronic part life cycle. IEEE Transactions on Components and Packaging Technologies, 23; 1; 190-192.

[7] Sandborn, P., 2007a. Designing for Technology Obsolescence Management. Proceedings of the 2007 Industrial Engineering Research Conference, 19-23 May 2007, Nashville, TN.

[8] Solomon, R., Sandborn, P. and Pecht, M., 2000. Electronic part life cycle concepts and obsolescence forecasting. Components and Packaging Technologies, IEEE Transactions on [see also Components, Packaging and Manufacturing Technology, Part A: Packaging Technologies, IEEE Transactions on], 23; 4; 707-717.

[9] Feldman, K. and Sandborn, P., 2007. Integrating Technology Obsolescence Considerations into Product Design Planning. Proceedings of the ASME 2007 International Design Engineering Conferences & Computers and Information in Engineering Conference, Sept. 2007, Las Vegas, NV.

[10] Howard, M. A., 2002. Component obsolescence – It's not just for electronics anymore. Proc.FAA/DoD/NASA Aging Aircraft Conference, San Francisco, CA, 16-19 Sept.

[11] Craig, R. W., Co, B. and St Louis, M. O., 2002. A methodology for addressing support equipment obsolescence. Aerospace and Electronic Systems Magazine, IEEE, 17; 5; 20-25.

[12] Frank, B. and Morgan, R. L., 2007. Obsolescence mitigation and management of electronics test equipment. Autotestcon, 2007 IEEE: 527-536.

[13] Mont, O., 2004. Product-service systems: Panacea or myth (Doctoral Dissertation thesis), The International Institute for Industrial Environmental Economics (IIIEE), Lund University: Lund, Sweden.

[14] Sandborn, P., 2007b. Software Obsolescence - Complicating the Part and Technology Obsolescence Management Problem. IEEE Transactions on Components and Packaging Technologies, 30; 4; 886-888.

[15] Sandborn, P. and Plunkett, G., 2006. The Other Half of the DMSMS Problem - Software Obsolescence. DMSMS Knowledge Sharing Portal Newsletter, 4; 4; 3-11.

[16] Merola, L., 2006, The COTS software obsolescence threat, Fifth International Conference on Commercial-off-the-Shelf (COTS)-Based Software Systems, 2006. San Diego, CA.

[17] Rumney, G. A., 2007, The Software Obsolescence Minefield: A Guide for Supporting Software and Electronic Information, 1st ed., COG International Ltd., UK.

[18] Romero, F. J., Roy, R., Shehab, E. and Wardle, P., 2009. Obsolescence Challenges for Product-Service Systems in Aerospace and defence Industry. The 1st CIRP Industrial Product-Service Systems (IPS2) Conference, 1st-2nd April 2009, Cranfield University, UK.

[19] IEC 62402:2007 - Obsolescence Management - Application Guide.

[20] Software Development Environment, available at: http://en.wikipedia.org/wiki/Software_development_environment (last accessed on 5/11/09).

[21] Shuman, L. L. (2002), Cost-Benefit Analysis Tools for Avionics Parts Obsolescence, Research Report AU/ACSC/02-103/2002-04, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama.

[22] Roy, R. and Cheruvu, K.S., 2009, A Competitive Framework for Industrial Product-Service Systems. Int. J. Internet Manufacturing and Services.

Benefits of a Product Service System Approach for Long-life Products: The Case of Light Tubes

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Abstract

Products designed for long-life often have significant potential for better sustainability performance than standard products due to less material and energy usage for a given service provided, which usually also results in a lower total cost. These benefits are not always obvious or appealing to customers, who often focus on price. Long-life products are therefore at an inherent disadvantage: due to lower volume of sales that results from the products' longer-life, the margins (price) often need to be higher. In this paper, we demonstrate that when the revenue base is shifted to be the service of light (instead of the sales of light tubes), there is an opportunity for a "win-win-win" for the light user, the long-life light provider and society. Through a product-service system approach, resulting in a well-communicated total offer, the full array of benefits becomes clearer to the customer, including that they avoid the high initial cost.

Keywords

sustainability performance, long-life products, product-service system, value chain, modeling

1 INTRODUCTION

This study has come about through a partnership between researchers at BTH and Aura Light International AB (Aura) which produces long-life fluorescent light-tubes with a life-length that is three times longer than the industry average. Like many firms, Aura Light is increasingly aware of the opportunities and risks being presented by an increasingly sustainability-driven market [1-2]. The Sustainability Assessments research team at BTH has specific competence with strategic sustainable development (SSD) [3-4] and application of SSD in the context of product development [5-6]. Due to the long-life nature of Aura's product, there are challenges when competing with producers of "standard" life-length light-tubes, i.e. Aura has 1/4 as many opportunities to generate revenue from the sales of a physical product as its competitors. From a sustainability perspective, the long-life product is obviously worth exploring since it reduces material flows by approximately one-fourth.

The concept of product-service systems (PSS) has been defined as a system joining products and services in order to meet customer needs. It emphasizes a shift in the focus from selling physical product to selling the function provided by this combination of products and services. Definitions of PSS typically include reference to increased competitiveness of PSS providers. Some definitions do not explicitly include reference to reduced environmental impacts e.g. [7-8]. However, PSS definitions frequently also include reference to reduced negative environmental impacts, e.g. [9-11].

Tukker has articulated two concrete questions that he suggests are often overlooked when analyzing PSS: First, "which factors determine whether a PSS business model is the best way to create value added?" and second, "which factors determine whether a PSS business model per se generates less material flows and emissions than the competing product oriented models, and thus provides incentives for sustainable behavior?" [12]. These two questions (creating added value and reduced material flows and emissions) make a PSS approach for Aura Light an interesting consideration.

This paper explores the concept of product-service systems as a potential way of overcoming this contradiction between reduced number of revenue-generating opportunities, desire for increased revenue, and demand for less negative sustainability impacts. Through the example, this paper will demonstrate the potential for a company with an existing long-life product (a physical product designed for a significantly longer average useful life than a "regular" product) to consider if it can have a competitive PSS-offer.

2 METHODS

Two approaches to selling the service of light are compared: the first a producer of standard-life light-tubes, and the second a producer of long-life light-tubes. For each approach, the economics of the approach are considered from the perspective of the user and the primary provider. The socio-ecological sustainability implications (i.e. broader society) are also considered. Thus, this paper considers four scenarios from three different perspectives.

Four scenarios:

- Standard-life light tube sold as a physical product
- Standard-life light tube sold as a PSS offer
- Long-life light tube sold as a physical product
- Long-life light tube sold as a PSS offer

Three perspectives:

- Customer (economic - cost of light)
- Producer (economic - profit)
- Society (socio-ecological sustainability)

The prices and costs here are provided for illustrative purposes and are not actual figures from a company. The researchers were "kept in the dark" in order to not compromise sensitive information, and thus these figures come from a survey of the lighting industry. The following assumptions are made for this analysis:

- Long-life light-tubes lasts 4x longer than standard-life light-tubes (12 yrs vs. 3 yrs at 4000 h/yr)

- Sales price is 4x higher for long-life light-tubes (10 € vs. 2,50 €)
- Cost to replace a light-tube (including labor, disposal fee, and downtime) is 5 €
- Light fixtures are pre-existing (so not included here)
- Both light-tubes use them same amount of electricity
- Both light-tubes provide the same amount of light
- Electricity cost is 0,10 €/kWh
- Annual discount rate of 3%
- No "rebound effect" will occur because of a shift from product to PSS offer

2.1 Customer (economic) perspective

To answer Tukker's first question from the customer's perspective, a simple life-cycle cost model considers the economic aspects of the four scenarios from the customer (light-user) perspective. Here the cost to the customer for light-tubes (as either a purchased product or a PSS) and replacement of the light tubes are considered for providing 4000 hours of light per year for a period of 12 years. A discount rate is included due to the long time period considered. Pricing alternatives are not optimized in any way; the prices used are only to demonstrate the way in which long-life products are able to capture and re-direct value to the producer and user.

Two criteria are considered for the customer: cost in the first year, and total cost for light over 12 years. Twelve years is used because it is the lifetime of one long-life light tube.

A price for the annual service of using a light-tube is set to 1 €. This rate was obtained by setting the net present value of the revenue generated by a long-life light-tube that is provided as a PSS-offer for 12 years equal to the net present value of the revenue generated by selling one light-tube that has an expected life of 12 years.

2.2 Producer's (economic) perspective

For a PSS-offer to be possible, it must also be profitable for the offer provider in addition to being attractive to the customer. In this case, the long-life light tube producer is trying to lower total cost to the customer while capturing for itself enough of the value realized through that cost savings to be competitive with the producers of standard-life light-tubes. This is represented by exploring if the customer savings is significant enough to compensate for the reduced number of light-tubes the customer must use to meet its need for light. All of the costs incurred by the customer are mapped, the costs that can be reduced by the long-life offer are noted, and a decision is made regarding whether or not the PSS-approach is profitable. Note that company data is not able to be published, so illustrations are used to demonstrate the concept.

2.3 Society's (sustainability) perspective

As a prelude to answering Tukker's second question regarding reduced material use and emissions, an approach is taken that incorporates a strategic sustainability perspective in order to not only quantify material and emission reductions, but also to be sure that the scenario is not causing other sustainability issues. This is done by using an approach called "backcasting from sustainability principles" that states there are four basic principles that will be met by a society that is sustainable [3; 13; 14-15]. These basic principles state that in a sustainable society, nature is not subject to systematically increasing:

1 concentrations of substances extracted from the earth's crust;

2 concentrations of substances produced by society;

3 degradation by physical means, and

4 in that society, people are not subject to conditions that systematically undermine their capacity to meet their needs.

Since these are principles for sustainability of global human society, we assume that companies, products, or PSS that comply with these conditions (and thus do not contribute to society's sustainability problems) will have a competitive advantage compared to those that do not meet these principles.

For the sustainability assessment, a strategic life cycle management (SLCM) approach is used to consider how the scenarios comply with basic principles for global socio-ecological sustainability during each of the life cycle stages [15]. This approach is used in order to first take a strategic overview of the sustainability implications before attempting to provide a quantitative response to Tukker's second question regarding energy and material flows; this allows a full sustainability perspective so that as some challenges are addressed (e.g. material and energy reduction), other sustainability challenges are not created unintentionally. The SLCM approach is implemented by using a strategic life cycle matrix to identify any differences between the offers being considered.

The columns in the matrix refer to those basic principles for a sustainable society. The rows in the matrix refer to life cycle stages of the product or PSS. This allows for the identification of any current or future sustainability challenges related to the life cycle of the product. The matrix is shown in Figure 1.

	Principle 1	Principle 2	Principle 3	Principle 4
Materials	*List of aspects of the offer that are not in compliance for each life cycle stage and sustainability principle*			
Production				
Packaging & distribution				
Use				
End of Life				

Figure 1: Strategic Life Cycle Management Matrix

One matrix is completed for each product or PSS being considered, and if differences are identified, then a more in-depth assessment can be conducted to consider the trade-offs. This step is in realization that "sustainable behavior" is not only about reducing material flows and emissions, and that by focusing only on these two items there is a significant risk of sub-optimization of sustainability performance.

After obtaining a strategic overview from the matrix, there is an opportunity to go into more detail to allow for the quantification of relative environmental impacts. Life Cycle Assessment (LCA) [16] is a tool suited for such a quantitative analysis, and has been referred to as a complementary tool in PSS development in other places [17]. The LCA software tool Simapro, utilizing EcoInvent [18] data, along with some assumptions with regard to transportation and energy, is used to obtain some order-of-magnitude estimates regarding environmental impacts due to reduced material use from the long-life product over the product's life cycle. While this is not an ISO 14040-certifiable LCA (that process requires a much more rigorous process for goal setting and scoping, data collection and verification, and impact assessment), this can be performed in a few hours to obtain an approximation of the improvement across the product's life cycle.

3 RESULTS OF ECONOMIC ASSESSMENT

The boundaries of this study with regard to the value chain focus foremost on the producer of the light-tube and the light user. Because it requires four standard-life light tubes and the associated activities throughout their life cycles to match the useful life of one long-life light tube, the costs throughout the value chain recur four times for the standard-life light tube for every one time in the long-life light tube's life cycle. This is illustrated in Figure 2.

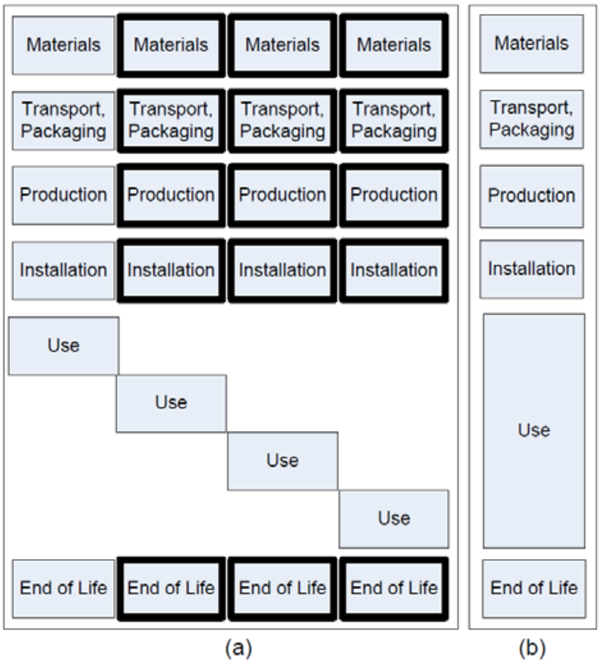

Figure 2: Activities where costs are incurred over the light tube life cycle when providing 48 000 hours of light with standard-life light-tubes (a) compared to 1 long-life light tube (b). Bold boxes show costs incurred in (a) only.

Light Customer Perspective

Economic considerations for the light user are presented in Table 1. Regarding initial cost, the long-life light tube sold as a product has a significantly higher cost than the other scenarios: 15 € (10 € for the light-tube in addition to the 5 € cost of tube installation) compared to either 7.50 € or 6 €.

Users of light have lower costs by using the long-life tubes, either by purchasing them outright or by accessing the light tubes through a PSS-offer. In this example, the 15 € difference between the total for standard-life and the total for long-life is simply the three installations (5 € each) that are not required with the long-life option. This difference remains significant when the net present value is considered, so here it seems that either of the long-life scenarios would be preferred by the customer.

Considering both the initial cost and the full costs over 12 years, the long-life light tube offered as a PSS appears most attractive to the customer.

Light Producer Perspective

The long-life light-tube producer's challenge is to do two things at the same time: first, to lower costs to the customer in order to make the long-life offer attractive, and second to increase the revenue that the customer is paying for the light-tubes (again remembering that the long-life producer is selling one-fourth as many tubes as a standard-life light-tube producer). Actual numbers from the company are confidential, but this concept is illustrated in Figure 3. Electricity costs are also included in the diagram in order to show the total life cycle costs of the customer (i.e. electricity is greater than 90% of the customer's cost).

Table 1: Customer costs of light-tubes and light in € over 12 years (48 000 hours of light).

Customer Perspective: Costs

	Standard life		Long life	
Year	Product	PSS	Product	PSS
2010	7,50	6,00	15,00	6,00
2011	0,00	1,00	0,00	1,00
2012	0,00	1,00	0,00	1,00
2013	7,50	6,00	0,00	1,00
2014	0,00	1,00	0,00	1,00
2015	0,00	1,00	0,00	1,00
2016	7,50	6,00	0,00	1,00
2017	0,00	1,00	0,00	1,00
2018	0,00	1,00	0,00	1,00
2019	7,50	6,00	0,00	1,00
2020	0,00	1,00	0,00	1,00
2021	0,00	1,00	0,00	1,00
Total	**30**	**32**	**15**	**17**
Net Present Value	**24,39**	**25,64**	**14,42**	**14,19**

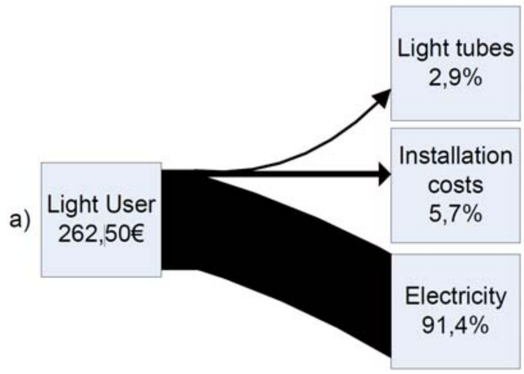

Figure 3a: Total customer costs for light during 12 year with a standard-life light tube sold as a product

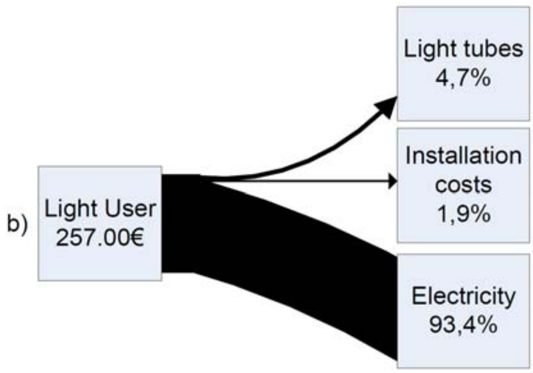

Figure 3b: Total customer costs for light during 12 year with a long-life light tube sold as a PSS

For the light consumer and the light-tube producer, there is an opportunity for the long-life light-tube to be mutually beneficial because it captures value that is otherwise distributed throughout other actors in the value chain. In this example, the captured value includes:

1 Savings by cost reduction due to changing tubes 1/4 as often (savings include e.g. the expense of manual labor and disruption to operations), and
2 Increased efficiency of light provided per material/energy input (1/4 as much material required and 1/4 as much energy for production, transport, etc. excluding the use phase)

4 RESULTS OF SUSTAINABILITY ASSESSMENT

Strategic Life Cycle Management Matrix

Due its focus on a qualitative overview to identify all potential sustainability concerns, the SLCM approach provides no distinction between the standard-life and long-life light tubes. This is because the life-cycles of both light-tubes contain the same sustainability concerns from a strategic overview perspective. See an example of a partially completed SLCM matrix for light tubes in Table 2.

Table 2: Example of an SLCM Matrix for light-tubes.

	SP1	SP2	SP3	SP4
Materials	Mercury Copper Lead	Solvents in marking ink	Land change due to mining	Worker safety
Production	Lead	Flame retardants Cleaning chemicals		
Packaging Distribution	Use of fossil-based plastics		Land use for transport	
Use	Use of fossil energy			Ballast noise
End of Life			Land change used for landfill	

Based on this conclusion, one can then say that probably the scenario that has less energy and material flows is the “more sustainable” alternative. With the long-life product reducing the raw materials, manufacturing, maintenance (e.g. light-tube replacement) and end-of-life phases of the light-tube’s life cycle by three-quarters, it clearly has environmental benefits over the standard-life light-tube (assuming that energy use for illumination is the same for both light-tubes).

Quantification of Environmental Impacts

Estimates are made using EcoInvent data in the life cycle assessment software tool Simapro. To make some quick estimates, these values were assumed:

- 150 kg-km of transport for light-tube components
- 100 kg-km transport of light-tube to customer
- 2400 kWh of electricity from the Swedish grid
- IPCC GWP 100a as the impact assessment method

This resulted in electricity during the use phase being about 94% of the environmental impact.

Then the electricity source was changed to the US grid, which resulted in the impacts due to electricity use being on the order of 99%. This assessment is sufficient for us to say that the global warming potential (using IPCC GWP 100- year) of using the long-life tubes with “dirty” electricity is about 3% less than standard tubes, and on the order of 17% less on a “clean” grid. In this scenario, the GWP is reduced on the order of 10%, even though material use is reduced by a factor of 4.

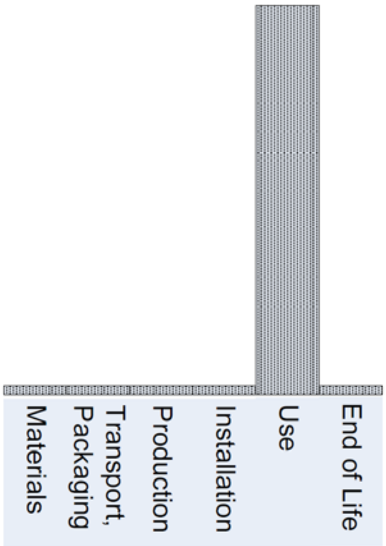

Figure 4: Approximate environmental impacts per life cycle stage of a long-life light-tube showing relative high impact during use phase.

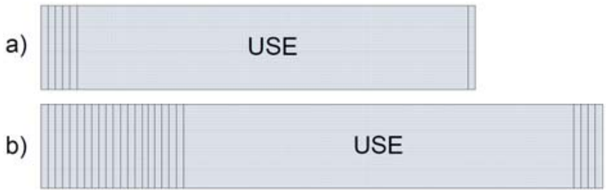

Figure 5: Environmental impact comparison between one long-life light tube (top) and three standard-life light-tubes (bottom). Vertical bars represent the life cycle stages in Figure 4. Top bar shows the long-life product, with 1/4 of impacts from stages other than use, compared to bottom bar that shows standard-life product. Impacts from use phase are the same for both.

5 SUMMARY OF RESULTS

The authors choose not to go into further detail with the LCA because this is not a trade-off situation: the long-life light tubes win from the producer’s economic perspective, the consumer’s economic perspective, and a broader societal perspective (from fewer negative sustainability implications) and there is no need to more exactly quantify the extent to which a long-life light tube is “less bad” than a standard-life light tube. Furthermore, on a sustainability-driven market where costs related to material and energy flows are expected to increase, the benefits from minimizing those flows are only expected to increase.

If, in line with current practice, revenue comes from the sales of light-tubes, then the long-life producer earns more profit than standard-life producer and the customer has a lower total-life cost, but the customer balks at the high initial cost. It is only when the long-life product is used as the basis for selling light that the long-life producer really wins: the long-life producer has a higher profit and the customer has both a lower total life cost and an initial price similar to what is offered by the standard-life product. The trade-off is that the producer must then front the capital costs for production.

Table 3: Summary of assessments

	Standard Life		Long Life	
	Product	PSS	Product	PSS
Consumer (Initial cost)	Prefer: lower initial cost	Prefer: lower initial cost		Prefer: lower initial cost
Consumer (total cost for 48 000 hours of light)			Prefer: lower total cost	Prefer: lower total cost
Producer				Prefer: because customer prefers
Society (full sustain-ability)	no differences identified			
Society (reduced materials and emissions)			Prefer: lower material and energy flows	Prefer: lower material and energy flows

6 DISCUSSION

This paper uses many of the same logical arguments in favor of a PSS approach that have been offered by early movers in this field. The contribution here comes from shifting the starting point of those arguments, particularly emphasizing that products designed for long-life gain competitive advantage through a PSS offer by capturing value that is otherwise distributed elsewhere in the value chain. Rather than having a regular product evolve into a PSS and then work toward longer-life, we start with a long-life product that gains competitive advantage by selling the function it provides: a different path to the same result.

6.1 Economics of Long-Life Products and PSS

Long-life products have the potential to capture value that can be shared between producers and consumers. However, consumers may hesitate at paying the price of the long-life tube that allows a long-life manufacturer to be competitive – remember that long-life producers have only a fourth as many products to sell, and thus must earn higher margins per light-tube to generate similar net incomes. Thus a PSS-approach based on offering the service of light is one possible approach for the long-life light-tube manufacturer. The example given here is only a limited PSS offer, and there is substantial more opportunity for a long-life light-tube provide to transition more toward the service-end of a PSS offer. This paper limits itself to a slight shift toward a PSS offer to make its point. The authors acknowledge that multitude of additional opportunities to shift even farther toward the service end of the PSS spectrum.

What needs to happen from a PSS-development perspective, then, are two things. First, to lower the cost to the customer, and second, to increase the revenue to the primary producer, So, the smaller the difference between these two (i.e. “primary producer revenue” – “user cost”), the more opportunity there is for the primary producer to make an offer that is attractive to the user. This is simply saying that PSS-developers need to look at broader life cycle costs of a PSS-offer, and not only the production costs within its own operation. Currently this idea that a long-life light-tube reduces life cycle costs is emphasized by Aura in its sales approach. Yet Aura still sells its light-tubes in a traditional way. This opens the opportunity to package both existing light-tube hardware and additional services into an offer to light users.

6.2 Assessing Sustainability

The methods used to assess the sustainability of concepts in this paper complement Tukker's implication that reduced energy and material flows leads toward more sustainable behavior. Tukker’s assumption is generally correct with one significant caveat: that the materials and energy sources have the same types of sustainability impacts. If, for example, the long-life product in our comparison contained substances that are not included in the standard-life product in order to give it the long-life property, then a more thorough assessment of the implications of the different materials would need to be conducted. This is certainly the case when comparing other lighting technologies ranging from the soon-to-be-banned incandescent bulb to LEDs, with the range of rare metals they often require. An SLCM matrix for these alternative lighting technologies demonstrates significantly different results.

However, the two physical products (standard-life and long-life light tubes) compared in this example do not differ in any significant way with regard to the materials throughout the life cycle of the product. The same materials are used in each tube, only in different quantities. If instead, the comparison was between long-life fluorescent tubes, incandescent bulbs and LEDs, then the SLCM approach would have identified as a significant difference that fluorescent tubes use mercury, or that LEDs use other rare metals. Traditional approaches to only quantify the differences in material and energy flows may miss this point, or may unintentionally focus on energy reduction without awareness of sustainability trade-offs of doing so. The authors do not suggest that such a decision is a bad decision – rather only that it should indeed be a *decision*, and not an unintended consequence.

6.3 Value Chain Cooperation

A point to clarify is the difference between providing alternative financing methods (i.e. the long-life manufacturer providing financing options to eliminate the light consumer’s balking at high initial cost) and having a PSS offer. The former does not provide an opportunity for the light-tube producer to capture the value that comes from eliminating the cost of replacing the light-tubes; it rather passes all of that value directly to the light user. By not only considering, but rather outright claiming for itself that value – and being willing to share that value with the customer – the long-life producer has the opportunity to be competitive with standard-life light-tube producers.

It is important to note that other value chain actors – particularly material suppliers for the light-tube production and service-providers who change the light-tubes– are likely to lose value when the long-life light-tubes are used due to the reduced number of light-tubes that are used. While it is outside the scope of this paper to consider the impacts of this, the authors suggest that there could be an opportunity to engage those extended value chain partners in discussions of opportunities for new innovations in the value chain to better adapt the value chain to a PSS offer so that value chain partners are not left behind or otherwise preventing the transition to a PSS offer.

6.4 Full System Perspective

The long-life aspect of the light-tube reduces the need for changing light-tubes, and this consideration follows Mont's [19] suggestion that a PSS needs to take a full system perspective. Precisely by taking this full-system perspective,

the long-life product identifies opportunities in the value chain to add value to the customer, and thus addresses Tukker's first point about determining the value creation of the PSS business model. Tukker's second point regarding reduced material flows is clearly addressed through the nature of the long-life product – and importantly – is addressed in this particular case without significant concern of a rebound effect.

Continuing to take a full system perspective, we must also acknowledge that the majority of both cost and environmental impact are due to electricity use. Throughout this paper we have not taken into consideration what either the producer or user might do to reduce costs/impacts related to electricity use, but rather have only assumed that electricity use for either standard-life or long-life light-tubes are the same. As part of a PSS-offer, certainly there could be opportunities for a "provider of the service of light" to incorporate ways to reduce lighting needs and further share the cost savings between the provider and user.

Other concerns related to long-life products should not be overlooked in the practical consideration of sustainability issues. One such consideration is technology change: with a usable life of up to 12 years, it is quite likely that lighting technology will advance during that time and become more energy efficient. With the vast majority of energy use (and thus arguably the majority of negative sustainability impacts) coming from the use phase, it is possible that "locking into" a technology with such a long life would result in increased energy use. A further shift toward the service end of the PSS approach would also further shift this burden from the user to the producer – whether good or bad, this is something to be aware of.

7 CONCLUSION

This paper extends the same logical arguments in favor of a PSS approach that have been offered by early movers in this field by shifting the starting point of those arguments. Here the emphasis is that products designed for long-life gain competitive advantage through a PSS offer by capturing value that is otherwise distributed elsewhere in the value chain. Rather than having a regular product evolve into a PSS and then working toward longer-life, it is possible to start with a long-life product that gains competitive advantage by selling function: this is a different path to the same result.

Specifically, this paper shows how value can be captured through cost-savings and then re-distributed directly to the consumer or the producer. Estimates of life cycle costs are made, including acknowledgement of the need to consider discount factors in economic analysis of products designed for long-life. This economic assessment addresses the life cycle costs of acquiring the function of light from the user's perspective, and addresses in simple terms the economic viability of a PSS-offer from the light-tube producer's perspective.

The long-life manufacturer creates value by producing long-life products that reduce the need to replace light-tubes, and the challenge is to capture that value because it is not contained within the value offer with their current business model. The value the long-life manufacturer creates essentially lies in the hands of their customers who, of course, appreciate the value created since it reduces their lighting costs. However, those light consumers are not necessarily willing to share this value (savings from not needing to change light tubes) by paying a premium to the long-life producer. Therefore the producer must find opportunities to capture that value, and a PSS-approach provides such an opportunity.

8 REFERENCES

[1] Willard, B. 2002. The sustainability advantage: Seven business case benefits of a triple bottom line. Gabriola Island: New Society Publishers.

[2] Berns, M., Townend, A., Khayat, Z., Balagopal, B., Reeves, M. and Hopkins. M. 2009. The Business of Sustainability: What It Means to Managers Now. MIT Sloan Management Review 51(1): 20-26.

[3] Broman, G., Holmberg, J. and Robèrt, K.H. 2000. Simplicity Without Reduction: Thinking Upstream Towards the Sustainable Society. Interfaces 30(3): 13-25.

[4] Robèrt, K.H., Schmidt-Bleek, B., Aloisi de Larderel, J., Basile, G., Jansen, J.L., Kuehr, R., Price-Thomas, P., Suzuki, M., Hawken, P. and Wackernagel, M. 2002. Strategic sustainable development - selection, design and synergies of applied tools. Journal of Cleaner Production 10(3): 197-214.

[5] Hallstedt, S. 2008. A foundation for sustainable product development. Doctoral Dissertation Series No. 2008:06, Mechanical Engineering, Blekinge Institute of Technology, Karlskrona, Sweden.

[6] Ny, H. 2009. Strategic life-cycle modeling and simulation for sustainable product innovation. Doctoral Dissertation Series No. 2009:02, Mechanical Engineering, Blekinge Institute of Technology, Karlskrona, Sweden.

[7] Manzini, E. and C. Vezzoli. 2003. A strategic design approach to develop sustainable product service systems: examples taken from the `environmentally friendly innovation' Italian prize. Journal of Cleaner Production 11(8): 851-857.

[8] Wong, M. 2004. Implementation of innovative product service-systems in the consumer goods industry. Ph.D. Thesis thesis, Cambridge University.

[9] Goedkoop, M., C. van Halen, H. te Riele, and P. Rommens. 1999. Product Service Systems: Ecological and Economic Basics. Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ).

[10] Mont, O. 2004 Product-Service Systems: Panacea or Myth?. Doctoral Dissertation, IIIEE, Lund University, Lund, Sweden.

[11] Baines, T. S., Lightfoot, H. W., Evans, S. Neely, A., Greenough, R. Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J. R., Angus, J. P., Bastl, M., Cousens, A. Irving, P. Johnson, M. Kingston, J., Lockett, H., Martinez, V. and Michele, P. 2007. State-of-the-art in product-service systems. Proceedings of the Institution of Mechanical Engineers; Part B; Journal of Engineering Manufacture 221(10): 1543-1552.

[12] Tukker, A. 2004. Eight Types of Product-Service System: Eight Ways to Sustainability? Experiences from Suspronet. Business Strategy and the Environment 13: 246-260.

[13] Holmberg, J. and K.-H. Robèrt. 2000. Backcasting from non-overlapping sustainability principles--a framework for strategic planning. International Journal of Sustainable Development and World Ecology (7): 291-308.

[14] Azar, C., Holmberg, J., Lindgren, K. 1996. Socio-ecological indicators for sustainability. Ecological Economics 18(2): 89-112.

[15] Ny, H., MacDonald, J. P., Broman, G., Yamamoto, R., and Robèrt, K.H. 2006. Sustainability constraints as system boundaries: an approach to making life-cycle management strategic. Journal of Industrial Ecology 10(1): 61-77.

[16] International Organization for Standardization (ISO). 2006. Environmental Management – Life Cycle Assessment – Principles and Framework, ISO 14040: 2006.

[17] Bey, N. and T. McAloone. 2006. From LCA to PSS – Making leaps towards sustainability by applying product/service-system thinking in product development. In 13th CIRP International Conference on Life Cycle Engineering. Leuven. 571-576.

[18] EcoInvent Centre 2007. Ecoinvent data v2.0. Ecoinvent reports No.1-25, Swiss Centre for Life Cycle Inventories, Dübendorf.

[19] Mont, O. 2001. Introducing and developing a product-service system (PSS) concept in Sweden, IIIEE reports, 1650-1675; 2001:6. Lund: IIIEE.

Environmental and Economic Benefits of Industrial Product/Service Systems

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Abstract

Increased competition and new customer requirements have forced manufacturers to strive towards selling industrial product/service systems. Product/service systems have derived partly from environmental research and development. However, it is still not clear how much can be earned in environmental and economic concerns.

This paper aims to explore the economic and environmental benefits of product/service systems from a life-cycle perspective in comparison to traditional selling approaches. To fulfill this aim, four case studies were performed at four product/service system providers in Sweden. The data was collected through semi-structured interviews, telephone interviews and data provided by the product/service system providers. A comparison Life Cycle Assessment (LCA) was conducted between traditional scenarios and product/service system scenarios. In addition, a Life Cycle Cost (LCC) analysis was conducted. To summarize, in all four cases the product/service system scenarios had environmental and economic advantages in comparison to their traditional selling scenarios.

Keywords

Integrated Product Service Offerings (IPSO), PSS, Life Cycle Assessment (LCA), Life Cycle Cost (LCC)

1 INTRODUCTION

Integrated product and service offerings (IPSO) is a trend, increasing worldwide, which rather than selling the product alone integrates products and services into an offer that meets the customer's needs. This type of offer applies to a variety of concepts such as integrated product and service offerings, Product/Service Systems (PSS), functional sales, integrated solutions, aftermarket services, turnkey products with added value and total solutions. In the following text the IPSO term will be used.

An IPSO is an offering that consists of a combination of products and services that, based on a life cycle perspective, have been integrated to fit targeted customer needs. IPSO further means that products and services have been developed in parallel and are mutually adapted to operate well together. This contrasts with the traditional sale when the provider transfers responsibility to the customer through the sales phase.

IPSO often create close contact between the supplier and customer, leading e.g. to offers being customized and improved to suit the customer better [1]. In many cases, the service provider retains responsibility for the physical products in the IPSO during the use phase. One example is when a client does not own the machines installed by the supplier, but only uses them and the products they offer and pays for the manufactured volumes. Then the supplier takes back the machines when the customer does not need them anymore. Such cases increase the provider’s interest to ensure that the customer uses machines installed as long as possible and that any disturbances, such as the need for repairs, are reduced. The increased responsibility by the IPSO supplier also potentially facilitates improvements identified and implemented in comparison to traditional sales. This could lead to a product lifetime extension.

This paper is a part of the KIPTES project, which has the purpose of collecting and establishing knowledge concerning the activities of Swedish companies and researchers within the area of integrated product service offerings, and subsequently to spread this knowledge. The study was divided into four steps: a literature review; mapping of Swedish researchers within the area as well as their research projects; mapping Swedish companies and their activities within the area; and finally in-depth case studies using e.g. LCA and LCC. This paper is based on the case studies in the fourth step while the third study is partly presented in Lingegård et al. [2] with focus on organizational changes associated with IPSO.

2 OBJECTIVE

The objective of this paper was to explore the environmental and economic benefits of industrial product/service systems. This exploration includes comparisons to traditional approaches of selling products at four providers of integrated product and service offerings in Sweden.

3 METHOD

Methods used for the research were mainly case study methodology including e.g. data collection through literature and semi-structured interviews with company staff. In addition, in order to conduct the assessments Life Cycle Assessment (LCA) [3] and Life Cycle Costing (LCC) [4] were used. The data collection for the four case studies [5-8] were mainly carried out by Larsson with support from the other two authors of this paper.

3.1 Inventory

When collecting data for the LCA and LCC, several different sources have been used. This is both because individual sources have not been able to supply data for the entire life cycle, and in order to confirm data that has been considered uncertain. It can generally be said that the aim here has been to look for data as close to the source as possible, i.e. suppliers and staff at the case companies.

This research is based on facts obtained by the case companies and where the data not been available, realistic assumptions were made in dialogue with these companies. To increase the performance quality as the assumptions on IPSO scenarios are always underestimated and the traditional sales scenarios overstated. This means that differences in the paper between IPSO and traditional sales scenarios are less than they probably would have been in reality.

All of the scenarios described in the case studies exist today at the companies, except for Scenario D in Case Study C, which is tentative. This means that the comparisons between the scenarios are valid and industrially practicable.

4 CASE STUDIES

The following paragraphs describe the four case studies conducted at the four IPSO providers for this research. In addition to the case study descriptions the results will be shown.

4.1 Case Study A – Cleaning of plaster exteriors [8]

The functional unit in this study is the cleaning of 1 m^2 of plaster exterior.

The company of Servicestaden Sverige AB cleans building exteriors as one of its businesses. The design of the building to be cleaned and painted affects implementation, and there are various options to facilitate work on the building exterior (facade). Extended nozzles for washing equipment, sky lifts, moveable scaffolding or fixed scaffolding are all examples of tools that facilitate the cleaning of facades. When the wall is to be painted after washing, it is advantageous to use a scaffold, which is mounted on the wall, making it easier for the painter.

Traditional exterior cleaning – In the traditional sale of facade cleaning, the customer first turns to a paint company to order facade painting. The painters then estimate the time based on the drying time of a traditional facade washing with high pressure water, which is equivalent to between six to ten working days. In the next step, the customer contacts a company that provides facade cleaning. The customer must schedule when the cleaning of the facade should be performed in order to permit enough time for drying in time for painting.

Exterior cleaning with high pressure water – Exterior cleaning traditionally consists of spraying the surface to be cleaned with a detergent, which may be allowed to sit for a short time. Then the dirt is rinsed and the facade is cleaned using high pressure water. A professional pressure washer is often small enough to fit in a smaller truck. When the pressure washer is used, the liquid may penetrate well into the wall, depending on water and water pressure. Because of this, painting cannot begin until the walls are dry.

Exterior cleaning with Qlean method – The Qlean method consists of cleaning done with ultra-clean water. Ultra-clean water is tap water that is completely free of bi-products such as salt, lime, minerals and metals. When ultra-clean water comes into contact with dirt, it not only loosens algae and exhaust fumes, but also functions equally well on grease and oil. Application of the ultra-clean water on the facade is done by piping with nozzles (see Figure 1).

To get the maximum power of the ultra-clean water, the Qlean method is always implemented from top to bottom on the facade. This means that the consumption of ultra-clean water and the time for washing is highest at the beginning of exterior cleaning. Hence, the ultra-clean water flows down the facade to loosen up the dirt even on surfaces that do not have nozzles directed towards them. The Qlean method does not allow moisture to penetrate deep into the exterior wall, so painting can take place as soon as a day after cleaning.

Figure 1. Application of ultra-clean water on the facade by a piping system with nozzles [9].

Scenarios – To identify the costs and impacts of facade cleaning, three scenarios were created. Scenarios and assumptions for each were determined based on consultation between the authors and Servicestaden. Common to all scenarios is that the facade cleaning requires the use of scaffolding and a staffing of two persons during the entire cleaning operation. After drying, scaffolding used in the facade cleaning remains until it is painted. Table 1 shows the differences between the scenarios.

Table 1. Summary of scenarios.

Scenario	T/I*	Washing Method	Capacity [m^2/day]	Drying Time [days]
A	T	Detergent – Pressure washer	300	6
B	T	Qlean-method	250	6
C	I	Qlean-method	300	0

*T/I stands for (T)raditional sales and (I)PSO

Scenario A: This scenario means the sale of traditional facade cleaning when using detergents and high pressure water. A day's cleaning corresponds to a cleaned surface of 300 m^2 with a drying time of six days.

Scenario B: This scenario means that the facade is cleaned by staff that rent ultra-clean water equipment from Servicestaden and thus applies the Qlean method, but that the facade cleaning is sold through a traditional sales model. This means that the client is still based on the painter's understanding concerning drying time of six days. This scenario also means that the company which rented the ultra-clean water equipment does not have time to clean as many square meters as the Servicestaden staff would have covered. A day's cleaning corresponds to a cleaned surface of 250 m^2.

Scenario C: This scenario means that Servicestaden offers the customer a clean and dry exterior wall one day after cleaning. This is conducted using the Qlean method. A day's cleaning corresponds to a cleaned surface of 300 m^2.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 2.

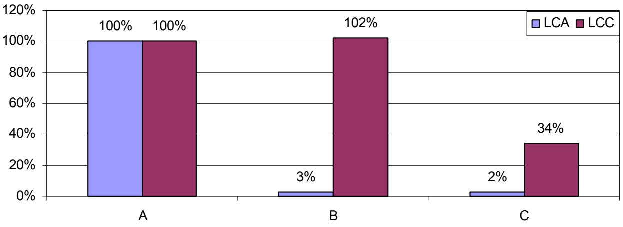

Figure 2. Summary of LCA and LCC in Case Study A.

Scenario A is set to be the reference value and thus become the scenario that all scenarios are compared with.

The results clearly show that it is environmentally preferable to use the Qlean method compared to the high pressure water method. To make it cost-rate motivational to switch methods, the drying time needs to be included, as in Scenario C. By applying IPSO which include short drying times for a customer, the customer can schedule an earlier painting. It is therefore in their best interest to choose IPSO over traditional marketing facade cleaning.

Discussion about the LCA – The inventory of life cycle analysis brought up several uncertainties surrounding the calculation, as discussed below.

It was hard to find data about the exterior detergent; instead, data based on assumptions and the detergents content was collected and aggregated from several databases. However, some detergent data was not found and was left out from the study. Therefore, it is likely that the exterior detergents' environmental impact is higher. This would imply that the high pressure water wash is even worse in comparison with the Qlean method.

It is uncertain to what extent the estimated supply pump is in line with reality. For example, it was calculated to be used on maximum load. The calculations still show that the supply pump's environmental impact is minimal in comparison with the production of high pressure water and ultra-clean water.

Discussions about the LCC – The inventory of life cycle cost brought to light several uncertainties. During the study, different assumptions and uncertainties were tested, but since the results were not significantly affected, it was decided to only discuss them here.

When a wall is flushed with high pressure water, there is a risk of delicate parts breaking and loosening. It is a question of who is liable, how big the damage is and the cost of repairing the damage. However, because of low pressure technology, the risk of facade breaks does not exist for the Qlean method.

As in the life cycle assessment discussion, there are uncertainties about the supply pump's actual cost. However, since the energy use results in a low cost compared to the whole, it is considered that the result still is valid. Labor costs are based on an estimate of the wages at Servicestaden. When wage variations occur, the result may change.

4.2 Case Study B – Clean floor [5]

The functional unit in this study is to hold a corridor's floor surface of 1 m^2 clean for a year.

The current situation is floor care at both the Valla Campus and the Cleaning Unit at departments at Linköping University, the latter abbreviated LV. LV has taken forward proposals for the departments' current needs and performance. Questions of interest have been e.g. what is needed to achieve the result of a clean floor?. They then make the departments' decisions on the basis of the actions needed to achieve the agreed upon outcomes. LV is interested in using the most effective and efficient method of floor care in relation to the defined customer need. This means methods that provide a clean floor at a low price, which is both environmentally and user friendly.

Definitions of floor care – Floor Care includes several elements that all have the aim of maintaining the floor function. After a floor is installed, a basic, so-called "construction cleaning", is performed. Following this, regular maintenance is conducted until the floor is replaced. In this study, the floor is assigned to "regular maintenance", the collective name for floor care i.e. frequent and periodic maintenance.

Frequent Maintenance – Frequent maintenance means the daily or weekly cleaning regularly occurs. Depending on factors such as congestion, filth, type of room, flooring and age structure, as well as customer demands for cleanliness and luster, the frequency and thoroughness of cleaning vary greatly [10-12].

Periodic Maintenance – The periodic maintenance is designed to facilitate the frequent maintenance and to ensure the floor is better protected [12, 13]. Periodic maintenance means that floor care resources are applied to create a protective layer on the floor. The layer also contributes to make the frequent maintenance easier. The frequency of required periodic maintenance varies due to e.g. if the frequency maintenance has not been performed sufficiently well or whether the burden has been higher than normal which led to increased wear. During periodic maintenance, the old floor care product is removed after which new products are applied. In this case, the periodic maintenance occurs during the times when the premises are used to a lesser extent, e.g. holidays.

Machine use in floor care – In larger premises and in the corridors, it is worthwhile to clean by hand instead of using scrubbing machines. Frequent maintenance with scrubbing machines may require that the floor first be dry mopped to remove any additional dirt particles or other volatile dirt. With both frequent and periodic maintenance, LV uses the same riding scrubbing machine, a "Taski Duospeed". The ride-scrubbing machines are mainly used in the corridors.

Chemicals – Both frequent maintenance and periodic maintenance may require various chemicals and chemical products. Regarding chemical use, it is difficult to generalize, especially when the concentration and volume are different and given that the wide range of different chemical products provides a wide distribution of environmental impact. In Larsson *et al.* [12], the problem of what effect chemicals can have is further developed.

Twister™ method – Instead of using chemicals in the performance of floor care, it is possible to achieve equivalent results with a mechanized solution. The Twister ™ method consists of a cleaning pad, prepared with millions of microscopic diamonds (attached to the Twister™ pads surface), which polishes and cleans the floor with only water as an additive [12]. As the floor care element is implemented, the Twister™ pad is worn down without affecting the lifetime of the floor. The binder holding the diamond anvil to the roundabout also contains a pigment, making it easy to see when it's time to switch to a new Twister™ pad.

Scenarios – In order to compare traditional sales and IPSO on floor care, two scenarios have been created. To facilitate the comparison based on two scenarios from a customer perspective, the LV is the executer of the floor care. The customer buys through a contract in floor care. The contract specifications help the customer determine what requirements LV must live up to. Depending on how the specification is designed, the conditions for introducing new approaches diverge. This is where the specifications are often based on the customer experience. The scenarios that were created to include floor care should be performed on plastics, linoleum and rubber flooring.

Scenario A: Scenario A refers to traditional sales of floor care and is based on the customer specifications that include a clear description of the floor care methods to be used (normally the previously used floor care method). LV earlier used a floor treatment method including polish, and therefore it is included in this scenario. It is assumed that LV uses this as the requested floor care method. The frequent maintenance should be performed every third day, with periodical maintenance once a year.

Scenario B: In this scenario, an offer of floor care, the customer's specifications made demands on the LV providing clean floors. The offer has meant that LV can use its experience of various floor care methods. LV has therefore chosen to apply the Twister™ method to achieve customer requirements for quality. This scenario corresponds to the current situation.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 3.

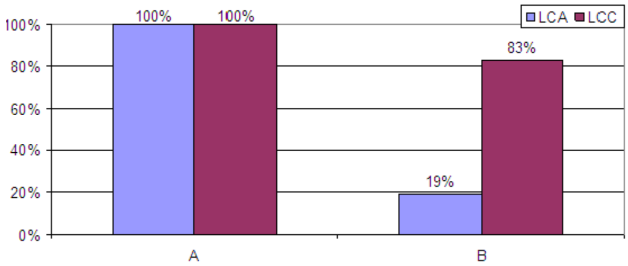

Figure 3. Summary of LCA and LCC in Case Study B

The results of the comparison show that Scenario B has a lower environmental impact and cost than Scenario A. The main difference is that traditional sales are settled using the existing methods, while IPSO are better able to adapt to new methods such as the Twister™ method.

Discussion about the LCA – Lindahl & Larsson [11] discuss among other things chemical eco-toxicity, and it shows that the floor care with polish has an even greater environmental impact than the result shows, which also applies in this example.

Based on that IPSO applied, there is greater opportunity to carry out the floor care and change the technology and methodology without violating the contract. This leads to the rapid conversion to new technologies that have lower environmental impacts such as the Twister™ method.

Discussions about the LCC – In an earlier study, it [11] was estimated that frequent maintenance took place every third day of the year's 365 days. In this study, the decision was made to build upon the previous results, but when the LCC is calculated from a usage rate that is lower than this, it is possible to discuss the differences between conditions in each method. If the LCC had been based on an equal use frequency as in the LCA it would have resulted in a cost increase; this occurs when periodic maintenance takes place, and would affect Scenario A for the worse. At the same time, this shows the sensitivity analysis of the LCC that increased utilization does not affect the cost of Scenario B significantly.

The difference between the two floor-care practices arose from the periodic maintenance. It should be noted that the cost for the scrubbing of a polish-treated floor and then the application of new polish does not include the time when the premises can not be used. Since the Twister™ method is easier to use than polish, time savings and cost reductions are achieved.

4.3 Case Study C – Soil compactor [7]

In this study, the functional unit was compaction of soils corresponding to a distance of one meter in width, 550 mm. Here ground refers to soil, sand, gravel, crushed rock and paving blocks.

Swepac International AB (Swepac) manufactures and performs service on soil compactors. From its manufacturing facility in Ljungby, Sweden, Swepac distributes soil compactors of different sizes to rental companies who then rent them out to different users. The IPSO Swepac provides its customers reconditioning, maintenance and repairs. Swepac strives to increase its machines' lifetime and leasability. This effort has resulted in several design improvements, some of which are interchangeable eyebolts, protective moldings and materials, to increase its soil compactors' leasability and technical lifetime.

A soil compactor is used to compact mainly soil in order to create a strong base. In this research, the soil compactor called FB 250 was studied (Figure 4).

Figure 4. Soil compactor FB 250.

Leasability and lifetime – A soil compactors' technical and economic lifetimes differ, especially in comparison with its leasability. It is easiest to get new machines, which makes it likely that the rental firm can maintain a higher price on those. This is valid as long as the customer, i.e. user, has a greater willingness to pay for the new machines than the older. That the client would rent a new soil compactor before renting an older one is partly to avoid problems in service, but also for more psychological reasons (it feels better to work with new and refreshed equipment). The context (e.g. misuse and irresponsible use) in which a soil compactors are used in general reduces the overall leasability to be shorter than the technical lifetime. This means that the rental firm probably has more functional machines in its inventory that can only be rented at a lower price or when newer machines already are leased. In this study, it is assumed that the rental firm's goal is to maximize its profits by hiring out soil compactors at as high a price as possible. This implies that considerations have only been taken towards estimated leasability and technical lifetime linked to repair and maintenance needs. The leasability assumes the number of years the soil compactor can be rented out without lowering its price.

Scenarios – In this study, a number of scenarios were designed to compare traditional sales with IPSO. The scenarios were created after consultation between the authors and Swepac. The differences between the various scenarios are described in the simplified section below, after which the various scenarios are presented more clearly. Figure 5 describes the principles of the main scenarios (Traditional Sales and IPSO) which are compared in this study. The letter "A" represents how a soil compactor is distributed from Swepac to a rental firm. The letter "B" represents a compactor that a rental firm rents out to a customer, who then returns the compactor to the rental firm when the lease period is over. The letter "C" represents the maintenance and the repairs Swepac conducts for the rental firm, thereby increasing its leasability. Only Scenario A applies the traditional sale while the other scenarios assume IPSO. The different scenarios are summarized in Table 2.

Table 2. Summary of scenarios

Scenario	T/I*	Surface Treatment	Leasability	Reconditioning
A	T	Varnished	5 y	0 time
B	I	Varnished	6 y	1 time
C	I	Galvanized	6 y	1 time
D	I	Galvanized	9 y	2 times

* T / I stand for (T)raditional Sales and (I)PSO.

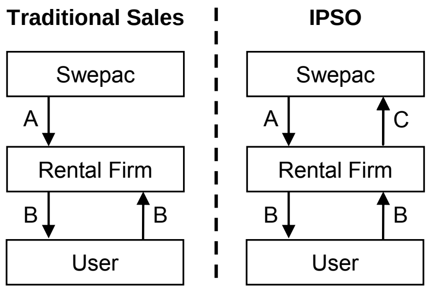

Figure 5. Description of the main scenario differences between traditional selling and IPSO.

Scenario A: Swepac only manufactures and sells soil compactors through traditional selling. This means that technological innovations that increase the technical lifetime are not valid. The scenario does not include any refurbishment, which adversely affects the lifetime of the compactors' components. The color wear and other wear makes the machines look unattractive after five years, making them harder to rent out.

Scenario B: This scenario is a reflection of the IPSO Swepac had previously, and includes the repainting and reconditioning of machinery. By reconditioning and repainting, the leasability is extended to six years.

Scenario C: To increase longevity and avoid repainting, the paint has in this scenario been replaced and certain parts galvanized. In order to compare how the galvanizing and vanishing are different, in consultation with Swepac it was assumed that soil compactors' leasability is six years.

Scenario D: This scenario implies that performing two reconditioning jobs could ensure a technical life of nine years. In the current situation, this scenario is not likely since the traditional economic thinking provides an amortization period of five years, after which most rental firms choose to buy a new machine. The scenario aims therefore to demonstrate the potential benefits that can arise when the technical lifetime is prolonged.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 6.

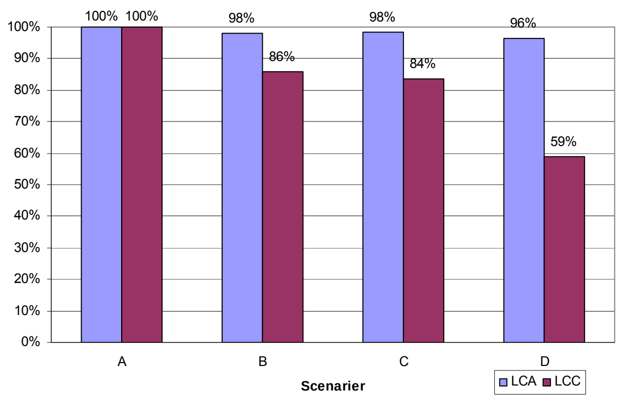

Figure 6. Summary of LCA and LCC in Case Study C.

Based Scenario A being set to be the reference value and thus becoming the scenario that all scenarios are compared with, the comparison shows that there is a clear correlation, both environmentally and economically, between traditional sales and IPSO. The results also show that the difference between the varnish and the zinc coating is not excessively large. But since varnish may have a greater impact than the findings in this study, it is likely to assume that the scenarios involving varnish (Scenarios A and B) have a greater impact than what is reported in Figure 6. Using zinc for galvanization is also preferred when the cost is lower.

Discussion about the LCA – The results of the LCA were influenced largely by the leasability that applies to each scenario. Generally, the results show clearly that the longer the leasability the soil compactor is assumed to have, the less environmental impact per meter-packed soil. With IPSO, there is an increase in the motivation to provide a product with optimal leasability.

Since Swepac performs reconditioning and develops good relationships with rental companies, it creates a better familiarity of how soil compactors works in operation and which parts need replacing. Swepac works on reducing the need of repairs and reconditioning by sharing its knowledge to rental firms and by gradually make improvements.

One improvement that Swepac has done is to galvanize some components. However, the LCA result shows that zinc used for galvanization can provide a greater environmental impact. It should be noted that data for both painting and repainting show that the environmental impact is limited, e.g. no transport to and from repainting are included in the results. Thus, it is reasonable to assume that a galvanized soil compactor can be better environmentally than a varnished one. This is where the difference between Scenarios B and C is not very large.

It is difficult to give a full picture of what portion of total environmental impact the repairs have been. A faulty component does not directly lead to preventing the soil compactor form working, but if not addressed it might imply that other more vital components are damaged. The need for repair depends on external factors such as handling during use. However, it can be concluded that with IPSO, in this case Scenarios B, C and D, there was a reduced need for repair.

In the LCA, shipments have been handled carefully. However, it is difficult to know how often transportation to and from the repair is needed and who in Scenario A performs the repair. It should be seen as self-evident that the more repairs, the more transportation, and that more transportation will lead to greater environmental impact. Clearly, many of the movements of the different scenarios are equal and cancel each other out in the comparison.

Discussion about the LCC – The discussion here is primarily to highlight observations that have not been possible to estimate economically.

A rental service should strive to be able to rent a soil compactor as long as it can get the same benefit as the renting of a new one. Through refurbishment and implementing measures that make soil compactors look like new, the number of years soil a compactor can go out to the customer not only increases, but also the number of years it may go out to the customer at the right price. Thus, it is in the rental company's interest to have a leasability perspective. In this case, the result shows that soil compactors by IPSO are, in the long-term, better than to buying into the traditional forms of selling.

Through refurbishment Swepac creates a cross-fertilization of product development. By adapting soil compactors the production facilitates refurbishment, and thus reduced working hours when the step should be performed. With refurbishment, knowledge is created about the conditions for developing better products, with less need of repair and with a longer lifetime. There are also several practical advantages to reconditioning as opposed to an increased risk of repairing. Foremost is refurbishment can be scheduled when demand for soil compactor use is low, thus avoiding loss of income, such as during winter months, when fewer construction jobs are carried out.

The study found that zinc coating for the galvanization of soil compactors is better in cost terms. It is clarified that

Swepac most likely would not have galvanized certain components if they did not use the IPSO approach. The reason is partly that traditional selling does not try to increase a product's lifetime to a high degree, mainly to avoid saturated market demands. It was through refurbishment that Swepac found that it is cost beneficial to galvanize certain components to avoid the costs incurred in repainting process.

The study has not included costs incurred when a soil compactor breaks down and when the work is delayed. This is where it is difficult to estimate the losses/expenses suffered by the user. However, it should be regarded as self-evident that higher costs and reduced revenues will be incurred when the repairs must be performed, and hence it should be an endeavor to reduce the risk that soil compactors will break. It was found that IPSO helps to gradually reduce this risk.

It has been revealed during the study that Swepac in some instances may give discounts. The discounts vary depending on the relationship between Swepac and the customer. This would lead to life cycle costs of leasing firms being reduced when the relations between them and Swepac are developed. This relationship development is a cornerstone of IPSO. Since the result still shows the benefits of product-service offerings versus traditional selling, it has not been considered necessary to clarify the benefits of IPSO by applying any discounts to the outcome.

The cost of transportation is not included in the study. It is then the rental company which is responsible for these costs, and such costs vary depending on where the rental company is located.

4.4 Case Study D – Core Plugs [6]

The functional unit in this study is the service a paper mill has of supplying a core plug used for paper rolls, that is sent to a customer once for a single use.

Polyplank AB manufactures and sells products consisting of a mixture of recycled plastic and wood. This unique material can be reused directly without further treatment. This study focuses on core plugs used by paper mills, which they use to plug the cores on which paper is rolled up and which follows the roll out to the customer. Through selling through the IPSO concept, Polyplank collaborates closely with its customer, the paper mill, and can thus take advantage of the core plugs when the paper mill's customers send them back to the paper mill.

Handling of used plugs – There are three main scenarios for what happens with the paper mill's customers used core plugs:

- Disposal by the paper mill's customer;
- Reuse by the paper mill (sent out to new customers); and
- Recycling by Polyplank.

Disposal by the paper mill customer – In some cases, used core plugs at the paper mill customer disappear or are discarded. This quantity is very small in comparison to the other two scenarios, and therefore this study is distinct from dealing with the core plugs not reused or recycled.

Reuse of core plugs – The most common scenario and the paper mill's most advantageous, is the reuse of core plugs. This means that core plugs after a period out at the paper mill customer are returned to the paper mill; after washing and quality control, these core plugs can be reused for new customers. If the core plug is worn out it is sent to Polyplank where it is recycled. Normally, the core plug is reused several times. With the IPSO concept, Polyplank aims to achieve a level of quality that will enable their core plugs to be reused several times. Even the paper mill's customers benefit from this approach; instead of the handling and the cost of discarding core plugs, they can easily send them back.

Recycling – When core plugs are finally discarded, they are returned to Polyplank where they are grinded down and sent to injection molding in order to become new core plugs. In practice, almost 100% of all incoming used core plugs become new core plugs.

Scenarios – A number of scenarios were created to compare different alternative potential offers that Polyplank or its competitors could offer paper mills. The main difference between the different scenarios is the number of times the core plug's material is reused by Polyplank, and how many times the mill can use the core plug before it is sent back to Polyplank for recycling. Table 3 describes the different scenarios. In the first scenario, virgin plastic is used in order to compare the pros and cons of Polyplank materials based on recycled plastics.

Table 3. Summary of scenarios.

Scenario	T/I*	Ingoing material	Use at final customer	Material use
A	T	Virgin material	1	1
B	T	Polyplank material	1	1
C	I	Polyplank material	1	6
D	I	Polyplank material	5	3
E	I	Polyplank material	5	6
F	I	Polyplank material	5	9

Scenario A: This scenario corresponds to the traditional production of core plugs and is a competitor to Polyplank's core plug offering.

Scenario B: The paper roll with the core plug is only used one time.

Scenario C: This scenario corresponds to what happens if the paper mills for unknown reasons do not reuse the core plug, but send it directly to recycling and have done so five times.

Scenario D: The paper mill customer returns the core plug back to the paper mill company where it is reused four times before it must be replaced. It is assumed that all replaced/discarded core plugs are returned to Polyplank, which through its recycling process reuses the material for new core plugs. Each plug can be recycled twice before the material eventually must be discarded.

Scenario E: The paper mill customer returns the core plug back to the paper mill company where it is reused four times before it must be replaced. It is assumed that all replaced/discarded core plugs are returned to Polyplank, which through its recycling process reuses the material for new core plugs. Each plug can be recycled five times before the material eventually must be discarded.

Scenario F: This scenario corresponds to what happens if recycling increases. The paper mill customer returns the core plug back to the paper mill company where it is reused four times before it must be replaced. It is assumed that all replaced/discarded core plugs are returned to Polyplank, which through its recycling process reuses the material for new core plugs. Each plug can be recycled eight times before the material eventually must be discarded.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 7.

Based on Scenario A being set as the reference value, it becomes the scenario that all scenarios are compared with. The comparison shows that there is a clear correlation, both environmentally and economically, between the choice of materials, recycling rate and recycling rate for the use of a core plug.

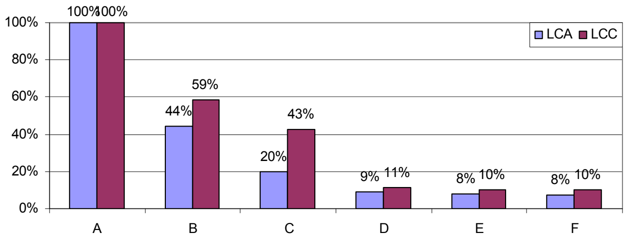

Figure 7. Summary of LCA and LCC in Case Study D.

The comparison clearly shows that if Polyplank would apply the traditional sale of core plugs as Scenario A shows, it would also impact the environment and causes the cost to increase significantly compared with current IPSO that Scenario E represent. This is where today's IPSO represents an environmental load of eight percent and a cost of 10% of the total, which stands for traditional selling.

Discussion about the LCA – The LCA results are discussed in relation to choice of materials and recycling rate.

The largest gain with core plugs based on Polyplank material is the use of recycled compared to virgin plastics for the core plugs in Scenario A. It gives a significantly reduced overall environmental impact. The more times the material of the plug can be reused, the less environmental impact. Polyplank's IPSO based sales has increased its ability to take full advantage of its materials.

Since the Polyplank core plug can be reused the overall environmental impact per use is decreased; however, reusability puts higher requirements on quality regarding durability. It has been confirmed that the core plug that Polyplank manufactures has sufficient quality to withstand at least five reuses, which helps reduce the overall environmental impact. If Polyplank would not work under IPSO and instead focus on selling more plugs, it would result in an increased environmental impact. To summarize, Polyplank IPSO-based selling helps to increase the possibility that the core plug reuse rate will increase.

Given the close cooperation between Polyplank and the paper mill, Polyplank can recycle core plugs, leading to a reduction in material consumption. The result shows that this gives a reduction in environmental impact compared to core plugs produced on virgin materials. The result also shows that the more times a core plug is recycled, the more the environmental impact is reduced.

Discussion about the LCC – To clarify, the LCC results are discussed for the different scenarios, such as differences in choice of materials and recycling rate.

The use of recycled instead of virgin plastic reduces the life cycle cost. Without the economic benefits of using recycled plastic, the question is whether or not core plugs would be made of recycled plastic, and it is therefore not surprising that the results demonstrate this.

When the paper mill does not need to consume as many core plugs, the life cycle cost per core plug is lower each time it is reused. From a traditional marketing perspective, this may in the short term be seen as something negative because it reduces demand for new core plugs. The interesting thing to consider is if Polyplank can offer a core plug which has a lower cost per use; if so, it is highly probable that that plug would take market share.

The results show that recycling is more cost effective than the use of virgin core plugs. However, there are many uncertainties in this case, when variable costs such as salaries are not included, and fixed costs of buildings and machinery are not considered. These costs are, however, not with the option of using virgin material.

5 CONCLUDING DISCUSSION AND CONCLUSION

Many researchers have emphasized that IPSO facilitate a dematerialization of the society and stimulate design of products that are beneficial for the environment [14-17]. The fact that the provider often keeps the ownership during the use phase also often implies a responsibility for the cost of maintenance and service [18]. This means that the supplier is interested in developing durable products with a long lifetime and low maintenance costs, something that effects how the company designs its products. In relation, this also generates economic drivers for reuse of the product and its components [19], something that potentially reduces the environmental impact regarding raw material and energy use for manufacturing [20, 21].

The four case studies described are in line with previous research by having the IPSO approach preferable from an environment as well as an economic perspective. The internal costs for maintenance imply that the supplier makes money on reducing those by e.g. reducing the resource consumption [16, 17].

It seems that IPSO enables a lower environmental impact than traditional business models as also described by e.g. Mont [22]. IPSO is not only positive from a business perspective but also from an environmental one. However, from these four case studies it is not possible to draw a general conclusion that IPSO always is preferable from an environmental perspective as also concluded by Lindahl & Ölundh [23] and Alonso-Rasgado et al. [24].

In conclusion, the calculations made in the four case studies show that the IPSO sales approach is both environmentally and economically preferable in comparison to their traditional selling approaches.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

[1] Sundin, E., M. Lindahl, M. Comstock, Y. Shimomura and T. Sakao (2009). "Achieving Mass Customization through Servicification." International Journal of Internet Manufacturing and Services 2(1/2).

[2] Lingegård, S., M. Lindahl, and E. Sundin, Organizational changes in connection with Integrated Product Service Offerings, in CIRP's 2nd IPS² Conference. 2010, CIRP: Linköping, Sweden.

[4] ISO 14 040, Environmental Performance Evaluation - Life Cycle Assessment - Principles and Framework. 1997, International Organization for Standardization: Geneva, Switzerland.

[5] Larsson, H., Kartläggning av miljö- och kostnadsfördelar som ett Integrerat Produkt- och TjänsteErbjudande av rent golv ger jämfört med traditionell försäljning av golvvård, LIU-IEI-R--09/0074--SE. 2009, Industriell miljöteknik, Institutionen för ekonomisk och industriell utveckling, Linköpings universitet: Linköping,Sweden.

[6] Larsson, H., Kartläggning av miljö- och kostnadsfördelar som ett Integrerat Produkt- och TjänsteErbjudande av en hylsplugg ger jämfört med traditionell försäljning, LIU-IEI-R-- 09/0076--SE. 2009, Industriell miljöteknik, Institutionen för ekonomisk och industriell utveckling, Linköpings universitet: Linköping,Sweden.

[7] Larsson, H., Kartläggning av miljö- och kostnadsfördelar som ett Integrerat Produkt- och TjänsteErbjudande av en markvibrator ger jämfört med traditionell försäljning, LIU-IEI-R-- 09/0077--SE. 2009, Industriell miljöteknik, Institutionen för ekonomisk och industriell utveckling, Linköpings universitet: Linköping,Sweden.

[8] Larsson, H., Kartläggning av miljö- och kostnadsfördelar som ett Integrerat Produkt- och TjänsteErbjudande av fasadtvätt ger jämfört med traditionell försäljning, LIU-IEI-R-- 09/0075--SE. 2009, Industriell miljöteknik, Institutionen för ekonomisk och industriell utveckling, Linköpings universitet: Linköping,Sweden.

[9] Sundin, E., N. Svensson, M. Lindahl, M. Björkman and P. Hammarstedt (2008). Innovation Potentials of Using Solvent-free Industrial Cleaning in Swedish Manufacturing Industry. Proceedings of Sustainable Innovation 08 - Future products, technologies and industries, 13th International Conference part of the 'Towards Sustainable Product Design' series of conferences. Malmö, Sweden.

[10] Paulsen, J., LCA på golvmaterial – fallstudier med särskild hänsyn till användningsfasen (In english - LCA of floor materials - case studies with special focus on the use phase), in Trita-Byma 1999:7, ISBN: 91-7170-462-0. 1999: Stockholm, Sweden.

[11] Lindahl, M. and H. Larsson. Life Cycle Assessment of Floor Care – A Comparative Study of the Twister™ Method and Floor Care Methods Using Polish and Wax. in in Proceedings of EcoDesign 2009. 2009. Sapporo, Japan.

[12] Larsson, H., M. Lindahl, and N. Svensson, Life cycle assessment of floor care - A comparative study of the Twister™ method and floor care methods using polish and wax. 2009: Linköping University, Sweden.

[13] Ecolabelling, N. Floor care products 051, version 3.1. 2008 [cited 22.12.2008]; Available from: www.ecolabel.se/Default.aspx?tabName=CriteriaDetail&menuItemID=6998&pgr=51.

[14] Lindahl, M., E. Sundin, A. Öhrwall Rönnbäck and G. Ölundh Sandström (2009). Integrated Product Service Engineering (IPSE) project – Final report. Linköping, Department of Management and Engineering, Linköping University: 48.

[15] Ölundh, G. and S. Ritzen, Funktionsförsäljning och produkters miljöaspekter – en studie i tre svenska tillverkningsföretag. 2002, Naturvårdsverket, ISBN 91-620-5234-9: Stockholm. p. 40.

[16] Mont, O.K., Clarifying the concept of product-service system. Journal of Cleaner Production, 2002. 10(3): p. 237-245.

[17] Berggren, C. and M. Björkman, Funktionsförsäljning/funktionsupphandling för hållbar tillväxt - Idépromemoria och kunskapsöversikt. 2002.

[18] Lindahl M., Sakao T., Sundin E. and Shimomura Y., "Product/Service Systems Experiences – an International Survey of Swedish, Japanese, Italian and German Manufacturing Companies", Proceedings of CIRP Industrial Product/Service Systems (IPS2), 1-2nd April, Cranfield, The United Kingdom, pp 74-81, 2009

[19] Sundin E. and Bras B., Making Functional Sales Environmentally and Economically Beneficial through Product Remanufacturing. Journal of Cleaner Production, Vol. 13(9), pp 913-925, 2005

[20] Östlin J., Sundin E. and Björkman M., "Product Life-cycle Implications for Remanufacturing Strategies", Journal of Cleaner Production, Vol. 17, Issue 11, July 2009, pp 999-1009, 2009

[21] Mont, O., Introducing and developing a Product-Service System (PSS) concept in Sweden. 2001, Financed by Nutek: Stockholm, Sweden.

[22] Mont, O., Product-service systems: Panacea or myth?, in The International Institute for Industrial Environmental Economics (IIIEE). 2004, Lund University: Lund, Sweden. p. 233.

[23] Lindahl, M. and G. Ölundh. The Meaning of Functional Sales. in Life Cycle Engineering: Challenges and Opportunities: 8th International Seminar on Life Cycle Engineering. 2001. Varna, Bulgaria: CIRP.

[24] Alonso-Rasgado, T., G. Thompson, and B.-O. Elfström, The design of functional (total care) products. Journal of Engineering Design, 2004. 15(6): p. 515-540.

SensCity: a new project opening the way for sustainable services in the city based on a mutualised M2M infrastructure

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Abstract

As ICTs became more powerful and accessible it became evident that objects would start to communicate. M2M progressively completed the idea of smart objects and M2M networks came into being, opening new scopes for services. Moving away from application orientated networks; SensCity will build a mutualised M2M infrastructure for sustainable city services. The project is led by a consortium of industrials, SMEs and research laboratories. This paper introduces the scope of services targeted by SensCity and overviews related technical and scientific issues. One concern is how to appreciate environmental impacts and benefits for this particular kind of PSS.

Keywords

Design for environment, impact assessment, M2M, product service system

1 INTRODUCTION

The project Senscity is a collaborative project involving a telecom operator, SMEs and research laboratories and is funded by the French ministry under the cluster of competitiveness label [1]. It seeks to combine the dynamics of small high-tech SMEs along with the forces of academic research and the experience and strength of a telecom operator, in the field of Machine-To-Machine (M2M) communication. The idea is to use a unique M2M infrastructure to construct an original city-wide telecom network that would support a great variety of services for its residents. These services would be structured around local M2M networks linking different types of sensors scattered around the city to a centralised M2M platform.

As environmental consciousness increases, particularly in today's global context of economical crisis, any new project must certainly pose the question of Sustainable Development. All the-more-so in a project dedicated to M2M services in the city. One of the important ambitions of SensCity will therefore be to develop Sustainable Services for Sustainable Cities.

The questions that this will raise are numerous; this article will give an overview of the different challenges as they are conceived from the start of the project. We will trace the evolution from everyday "things" to a project for urban M2M services and take an insight to the possibilities opened out for Product Service Systems (PSS). Some illustrations of M2M urban services will be presented.

2 AN M2M INFRASTRUCTURE AND SUSTAINABLE DEVELOPMENT

2.1 Sustainable Development and ICTs

A Fair Balance

It is becoming more and more evident, and this well before the outbreak of the current financial crisis, that the model of everlasting development at any cost is impossible to maintain. It is important to keep in mind that one of the important goals of the project is the respect of urban sustainability.

In 1987, the Brundtland Report officially laid the basis for sustainable development [2]. Since then, some authors have stressed on the fact that there is a tendency of forgetting that the satisfaction of needs in developed countries must be "combined with the requirements for a nation as a whole to keep its consumption level within an 'ecological scope'" and at the same time, compatible with "the goal of raising the material standards of living in poor countries" [3]. In a paper on urban planning, Campbell explains the triangle showing three priorities and three resulting conflicts (Figure 1). "'Grow' the economy, distribute the growth fairly, and in the process not degrade the ecosystem." [4]

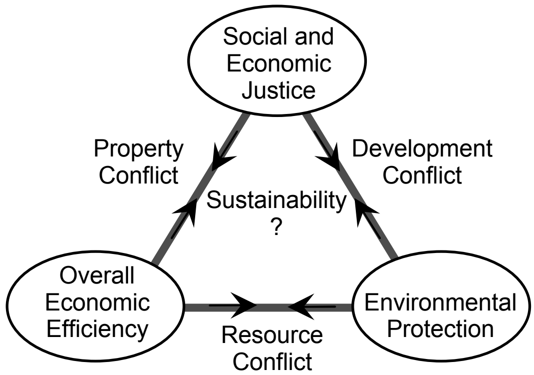

Figure 1: Green, Profitable and Fair.

The term 'grow' must be consistent with the Brundtland recommendations. It is only acceptable if it means a significant reduction of input resources and is principally directed to activities demanding less energy and fewer resources. A fair distribution between generations must also be fair to poorer countries and amongst social groups within a country. Special care must be taken with the ecosystem as decisions taken on a local city scale would affect ecosystems on the other side of the planet. The respect of future generations therefore implies that any development must, in the very least, respect a fair balance between economical, social and societal and environmental benefits under these conditions.

The nature of micro-electronic products involved in this project means that particular attention must be paid to global consequences and to the benefits or drawbacks that would be obtained.

The possible role of ICTs

Since their beginnings, micro-technologies have been making fast progress. Together with developments in other domains, like informatics and ergonomics, they have made possible a spectacular development of Information and Communication Technologies (ICT) as shown in Figure 2.

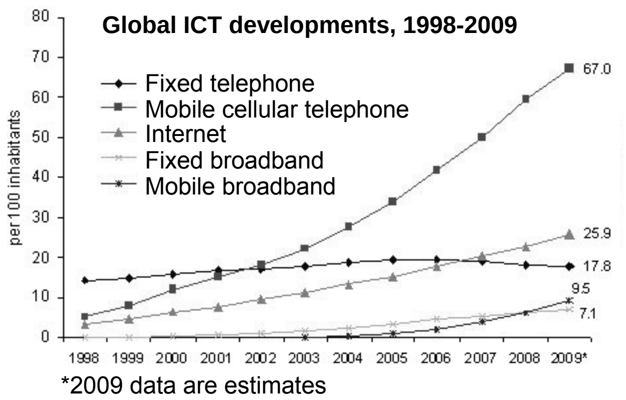

Figure 2: Growth of ICTs [5].

Low-cost potentials for mass production combined with low energy consumption during the use phase of their life cycle, particularly if compared to other heavy mechanical or electrical equipment, raise hopes of low environmental impacts for such electronic devices. These technologies can lead to important changes in our lifestyles and working conditions. They can modify the perception of our environment, homes, industries and towns. The very concept of citizenship must be reviewed with ICTs. They open up possibilities for a multitude of new concepts and new uses. ICTs have often been cited as a chance for sustainable development in so much as care is taken to avoid the rebound effects [6].

2.2 From RFID to networks

Things and smart objects

In a world tuned to internet and the world-wide-web, the "internet of things" is also gradually taking shape and becoming a reality. "Things" people our world. They can be designed either to help us or become too complicated for simple use. The questions of the ergonomics of things have been posed in [7]. As if to overcome the problems of simple use, the idea that things could communicate and therefore become "smart" began to germ. Smart objects are basically objects that communicate. They can communicate with man and also between themselves.

Amongst the different possibilities opened out by smart objects, a few illustrations can help to fix ideas: it is not uncommon to see the garage door open automatically as the owner's car approaches; the alarm goes off as the burglar tears the painting off the wall; point the PDA towards an electrical appliance and the user manual appears on the screen.

Smart Objects seem to concentrate all the burning questions concerning practices in usage. Are they useful? Do they fit into our lifestyles today? Are they harmful? Can we cope with their use? Will they intrude into our privacy? Are they acceptable? ... They have a tendency of destroying the barriers between the professional and private spheres of our lives [8]. There are basically three ways of tackling these problems of use, especially in the quest of new communicating objects: marketers study how to obtain value in existing markets for the future objects; ergonomists make sure that the objects are easy to understand and to manipulate, making the value accessible; sociologists determine if they make sense to the user and in that way, create the value |9].

From the technical point of view, if you consider that smart objects need to be rather mobile, or at least not always close to a telephone line or some other power line capable of providing a communication support, then communication must go wireless. In order to help achieve this, numerous short-range wireless communication protocols focus on the issue.

RFIDs

One particular set of communicating objects that can be identified is RFID. A radio-frequency link needs to be established with mobile objects that want to communicate. Next, each object must be identifiable. The simplest way is to give it an identification number and the RFID becomes an electronic tags. The barcode is actually an ancestor of modern RFIDs.

Actually RFID technologies first appeared during World War to identify planes as being fried or foe. The size of the devices has obviously no common measure with today's possibilities. Today it refers to an electronic device capable of basic communication. Miniaturised it can be stuck, "tagged", on to any ordinary object and make it "communicate".

Passive tags

Le simplest RFID does not have its own source of energy. Such a passive tag is equipped with an antenna that captures an RF signal from a second, more powerful device, known as the reader. The reader must come in close in order to communicate with the RFID tag. The energy contained in the incoming signal can then be used to drive the tag allowing it to re-emit information contained inside (Figure 3).

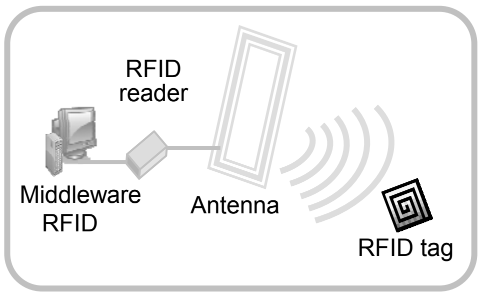

Figure 3: RFID communication.

The minimum of information necessary is an identification number that has to be unique to the object and recognisable by the reader. It could also contain some other simple information but without an internal power supply, possibilities are very limited. RFID passive tags are cheap and widely used for identifying objects such as commercial objects, but are not directly the subject of this paper.

Active tags

Increased functionality becomes possible if the tag possesses its own internal power source. An active tag can communicate over a much larger radius and hundreds of meters are quite possible even in difficult environments, like across buildings or other unfriendly obstacles. Another advantage of having an internal power source is obviously the increased capacity of stocking and processing information.

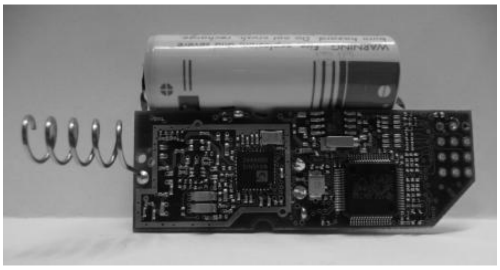

Figure 4: Coronis Active Tag Communication Module.

Active tags (Figure 4) can be associated with all kinds of machines, sensors or actuators. With active tags it becomes possible to consider placing them all over the place, doing all sorts of things. If distances become too long, repeaters can be placed between the tag and its reader.

Capillary Networks

In this way we construct a network. The ordinary RFIDs in the network will execute activities locally, such as collecting data or other functions. They are called end-points. Others, the repeaters, will be used to forward the data towards different points in the network. Of course RFIDs can also combine the repeater function and carry out local activities. Somewhere along the line we may want to interconnect the local network to existing telecommunication networks, like internet or mobile networks. A gateway is necessary to communicate locally with the RFIDs and distantly via these larger more extensive networks.

Our network begins to look like a sort of capillary network able to feed or receive information from the other major networks. Different topologies exist like star; tree and meshed, they are illustrated in Figure 5.

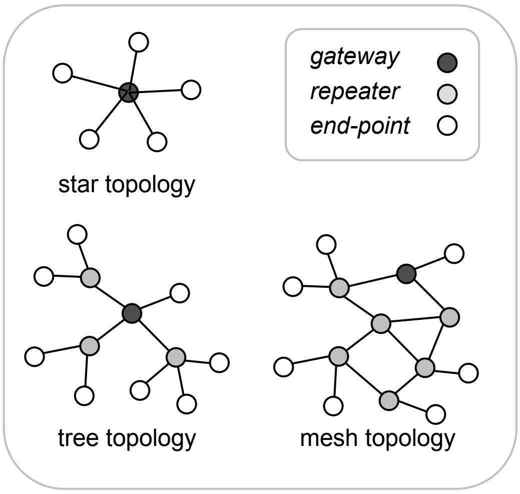

Figure 5: Network Topology.

Of course, all this is without considering technical difficulties related to the absence of universal language and communication standards, neither the problems of acceptability due to the installation of such networks all over the place.

2.3 M2M infrastructure

Exchanging data between objects independently to human intervention is called Machine-to-Machine communication. The earliest uses of M2M were by the American space agency, NASA and some large petrol companies. From the early 2000s, le M2M concept was formalised in various white papers throughout the world [10-11]. The concept results from the association of ICTs and smart objects enabling the objects to interact with information systems without human intervention. M2M can be considered as a technical artefact that extends ubiquitous computing (i.e. human-computer interaction in which information processing is completely integrated) to everyday objects and activities to machines and objects.

M2M infrastructures offer wide possibilities for telemetry applications. However to build up such systems it is important to consider what must go to or come out off a machine. Here, the essential elements are the sensors linked to the machines. They represent the awareness and this is what justifies the need to communicate.

Once again, advances in micro- and more recently nano-systems provide low-cost miniature sensors and actuators of all kinds allowing them to be disseminated all over. Physical values such as temperature, pressure, voltage, acceleration, counters, etc. can be measured and data from the different sensors can be aggregated together enabling decision centres to respond in real-time to evolving contexts. Where actuators are available it can be possible for the system to take action independently. In other cases it is possible to resort to traditional services that are enhanced by the information collected and processed by the system.

Figure 6: A solar powered gateway.

It is estimated that there are potentially hundreds of billions of machines that could be inter-connected in the world. The environmental impact of M2M communications even at much smaller scales would become a major issue. Furthermore, machines obviously are very different and display heterogeneous natures. Very much coherence and convergence will be necessary in order to make them link to one another. Today there appears an urgent need for international norms and standards.

Vertical Applications

M2M systems find applications in many different areas: transport and logistic; home automation and security; energy management; healthcare; utility metering; public infrastructures and environment, to sight just a few of them.

Generally speaking however, most systems used today are proprietary systems and treat only a limited number of applications, basically just one. The market is orientated vertically and systems are expected to run in parallel in competition with one another. This situation evidently cannot carry on indefinitely. For economic, technical and environmental reasons the systems must evolve towards open infrastructures.

An Urban M2M Network

A good way of moving away from vertical-orientated applications towards non-proprietary open systems is to delimit coherent geographical domains displaying a clear interest in multiservice. Such perimeters could be, for instance, premises of homes, industrial zones or international transportation networks. Amongst them is the city. SensCity occupies this particular area of study, full of promising applications.

2.4 PSS and M2M services

If the prospect for developing interesting services in the city is clear it must also be clear that the choice and more importantly, the model for services, are very important considerations. The case of PSS is therefore interesting to examine and can guide the choices made.

An Industrial Product-Service System (IPSS) is "an integrated product and service offering that delivers value in use". Various authors have described PSS and show the potential interest for sustainable development [12-13]. PSS strives to shift perspectives from focusing only on products to a more systemic approach opening the way for radical innovation. The products are owned by the producer throughout the complete life-cycle and this will change his vision and encourage interaction with final users and the rest of society. The product is considered as the carrier while services, as experienced by the end-user, appear to be dematerialized. Access to such services using ITC is also very promising and can permit customised services which are thought to be generally more sustainable. The PSS structure, through better maintenance and adequate upgrading ensured by professionals over the full life-cycle of the product, brings the promise of services with longer life and better quality. This would contribute to more sustainable services providing that care is taken to limit abuse, for instance due to too easy access to the services.

2.5 Requirements for the Infrastructure

A well planned M2M infrastructure could become a particular advantage for cities. On one hand we see opportunities for new services through a new mutualised communication infrastructure and on the other there is a growing and urgent need for sustainable development in sustainable cities. It is clear that in order to develop the network on a city scale a certain number of points must be taken into account of during the project.

Environmental

The project must develop sustainable services in a sustainable city that are green, profitable and fair; minimise the environmental impact during the full life-cycle of the services; take into account that the large number of small electronic devices could eventually display large impacts; reduce energy consumption; economise land-use and provide necessary green areas while still allowing the conservation and development of continuous agricultural and natural land outside the city; reduce pollution and noise; promote closed local flows to reduce waste; and avoid ICT rebound effects.

Network

Without going further into detail, the major technical questions are concerned with adopting a universal language of communication between the multitudes of heterogeneous machines; developing international norms and standard communication protocols; the infrastructure must be open with non-propriety systems; sensors and communication modules must be developed together with adequate energy sources.

Services

The domain has to be well identified and service infusion should inspire from PSS. Services should look towards multiservice instead of vertical applications; interactions and solidarity amongst users; customised services; web services; enhancement through sensor network data. They should display good ergonomics; propose good significations of use; be acceptable; have market value and be economically viable.

3 SENSCITY

3.1 Objectives

The project's goal is to contribute to sustainable development, particularly through environmental considerations, together with the development of an urban M2M infrastructure, comprising the sensor networks and the services associated. These are the motors that had initiated the project SensCity [1]. Is it possible to conceive an embryonic city-wide network with potentially tens or even hundreds of thousands of interconnected sensors and other machines without degrading the environment? Can the nature of the services provided both contribute to relieve the strain of dense city-life and reduce the burden on the environment? These are the important questions that must be addressed.

3.2 Organisation of a "SensCity City"

The "SensCity City" can be viewed at different levels depending on the part of the infrastructure considered (Figure 7).

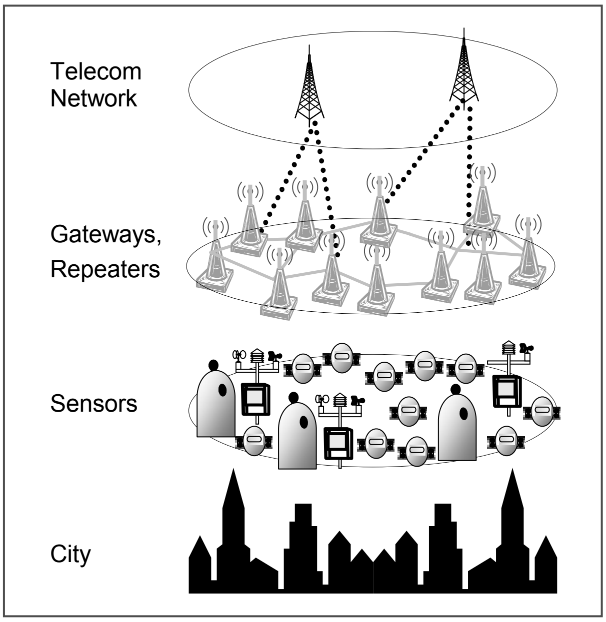

Figure 7: Networks in the City.

The first physical level will be the town structure with its people, buildings and other facilities. The town leads its own life. Next there is a vast network of sensors and actuators in the city. New material can be installed or obsolete ones taken away. The activity of these sensors and actuators can be very high, and once again, have their own life. Above, a set of repeaters covers the town and is ready to relay data and interrogate the different sensors. Yet above, are the gateways that convey data to and fro the lower levels. The gateways are linked via GSM to traditional telecommunication networks. Data will then go on to an M2M platform.

3.3 Proposed System Architecture

The simplified overall architecture of the system is illustrated in Figure 8. The data is collected on the left hand side of the schema. The sensors (or actuators) are distributed in the city according to initial service-requirements. They are associated with their communication modules that are able to connect via the repeaters to the gateways. The data that they gather enters the telecommunication networks through the mobile GSM network and on to the internet. The M2M platform, connected to internet, controls data-collection and sensor-management. For instance, instructions can be relayed to

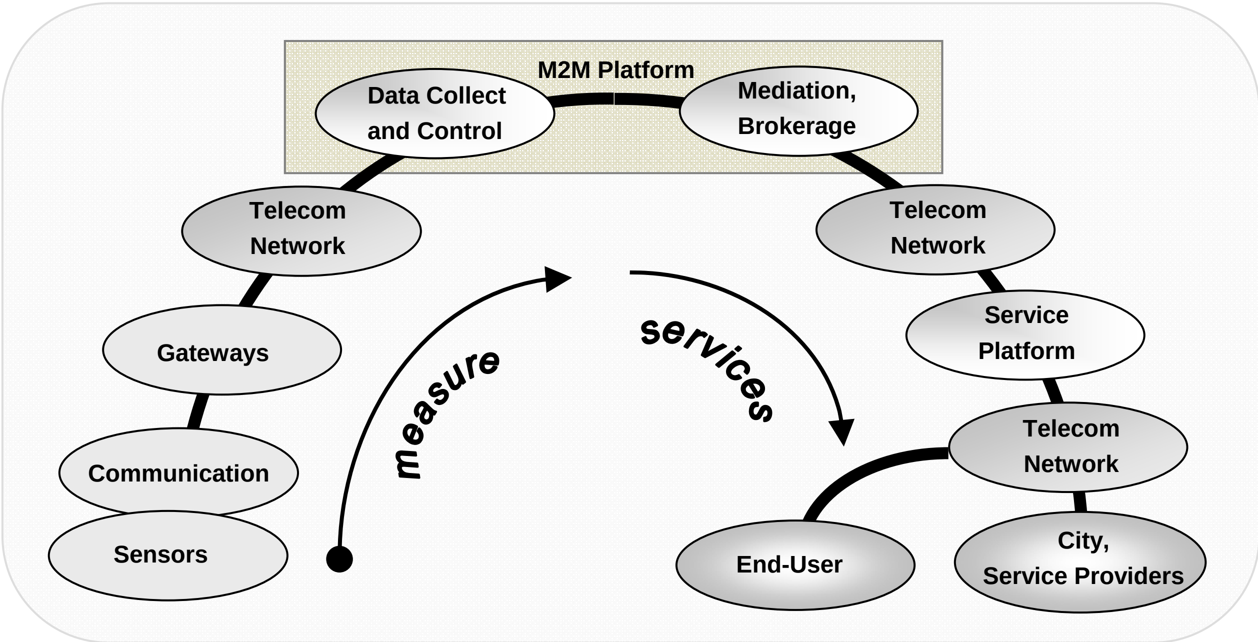

Figure 8: Simplified Architecture for SensCity.

the sensors or actuators in order to modify measurement frequency and times. In the other direction, any new installation of end-equipment can be discovered and integrated into the network.

Services are then be deployed on the right hand. The M2M platform organises data-management and safeguard. It also takes care of legal questions like rights of access to information, ensuring security and privacy. Service provider platforms are connected to the M2M platform through internet and will thus be able to pilot different offers of services, including web services and other types of services. In this way the information is made available for city public administrations or residents.

3.4 Scientific questions addressed in the project

SensCity addresses the global M2M infrastructure. On the technical side the project must develop:

- the sensors and gateways;
- the capillary network and communication protocols, in accordance with application requirements;
- the M2M platform with the functions of mediation and brokerage along with planning and administrative tools;
- the M2M applications together with the framework for new services and standard user interfaces;
- normalisation and standardisation.

As for environmental considerations, the project will pay a particular attention to ecodesign and the appreciation of impacts:

- Life-Cycle Analysis (LCA) methodology adapted to this kind of services will be developed;
- the choice of indicators adapted to the city context is fundamental.

A close cooperation with the SMEs involved with the infrastructure or with services is necessary and the project aims to help them move towards a greater consciousness in ecodesign.

3.5 Project Organisation

The industrial partners of SensCity include SMEs participating at different levels.

Some SMEs install sensors or actuators; others are more concerned with services that make use of the data coming from the different sensors. Yet others are involved in middleware or network management. Of course one SME can also intervene at different levels.

The main interlocutor for the city would be the telecom operator. It is the leader who must globally organise the implementation of the system and insure service continuity, security and quality.

SensCity is an open structure that has high perspectives for evolution. In the future, when the infrastructure is fully running, new actors could integrate the structure at all times so long as they comply with the norms of SensCity. For instance, a new service could be proposed combining data from different kinds of sensors run by different SMEs or new sensors could be introduced.

Planning and Resources

The total budget allocated by the project is 6M€ with a total of 51 man-years. Le project will last from September 2009 to August 2011, although PHDs involved in the project will carry on for an extra year.

2009 will be used to validate the different technologies and define functional specifications of interfaces, equipments and services. 2010 will see implementation of the different equipments and the development of the urban service applications. Finally in 2011 the services will be experimented globally.

Project Partners

The industrial partners of SensCity include Alcion; Azimut; BH Technologies; MIND; Coronis; Dot Vision; E-Gee; HP; Numtech; Orange Labs (project leader) and Webdyn. The academic partners are from the University of Grenoble.

3.6 Illustrations

Various vertical applications of urban M2M services have already been experimented and some are currently working in cities (figures 9-10). The project will pay a particular attention to them in the early stages and will use them as case studies to validate methodological and technological developments.

Glass Recycling Banks

Used glass is collected in glass banks. As the disposal containers fill up they are emptied into a collect truck. The truck has to go round systematically to every bottle bank even if there is not enough glass to be emptied. It is obvious that if the driver knew before hand the filling level for each container it would save a lot of kilometres and reduce traffic and noise.

Figure 9: Glass Collection.

An ultrasound sensor placed in the column at the top can measure the remaining space in the container and send the information to the collector via an M2M network providing a precious service to the city [14].

This service could also contribute to more efficient collects, especially seeing that overflowing containers are difficult to clean and usually mean more complaints to the city council.

Public Lighting

Streetlights and other public lighting are very critical for a city. Their electrical consumption is very high and there are many potential environmental gains for smart-lighting M2M services.

Services using sensors in an M2M network could monitor the state of individual lamps allowing automatic detection of aging or lamp failure. At the same time they could control power and save energy though dimming at certain hours, when street frequentation goes down.

Figure 10: Gateway Installation.

Today, lamps must be systematically changed at the end of their guarantee period because of maintenance. Sensors that can anticipate lamp failure through the detection of unusual functioning could introduce radical change in the way street-lighting is managed and eventually lead to important extensions of the effective lifespan of lamps.

Pollution, noise and weather conditions

The knowledge of pollution, noise and weather conditions with sensors placed in critical points in the city has evident advantages for a sustainable city. Data on pollution is important for security reasons and could de used in real-time traffic control. Information on weather conditions would help understand temperature and wind variation across the city and would be very complementary to pollution level measures. Doctors could combine data on pollution and weather so to advise patients with asthma for instance to avoid certain places.

Here we are obviously dealing with new kinds of inexistent services. Introduction of new service will directly increase environmental impacts in the city. Care must be taken to insure that the services rendered compensate effectively this factor.

Electric car recharge stations

A more futurist application concerns fleet management in the city and in particular problems of energy sources and parking spaces. Potentially, electric cars will become a low-pollution means of transport in cities. There will be a growing need for environmentally friendly installations to recharge car-batteries in the city. The management of a fleet of electric vehicles and a park of recharge stations would be facilitated by M2M services. The recharge stations could use local sources of renewable energy, like solar or wind energy. In this case the M2M network would monitor the park and update information of the state of each station. By combining information from the different vehicles and the recharge stations, they could optimise resources by directing vehicles towards certain stations and help determining, for instance, which vehicles need to be recharged in priority and for how long. Sometimes the vehicles could exchange their batteries for recharged ones.

The same kind of service platform could also serve car-sharing schemes and monitor parking spaces.

4 DISCUSSIONS

4.1 What Sustainability?

The type of services provided by SensCity and the modalities of implementation and exploitation are important issues.

There are different ways to view sustainability in city services. They should, as mentioned above, respect the constraints for a really sustainable city, contribute to the rights of future generations to access le same quality of life and to those of developing countries that aspire better living standards. This could only be true if the services:

- contribute, by their functions, to sustainable cities,
- obey themselves sustainability criteria.

The services proposed by SensCity would sometimes replace existing services or improve them. They could be innovative, resulting from evolutions in society or technological advances. They could also come out of particular features or certain combinations that appear within the network itself.

4.2 Services for a Sustainable City

The services retained should favour the evolution of existing cities towards sustainable ones. As explained above, sustainable urban development in developed countries must not be based solely on means-ends rationality but should examine the environmental consequences of different solutions and be directed towards long-term goals.

Environmental and social considerations

As a first approach we could aim for public services that tend to reduce the inconveniencies and improve the attractiveness of high-density cities that appear more favourable to sustainability:

- Reduce energy consumption to a level compatible with global criteria
- Reduce the use of environmentally harmful materials
- Valorise public transport and diminish pollution, noise and traffic

- Minimise land-use leaving space for continuous natural areas, eco-systems and agricultural areas
- Encourage solidarity, autonomy, independence, integration and exchanges between residents
- Replace open-end flows producing waste with closed-loops using local resources.

Vertical Applications vs. Multiservice

The choice of multiservice as opposed to vertical applications appears to be a positive factor for sustainability. However care must be taken that the infrastructure does not become an excuse for introducing services for pretexts not really complying with criteria of sustainability.

4.3 Sustainable Services for an M2M infrastructure

LCA for Sustainable Services

Any activity has an effect on the environment. SensCity services themselves must be eco-designed, irrespective of the benefits they can bring to the city's context. It is important to compare environmental impacts of different possible architectures, materials, usage and end-of-life scenarios, etc. Impacts are usually measured by indicators using LCA. Indeed it is important to study the services taking account of their full life cycle, that is to say, all the phases from the production of raw materials to transport, fabrication, use and end of life.

In the case of products, methods for LCA are quite well mastered today. For services, methodology is not that straightforward and requires special attention. In our case the mutualised M2M infrastructure and telecom networks must be accounted for. The services, that do not yet exist, must be compared with solutions that are not necessarily exactly equivalent.

Impact transfers must be avoided. For instance, gains in the greenhouse effect could mean adopting solutions presenting undesired water problems. It is important to use multi-criteria to appreciate the effects of running the services. As mentioned before, the system chosen in this project is based on high-tech electronic devices. Some of the services provided would reduce transport needs. In these cases, compared to the transport systems, electronics show relatively poor performances concerning raw material depletion, water pollution and waste generation. On the other hand advantages would be expected in terms of the greenhouse effect, ozone and air quality. All these factors must be considered globally.

4.4 PSS for M2M

SensCity is a good terrain for PSS. The multitude of SMEs concerned; infrastructure mutualisation; mixed technologies; multi-service potentials and necessary interactions with urban actors are just some of the factors that oblige a certain dynamic during the project and would certainly transform the visions of the different partners. The existence of a strong telecom operator as leader can also be a positive factor for conversion towards PSS.

It is easy to understand the rapprochement between SensCity's M2M services and PSS. In the two cases there is a concern for environmental issues.

By their nature, M2M services can be dissociated from the physical infrastructure that makes them possible. In fact that is one of the reasons for mutualisation. A sensor initially set up for a certain application and run by a certain company, can later find use within another service. There is not necessarily a connection between the service provider and the sensor network provider. The provider can even combine data from sensors run by different companies.

Service infusion is high in the two cases. More than not, access to M2M services will be done through some kind of web service. This opens the way for personalised services via the internet, which is another strong point for PSS.

4.5 Economic viability

Of course it is important that the M2M infrastructure be economically viable and interesting. That is why great importance must be given to the research and development of worthwhile sustainable services. Perhaps the real challenge for the project lies here.

5 SUMMARY

The paper traces how the idea of an urban infrastructure for M2M services took form and inspired the project SensCity. The different environmental and other challenges to be faced have been discussed. Illustrations of services provide a good overview of the context and challenges. The issue of PSS has also been treated and the basis has been laid for new services.

6 ACKNOWLEDGMENTS

The authors would like to thank all the project partners as well as the project leader, Giyyarpuram Madhusudan, who have directly or indirectly contributed to this article. In Orange Labs, Roland Airiau and Gabriel Chegaray and their associates have over these past years inspired the reflexions on the evolutions described above that finally led to the existence of SensCity.

A special thanks to all those who had contributed to the glass collect experimentation mentioned in the article. This was one of the important stages inciting the telecom operator to invest in such a city-wide project. René Ebel and Michel Remy had technically conceived and set up the experimentation. The experimentation was made possible with the precious help of the Communauté d'Agglomération du Pays Voironnais, in particular Jean-Marc Bouzon and Romain Chatel, and the participation of le local operational units of Orange.

7 REFERENCES

[1] SensCity, http://senscity.minalogic.net

[2] Our Common Future, Report of the World Commission on Environment and Development, World Commission on Environment and Development, 1987

[3] Næss P., 2001, Urban Planning and Sustainable Development, European Planning Studies, Vol. 9, No. 4: 503-524

[4] Campbell S., 1996, Green cities, growing cities, just cities? Urban planning and the contradictions of sustainable development, Journal of American Planning Association, 62: 296-312

[5] The World in 2009: ICT facts and figures, 2009, ITU World Telecommunication Indicators Database: 1

[6] SMART 2020: Enabling the low carbon economy in the information age, Report by The Climate Group on behalf of the Global eSustainability Initiative (GeSI), 2008

[7] Norman D., 1988, The Design of Everyday Things, The MIT Press

[8] Lelah A., Cayuela C, Geraud N., Gallice P., Airiau R., 2003, An Innovative Pen-Mouse Concept, SOC'2003 Proceedings

[9] Mallein P., Tarozzi S., 2002, Des signaux d'usage pertinents pour la conception des objets

communicants, Revue de l'électricité et de l'électronique, n°8 :82-86

[10] IBM, 2004, Item-level RFID technology redefines retail operations with real-time, collaborative capabilities

[11] Orange, FING, Syntec Informatique, 2006, White paper Machine To Machine, stakes and prospects

[12] Goedkoop, M., van Halen, C., te Riele, H., and Rommens, P., 1999, Product Service Systems, Ecological and Economic Basics, Pre Consultants

[13] Mont O., 2000, Product-Service Systems, Final Report, AFN, Naturvårdsverket (Swedish Environmental Protection Agency), AFR-REPORT 288, ISSN 1102-6944, Stockholm

[14] Graindorge J., 2007, Vers des tournées de collect programmées juste à temps, Dialogues No. 38 : p7

Session 2A:
Requirements

Guideline to elicit requirements on industrial product-service systems

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Abstract

Industrial solutions integrating products and services are common practice in many business-to-business applications and branches. An explicit integrated planning, development, delivery and use of products and services, which is important for so-called industrial product-service systems (IPS^2), is hardly implemented. Thus, a need and potential for enhancement of IPS^2 design is driving our research. In our contribution we will present a new guideline to elicit and analyze requirements on IPS^2 properties and quality. The guideline is based on a comprehensive review of product development, service engineering and IT literature. It contains a new checklist of clustered criteria to retrieve and describe IPS^2 requirements systematically and it supports different design views. The guideline is compatible with known approaches as for instance guidelines presented by Pahl et al., van Husen, Steinbach or CobiT/ITIL. Within the paper we discuss reviewed references and present the guideline and the entire checklist.

Keywords

IPS^2 design, IPS^2 requirements and quality, guideline, checklist

1 INTRODUCTION

Industrial solutions integrating products and services are common practice in many business-to-business applications and branches. An explicit integrated planning, development, delivery and use of products and services, which is important for so-called industrial product-service systems (IPS^2) [1], is hardly implemented. Thus, a need and potential for an enhancement of IPS^2 development is driving our research.

During our research we found out that for many domains generic guidelines for requirements generation exit, but that for IPS^2 development no such guideline was published until now. Many authors just mention customer needs and requirements without offering a methodical support to handle those on a more detailed level of abstraction, cp. elaboration in [2]. Thus, the aim was to set up a systematic support for the generation of requirements during the planning and early development phase of an IPS^2.

The following subsections introduce major aspects of IPS^2, requirements engineering and generation and our research methodology. In section 2 we provide an overview of the bandwidth and the content of a comprehensive literature review; in section 3 we compile a guideline for IPS^2 requirements generation; in section 4 we report on applications and findings before we close in section 5 with a summary and an outlook.

1.1 Characteristics of (industrial) Product-Service Systems

The value provided by the concept of (industrial) product-service systems is a broad, holistic view on technical systems by taking into account technical artefacts, services, business models, and drivers like sustainability and dematerialization. The premise is to provide added value to satisfy customer needs along the whole lifecycle of a product-service system. [3]

The basic idea is not to sell products and services separately but to sell a defined result, a system's availability or just functionality. Customer needs are not simply reduced to the single need for product ownership. According business models [4-6] define the value for the customer and couple customers and providers for longer time. Maintenance, adoption to changing needs and boundary conditions, reconfiguration or upgrading can be part of an IPS^2, e.g. in form of services included in the business model. The integration of products and services finally can maintain or enhance functionality of a product or a service or implement new functions, which are not available without integration. In the area of high-cost machinery IPS^2 are sold instead of standalone products or services to exploit earlier unused economical and technical potentials or to enhance the value for the customer [5, 7]. Responsibility and risk are shared among the contractors.

Brief definitional summary

[Necessary] Product-Service Systems (PSS) are customer, lifecycle, and foremost sustainability oriented systems, solutions, or offers, integrating products and services.

[Sufficient] Business models framed by contracts align incentives of the customer and the provider, aim at assuring functionality throughout system life-time and aim at implementing added value to satisfy customer needs.

[Remarks] Industrial Product-Service Systems (IPS^2) represent PSS business-to-business applications. Explicit PSS and IPS^2 are characterized by an integrated planning, development, delivery and use of products and services. Implicit PSS and IPS^2 are not explicitly planned, developed, delivered and used in "integrated" processes, but already existing in today's markets and (somehow) integrating products and services.

Figure 1 illustrates a simplified architecture of IPS^2 core elements. Next to core products and services, stakeholders and contracts are important. IPS^2 are type of long-term commitments regulated by a contract. The contract provides tight linkages between stakeholders and defines how risk, responsibilities, and costs, concerning the integrated delivery and operation of product and service shares, are distributed among them.

Simplified, the stakeholders are one provider, multiple suppliers, and one or more customer(s). They are typically organized in a locally distributed network with partly

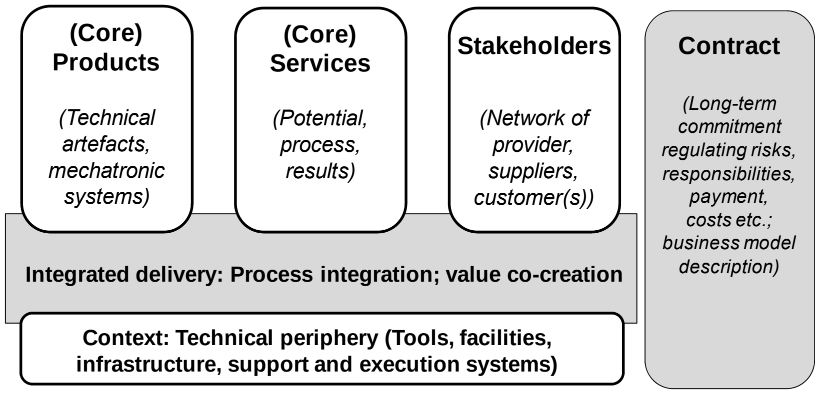

Figure 1: Simplified PSS / IPS^2 architecture.

integrated business processes. An important aim is a value co-creation among the stakeholders during the integrated delivery. Supplemental systems and tools have to be taken into account to enable the delivery of products and services and the exchange of information.

1.2 Requirements Engineering

Definition of a requirement

According to Kruse [8] „a requirement is a defined behaviour, characteristic or property, to be assumed for an object, a person or an activity which has to assure a certain result in a value creation process". (Original text in German: "Eine Anforderung ist ein definiertes Verhalten oder [eine] bestimmte Eigenschaft, anzunehmen von einem Objekt, einer Person oder Aktivität zur Sicherstellung einer Leistung in einem Wertschöpfungsprozess.") This definition has been chosen for our contribution, because it considers objects, actors / stakeholders, activities and values, which all are relevant in the IPS^2 context.

The process of requirements engineering

According to [9] the process of requirements engineering includes the following activities:

- Requirements elicitation (input: user needs, domain information, existing system information, regulations, standards, etc.)
- Requirements analysis and negotiation
- Requirements documentation
- Requirements validation (based on a requirements document which is further used to set up the system specification)

Requirements engineering is a process which is accompanying the planning and development of a system. Starting with an elicitation of customer needs, system level requirements have to be derived and broken down into function and component level requirements. Especially in IPS^2 planning and development a clear distinction of customer needs and requirements is vital in order to exploit the full solution space offered by product-service integration, cp. [2]. Reuse of requirements from former system developments is typical.

The elicitation or generation of requirements, which includes the retrieval, an awareness of relevant issues and the formulization in order to document and model requirements, is not addressed properly in IPS^2 planning and development research so far.

1.3 Research methodology

Perspective, focus and limitations of this paper

The study has been undertaken from an engineering design perspective. The background of the authors is mechanical engineering, engineering design methodology, industrial information technology and virtual product creation technologies. Impulses manly came from experiences in the branches automotive, software engineering, production technologies and renewable energy systems. The aim was to set up a simple guideline which supports the generation of requirements for an IPS^2 to be developed. The aim was not to work out a new theory of requirements engineering. All elaborations in this paper are in principal equally suitable for PSS and IPS^2. A conceptual publication preparing some of the results mentioned here has already been made in late 2008 [10].

Research approach

The investigation was executed in the following steps:

1. Clarification of need for systematic IPS^2 requirements generation.
2. Analysis of the state of the art in research and industry.
3. Compilation of results and solution approach.
4. Application and evaluation.
5. IT tool support implementation.

In step 1 and 2 we made a comparison of implicit IPS^2 from automotive industry, material flow solution providers and PLM vendors [11]. Some findings came from industrial workshops in the area of micro-financed electrification solutions for emerging countries (a brief report will be released in late spring 2010). Others came from interviews in German industry. A comprehensive literature study formed the basis for our new approach. The compilation will be described in the following sections. The development of a micro-manufacturing IPS^2 (show case scenario) with partners in the research project Transregio 29 "Engineering of Industrial Product-Service Systems" is used as an application case. An explorative examination of IT tools for requirements engineering helped to plan how to implement an IT tool support based on existing software tools.

Research questions (RQ)

The following research questions were set and, as far as possible, addressed in our study:

RQ1: Which domains should be considered for IPS^2 requirements generation? (Bandwidth)

RQ2: Which guidelines do exist in such domains?

RQ3: Which characteristics do the existing guidelines have in terms of content and outward appearance?

RQ4: Do we need a new guideline for IPS^2 and PSS requirements generation?

RQ5: Which type of support should be given by a new guideline for IPS^2 requirements generation?

RQ6: How can the existing guidelines be adopted or incorporated in a new guideline? (Compatibility)

2 LITERATURE REVIEW

2.1 Bandwidth of the study and new guideline (addressing RQ1)

As (industrial) product-service systems integrate products and services, the consideration of product development and service engineering is clear. As many functions of modern products and services base on information and communication technologies, IT approaches are obviously important. The rising amount of embedded systems requires an analysis of systems and requirements engineering approaches as well. As software, systems and requirements engineering are methodical and technical close domains we summarized those in one group. Table 1 summarizes references from such domains, which have been analyzed.

2.2 Methods to generate requirements, a small sample (addressing RQ2)

A small sample of guidelines is shown in this subsection to give the reader an idea of where our work is positioned. Not all guidelines and approaches are discussed in detail.

Table 1: Domains investigated in study.

Domain	Comment on focus	References investigated
Product Development	"Classic" references, foremost mechanical engineering	[12-21]
Service Engineering	Foremost European and Japanese references	[22-31]
Software, Systems, and Requirements Engineering	Generic references of organs and communities working on IT development, methodology and standards	[32-38]
PSS and IPS^2 Engineering	References, where requirements or quality criteria are addressed	[7, 39-41]

Product Development

Pahl and Beitz [18] propose a well-known guideline to retrieve requirements in mechanical engineering. This guideline refers to customers, designers, lifecycle phases, cost and time as sources for requirements and quality criteria. It considers many areas, which are addressed by design for X guidelines (e.g. Design-for-Assembly). The mentioned areas are broad and the designer has to search for required system properties on his own. The model of Ehrlenspiel [16] is hierarchical and has two main branches, (i) technical-economical requirements and (ii) organizational requirements. To search for requirements, these are detailed in a tree structure. Below the leaves of the tree (which are pure technical requirements, technical periphery, law, human, society, cost, time, staff, and tools) are "question terms" listed to retrieve requirements from various system lifecycle phases. These question terms are very heterogeneous, considering the abstraction level (examples of questioned issues: manufacturability, transport problems, maintenance duration, or training). Ahrens [12] compares various approaches to retrieve and manage requirements, but she does not compile a new checklist to retrieve requirements in product development.

Service Engineering

Jaschinski [24] elaborates on the process of a quality-oriented redesign of services but he gives no guideline or checklist, which helps to retrieve requirements on service properties in detail. In his thesis, van Husen [23] comes up with checklists to discover stakeholders and influencing factors (strategic, economic, legislative, and social factors, and boundary conditions) to analyse requirements for product-related services. Watanabe et al. [31] elaborate on the process of requirements negotiation embedded in a Japanese Service Engineering Methodology. Here a link is made between requirements and Receiver State Parameters, which represent the desired state of a customer after having received a service.

Software, Systems, and Requirements Engineering

Many sources contain general remarks on the importance of requirements engineering in IT development, cp. for instance [34], issues like IT security, interoperability etc. In some cases generic models like the CObIT cube, cp. Figure 2, define areas where requirements or quality issues come from. Detailed listings have not been found in public domain literature during our studies.

PSS and IPS^2 Engineering

Steinbach [41] delivers a comprehensive list of service characteristics and properties collated from business approaches and sources (examples of service properties mentioned: friendliness, responsiveness, patience, duration of delivery, reliability etc.). Berkovic et al. [39] considered product, service, and software engineering in their study and focused on the process and tools of the requirements engineering, but there was no elaboration on check criteria on requirements and quality.

2.3 Characteristics of existing methods and tools (addressing RQ3 and RQ4)

So far, there is no generic method, guideline or checklist, which addresses the system *IPS^2*, as described in section 1.1, as a whole in order to generate requirements.

Generalized, we found a weak consideration of

- use processes (lifecycle activities, system use-cases), contracts, and customer value in the area of product development literature.
- information and communication technologies as enabler for modern delivery processes in product development and service engineering literature.
- product and hardware specifications in service and software engineering.

This is not surprising as most models are domain specific.

Outer appearance

All models have different outer forms which hampers a straightforward integration of such guidelines for use in IPS^2 development.

Communality

The existing guidelines investigated in our study are foremost listings or simple models, which ether (i) systematize factors and sources influencing requirements and quality issues (cp. Figure 2) or (ii) capture system areas for which requirements have to be considered (cp. Figure 2). In most cases, the influencing factors are grouped or clustered (cp. Figure 2). These methods in general are not system (product, service, application), process or software tool specific. They have the characteristic of "awareness tools", they are not real checklists.

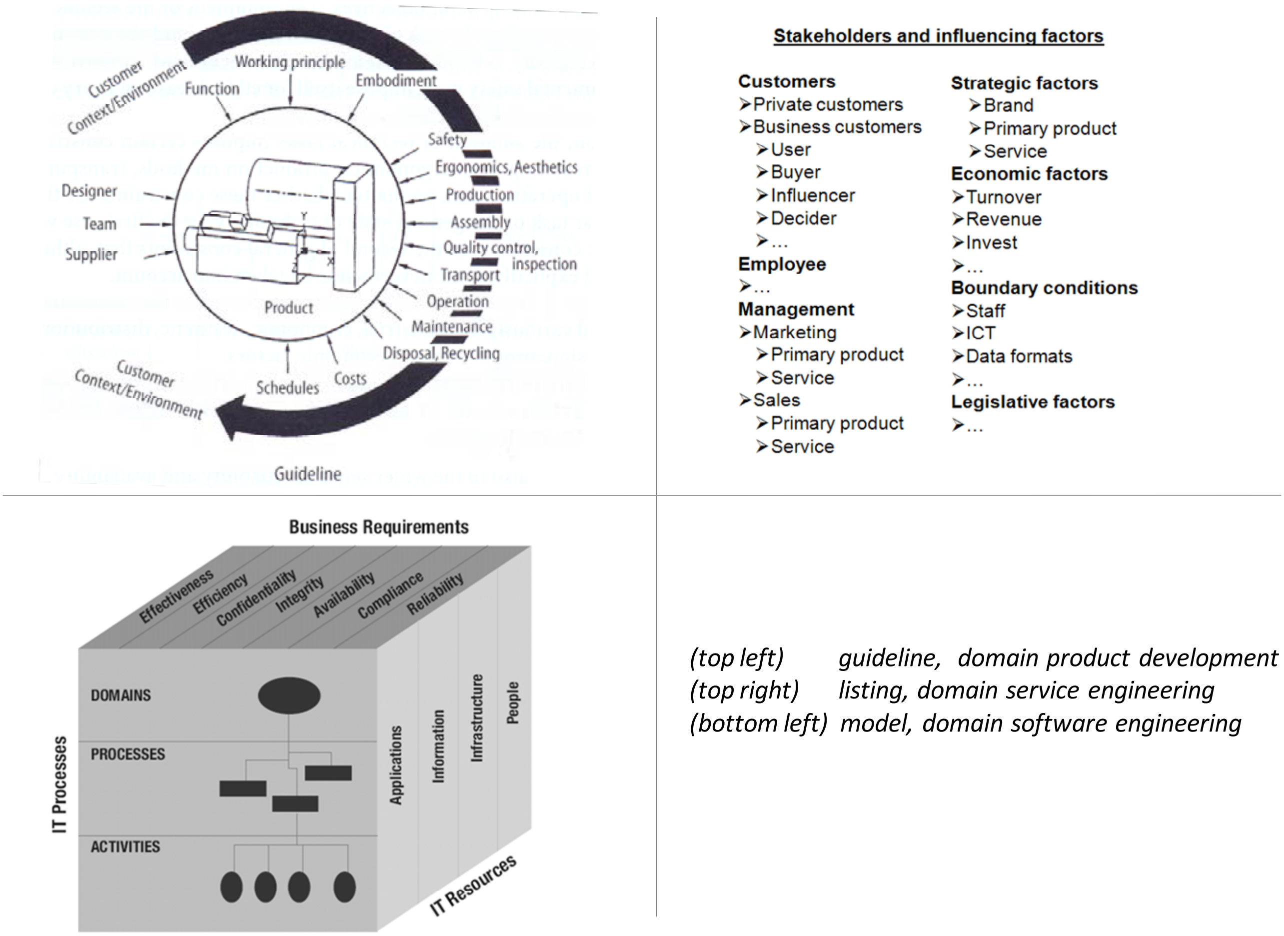

Figure 2: Guidelines and listings from product, service and software engineering after [18, 23, w5].

Software support

Software tools like Doors [w1], TeamCenter Engineering Requirements Management [w2], or in-Step [w3] support text based requirements management and link requirements to system elements or, for instance, UML diagrams for the systems specification. In general this is not depending on the system which has to be developed. The Japanese Service Explorer Tool [w4] implicitly captures requirements by aforementioned Receiver State Parameters. Thus, such tools do not depend on domain or application specific guidelines. The implementation of new domain specific guidelines or checklists in such software tools seems possible.

3 GUIDELINE – REQUIREMENT CHECKLIST FOR (INDUSTRIAL) PRODUCT-SERVICE SYSTEMS

3.1 Approach (addressing RQ5 and RQ6)

As none of the methods investigated offered the bandwidth needed for IPS^2 development and because none is directly adaptable for IPS^2 development we started to set up a new "checklist". The checklist is predominantly based on clustered text listings which borrow many elements from the approaches investigated. An earlier conceptual version has been introduced in autumn 2008, but without such a deep dive into its background [10].

3.2 Characteristics of the checklist

The entire list has more than 100 entries, i.e. criteria to retrieve requirements. It is not the idea to "tick" every criterion for every potential system function or element when defining the requirements of an IPS^2. The aim is to make the designer aware of relevant influencing factors.

- Clusters help to keep the checklist in mind.
- The checklist is generic and open for customization to a specific branch, user group or type of IPS^2.

3.3 Clusters of the checklist

The checklist provides object and process oriented clusters (most in suitable pairs). The clusters *System* and *Behaviour* support a typical systems view on a very high level of abstraction. The clusters *Technical artefact* and *Service* address the core elements of an IPS^2. The clusters *Information* and *Communication* take into account that delivery processes contain a lot of information which is communicated by IT systems and actors. *Actors* and *Lifecycle activities* are core areas of interest in IPS^2 research and thus the next pair. Actors are performing activities in product use, service consumption and delivery. In lifecycle activities deliverables (products, information etc.) are generated to implement value for the customer. Creation of added *Value* is one of the major drivers for IPS^2 and considered in another cluster. *Business and operation models* and *Contracts* are rarely mentioned in most other methods, but they frame an IPS^2 and thus they should be considered equally.

Criteria collected from products, software, service and IPS^2 engineering have been allocated to the clusters. For some we used the original terms and for some we used synonyms, which were more suitable for IPS^2 development. Additional contributions we have made in all clusters based on experiences and theory.

Figure 3 illustrates the structure of the checklist. Table 2 and Table 3 summarize all collected and added criteria in

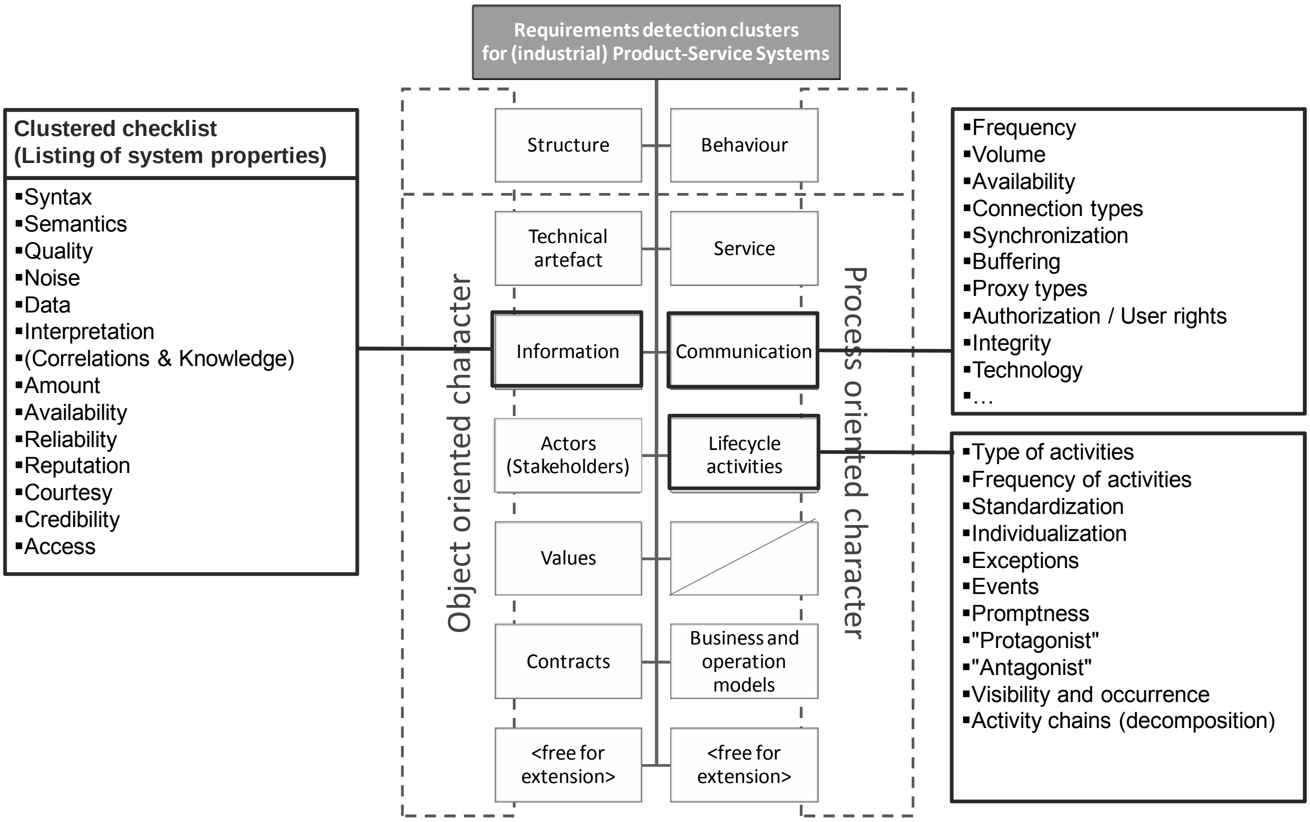

Figure 3: Clustered checklist for requirements generation.

compressed form. However, such a generic list cannot be complete. Some criteria can be allocated to more than one cluster if necessary for the user.

Example

A provider plans to offer a spindle for a milling process in a manufacturing system. The business model is availability-oriented. Now the checklist can be used to retrieve and formalize requirements. The following bullet list shows some requirements on a component level. The items in square brackets might be checklist criteria, which helped to find the particular requirement:

- Requirement 1: The activity maintenance of the deliverable spindle has to be carried out twice a year [LIFECYCLE ACTIVITIES → FREQUENCY] or the spindle functionality has to be monitored permanently to ensure an availability of 98%.
- Requirement 2: The activity maintenance has to fit the

Table 3: Checklist of criteria to generate requirements on (industrial) product-service systems (continuation).

Lifecycle activities	Values	Contracts	Business and operation models
• Type of activity • Frequency of activity • Standardization • Individualization • Exceptions • Events • Promptness • Visibility and occurrence • Activity chains (decomposition) • Min., max., mean duration • Earliest start, latest end • Facultative, optional or supplemental execution • Schedules • Process durations • Process type (management, core or support process) • Process trigger • Push or pull execution • Milestones	• Economic benefits (saved money, raised revenues) • Ecologic benefits (less resource consumption, less waste, ease of recycling and reuse) • Social benefits (access to education etc.) • Technologic values (technological advantage, technology substitution, higher efficiency) • Healthiness • Information and knowledge advantage • Time (saved time) • Training of skills • Flexibility, etc. • Functionality	• Incentives • Partners • Allocation of responsibilities • Duration • Conditions (if, else) • Options • Dependencies • Exceptions • Parameters coupled to market values or operation efficiency • Cost • Payment regulations • Fines • Allowances • Restrictions • Continuation conditions • Context • Risk allocation • Events • Exceptions • Policies	• Operation model (build-transfer-operate; build-operate-transfer, build-rent-transfer, build-operate-own) • Business Model (function oriented, availability oriented, result oriented) • Contract types (reimbursable, cost plus fee, fixed price engineering, engineering procurement construction, turn-key solution)

Table 2: Checklist of criteria to generate requirements on (industrial) product-service systems.

Structure	**Behaviour**	**Technical artefact (core products, periphery, infrastructure)**	**Service**
• Architecture and modularization • Elements and relations • Supplemental infrastructure (e. g. support and execution systems) • Supplemental services • System border set correctly set? • Stakeholders identified? • Input, throughput, output clear? • Lifecycle elicitated? • As-is processes and systems of customers know? • Needs and preferences of customers sufficiently know or anticipated? • Robustness	• Actions, reactions • Velocity of reactions • Delay of reaction • Stimuli • Accuracy • Repeatability • Flexibility, agility • Safety • Main functions • Overall behaviour (background working like operating system, watch-dog like permanent service, chronological execution, execution when requested like IT application)	• Main function (aim) • Related products/artefacts • Interfaces • Related activities • Related service offers • Availability • Robustness • Flexibility • Safety • Input, throughput, output • Required quantity • Design for X requirements • Ownership and "Usership" • Qualification level of user • Cost • Location of product operation	• Required resources • Related activities • Estimated results • Required information • Facultative services • Additional services • Supplemental services • Location of service application
Information	**Communication**	**Actors (Stakeholders, Personas, Players)**	
• Syntax • Semantics • Quality • Noise • Data • Interpretation • (Correlations & Knowledge) • Amount • Availability • Reliability • Reputation • Courtesy • Credibility • Access • Consistency • Traceability	• Frequency • Volume • Availability • Connection types • Synchronization (asynchronous, synchronous); Buffering, Proxy types • Authorization / User rights • Integrity • Technology • Interfaces • Infrastructure (support and execution systems) • Responsiveness • Security • Patience	• Receiver(s) • Supplier(s) • Provider • Individual needs ("personas") • Cultural needs • Individuals and roles • Units within networks • Virtual agents / software agents (e. g. broker) • Target groups • Qualification • Quantity • Authorization • Knowledge • Responsibilities • Empathy • Organisation	• Network type (e.g. "Virtual Enter.") • Fluctuation in network • Start of collaboration (e.g. ad-hoc) • End of collaboration (e.g. ad-hoc) • Duration of collaboration • Internal/external services or products to be delivered • In-sourcing / Outsourcing • Decision making in the network • Risks • Competencies • Authorization • Core processes • Partner, competitor, supporter, ...

customer's operation plan [LIFECYCLE ACTIVITIES → ACTIVITY CHAINS] in order to avoid interruptions in his manufacturing process.

- Requirement 3: In case of permanent monitoring by the provider the customer has to allow the provider access to his IT infrastructure by the contract [CONTRACTS].

The search criteria of the checklist can be used to tag requirements for computer based processing or to link or search requirements in a requirements list.

4 APPLICATION AND FINDINGS

The checklist has been applied during two industrial workshops, in a student project, and in the research project Transregio 29 [w6]. We learned that it is applicable by a moderator in an IPS^2 planning process, but that such a holistic approach contains too much information for users, which are not familiar with this list. The checklist helps to discover requirements quickly, precisely, and well structured within the planning and concept design for PSS. Furthermore, the checklist is relatively easy to implement in software tools due to its tree structure.

5 SUMMARY AND OUTLOOK

A comprehensive literature review has been undertaken and many criteria to generate requirements in product, service and software engineering have been identified. To make those applicable in IPS^2 development we composed a new checklist which includes information of the investigated approaches and many self added criteria. The checklist will be implemented in a project and requirements management software soon. It will be applied with a second method called *PSS Layer Method* [3, 10] for a model driven requirements generation.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] H. Meier, E. Uhlmann, D. Kortmann, 2005, Hybride Leistungsbündel, Nutzenorientiertes Produkt-verständnis durch interferierende Sach- und Dienst-leistungen, wt Werkstattstechnik online, 95: H. 7/8.

[2] Ericson, Å., Müller, P., Larsson, T., Stark, R., 2009, Product-service systems – From customer needs to requirements in early development phases, in: Roy, R., Shehab, E. (eds.), Proceedings of the 1st CIRP IPS2 Conference, Cranfield University, Cranfield, p. 62 – 67, ISBN: 978-0-9557436-5-8.

[3] Müller, P., Kebir, N., Stark, R., Blessing, L., 2009, PSS Layer Method – Application to microenergy systems, in: Sakao, T., Lindahl, M. (eds.), Introduction to Product/Service-System Design, Elsevier.

[4] A. Tukker, 2004, Eight Types of Product-Service System: Eight Ways to Sustainability? Experiences from Suspronet, Business Strategy and the Environment, 13: 246 – 260.

[5] Meier, H., Uhlmann, E., Kortmann, D., 2005, Hybride Leistungsbündel – Nutzenorientiertes Produktverständnis durch interferierende Sach- und Dienstleistungen, wt Werstattstechnik online, Jahrgang 95, H. 7/8.

[6] Meier, H. (ed.), 2004, Dienstleistungsorientierte Geschäftsmodelle im Maschinen- und Anlagenbau, Springer-Verlag, Berlin, Heidelberg.

[7] Uhlmann, E., Stelzer, C., Geisert, C. Bochnig, H. Meier, H., Sadek, K., 2008, Design of PSS based on Customer Requirements, in: Proceedings of the International Seminar on PSS, TR29, Bochum.

[8] Kruse, P. J., 1995, Anforderungen in der Systementwicklung, VDI Fortschrittberichte Reihe 20, Nr. 191, 1996, VDI Verlag GmbH, Düsseldorf.

[9] Kotonya, G. Sommerville, I., 1998, Requirements Engineering: Processes and Techniques, John Wiley & Sons.

[10] Müller, P., Stark, R., 2008, Detecting and structuring requirements for the development of product-service systems, in: Meerkamm (ed.), Konferenzband zum 19. Symposium „Design for X", Neukirchen, S. 1–10, ISBN: 978-3-9808539-6-5.

[11] Stark, R., Müller, P., 2009, Product-Service System Methodologies in Research and Industry, in: Proceedings of the International Seminar on IPS2, TR29, Berlin.

[12] Ahrens, G., 2000, Das Erfassen und Handhaben von Produktanforderungen - Methodische Voraussetzungen und Anwendungen in der Praxis, Maschinenbau und Produktionstechnik, TU Berlin, Berlin.

[13] Deubzer, F., Lindemann, U., 2009, Networked Product Modeling - Use and Interaction of Product Models and Methods during Analysis and Synthesis, International Conference on Engineering Design, ICED'09, Stanford University, Stanfort, CA, USA, 24-27 August .

[14] DIN e.V.,1997, DIN EN ISO 9241: Ergonomie der Mensch-Maschine-Interaktion, Beuth Verlag GmbH, Berlin.

[15] DIN e.V., 2007, DIN EN ISO 10993: Biologische Beurteilung von Medizinprodukten, Beuth Verlag GmbH, Berlin.

[16] Ehrlenspiel, K., 1995,Integrierte Produktentwicklung – Methoden für Prozessorganisation, Produkterstellung und Konstruktion, Carl Hanser Verlag, München, Wien.

[17] Hubka, V., 1984, Theorie Technischer Systeme – Grundlagen einer wissenschaftlichen Konstruktionslehre, Springer-Verlag, Berlin, Heidelberg, New York, Tokyo.

[18] Pahl, G., Beitz, W., Feldhusen, J., Grote, K. H., 2007, Engineering Design - A Systematic Approach, 3rd ed., Springer-Verlag, London.

[19] Verein Deutscher Ingenieure, 1982, VDI 2222 Blatt 2: Erstellung und Anwendung von Konstruktionskatalogen, VDI-Verlag GmbH, Düsseldorf.

[20] Verein Deutscher Ingenieure, 2004, VDI 2223: Methodisches Entwerfen technischer Produkte, Beuth-Verlag GmbH, Berlin.

[21] Fraunhofer, 2008, Projektmanagement im Anlagenbau, Arbeitsbericht 8. Industriearbeitskreis "Kooperation im Anlagenbau", Fraunhofer IRB Verlag.

[22] Benkenstein, M., Güthoff, J., 1996, Methoden zur Erfassung der Qualität komplexer Dienstleistungen. Marketing und Marktforschung, pp. 514 - 536.

[23] van Husen, C., 2007, Anforderungsanalyse für produktbegleitende Dienstleistungen, Jost-Jetter-Verlag.

[24] Jaschinski, C., 1998, Qualitätsorientiertes Redesign von Dienstleistungen, FIR, RWTH Aachen.

[25] Kaner, M., Karni, R., 2007, Design of service systems using a knowledge-based approach, Knowledge and Process Management, 14/4: 260-274.

[26] Parasuraman, A., Zeithaml, V., Berry, L., 1985, A conceptual Model of Service Quality and its Implications for future Research, Journal of Marketing, 49: 41-50.

[27] Ramaswamy, R., 1996, Design and Management of Service Processes, Addison Wesley Publishing Company Inc.

[28] Scharitzer, D., 1994, Dienstleistungsqualität - Kundenzufriedenheit (Broschüre), Service Fachverlag, Wien.

[29] Schwarz, W., 1997, Methodisches Konstruieren als Mittel zur Systematischen Gestaltung von Dienstleistungen, Druckhaus Berlin-Mitte GmbH, Berlin.

[30] Webster, F. E., Wind, Y.,1972, A General Model for Understanding Organizational Buying Behavior, Journal of Marketing, 36: 12-19.

[31] Watanabe, K., Kimita, K. Tateyama, T., Shimomura, Y., 2009, Requirement negotiation for feasible service development, ICED'09, Stanford.

[32] Bundesministerium für Sicherheit in der Informationstechnik: E-Government Handbuch (Loseblattsammlung). Bundesanzeiger Verlag, Köln. ISBN: 3-89817-180-9. online: https://www.bsi.bund.de/cln_134/ContentBSI/Themen/Egovernment/EgovernmentHandbuch/Onlineversion/onlineversion.html (14.09.09, 14:00).

[33] The Institute of Electrical and Electronics Engineers, Inc., 1998, IEEE Recommended Practice for

Software requierements Specifications, ISBN: 0-7381-0332-2.

[34] Kruchten, P., 2006, The rational unified process: an introduction, 3rd ed., Addison-Wesley.

[35] Rupp, Ch., 2004, Requierements-Engineering und -Management, 3rd. Ed., Carl-Hanser-Verlag, München Wien.

[36] Sommerville, I., Sawyer, P., 1997, Viewpoints: principles, problems and a practical approach to requieremts engineering, Annals of Software Engineering, 3: 101-130.

[37] VDI-Handbuch Energietechnik, 2007, VDI 4602: Energiemanagement, Beuth-Verlag GmbH, Berlin.

[38] Wolf, S., 2006, IT-Governance mit ITIL, CObIT und der Balanced Scorecard (Diplomarbeit), Hochschule Niederrhein.

[39] Berkovic, M., Esch, S., Leimeister, J. M., Krcmar, H., Requirements Engineering for Hybrid Products as Bundles of Hardware, Software and Service Elements – A Literature Review.

[40] Meier, H., Kortmann, D., Golembiewski, M., 2006, Hybride Leistungsbündel in kooperativen Anbieter-Netzwerken, Anforderungen hybrider Leistungsbündel an die unternehmensinterne und kooperative Organisation von Anbieter-Netzwerken, Industrie Management 22: 25-28, GITO-Verlag.

[41] Steinbach, M., Bley, H. (edt.), Weber, C. (edt.), 2005, Systematische Gestaltung von Product-Service Systems – Integrierte Entwicklung von Product-Service Systems auf Basis der Lehre von Merkmalen und Eigenschaften, Lehrstuhl für Konstruktionstechnik/CAD, Saarbrücken.

[42] Müller, P.; Sakao, T., 2010, Towards Consolidation on Product-Service Systems Design. CIPR IPS2 Conference, Linköping.

WEB LINKS

[w1] Rational DOORS, IBM: http://www-01.ibm.com/software/awdtools/doors/

[w2] Teamcenter Engineering, SIEMENS UGS: http://www.plm.automation.siemens.com/en_us/products/teamcenter/

[w3] in-Step, microTOOL: http://www.microtool.de/instep/

[w4] Service Explorer, Service Engineering Forum, Japan: http://www.service-eng.org/index-e.html

[w5] CObIT cube figure: http://iea.wikidot.com/local--files/cobit/COBIT_Cube.png

[w6] Transregio 29: www.tr29.de (Last request of all web links on March 12th, 2010.

Requirement Analysis for Strategic Improvement of a B2B Service

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Abstract

Manufacturing companies are starting to recognize that services offered through a product are important. From the viewpoint of offering products in combination with services, it is important for designers to focus on requirements. This paper proposes a method to analyze the identified requirements for a strategic service improvement. By evaluating the requirements qualitatively from both the service customer's and provider's perspectives, some significant suggestions to define specific requirements which should be focus of improvement are presented. The effectiveness of this method is demonstrated by a case study where a utility company is a client of a service.

Keywords

Service Improvement, Requirements, Service Engineering, Strategy, Service Design

1 INTRODUCTION

As society matures, services are becoming central to economic growth, especially in developed countries. Services, therefore, are becoming increasingly important in many industries. In manufacturing, offering services through a product is regarded as more important than offering only a product. As a result, "Product-Service Systems" [1-2] that provide values by combining a product and a service have been attracting much attention.

To increase the productivity of services, to analyze developed large-scale and complicated services, or to create new services, a systematic approach to design services is important. The authors, therefore, have carried out fundamental research on "Service Engineering (SE)," which aims at providing design methodology of services from an engineering viewpoint [3-4]. In SE, a service is defined as *an activity between a service receiver and a service provider to change the state of the receiver* [3-4]. This definition includes a broader sense than typical definitions in a traditional service management or marketing field, which are used to clarify the difference between services and products (e.g., [5]). In this definition, most business activities are services, including manufacturing, selling, or maintaining physical products. The term service used in this study, therefore, corresponds to PSS.

1.1 "Requirement" in the SE context

One of the most important processes in service/PSS design or improvement is identifying "requirements" in a service, since service/PSS should be developed to fulfill specific "customer needs" [2].

The term "(customer) needs" is often used to represent something that is necessary for life or the reasons for the actions [6]. "Requirements" is represented to define specified characteristics or specifications, which are more formalized into a precise description of the product [7]. When a product/service is designed to meet customer needs, the needs are translated into requirements, and the requirements are regarded as design targets [8].

According to our definition, a service is offered to realize the receiver's state change, and when the state changes to a new desirable one, the receiver is satisfied. Therefore, states that a receiver desires to change should be a design target, that is, "requirements" in a service design. In the SE context, the target receiver's state is represented as a set of parameters called Receiver State Parameters (RSPs) [3]; namely, in this study, requirements are represented as RSPs.

1.2 Continual service improvement

Generally, the value of a service is determined by service receivers [9-10], whose needs are influenced by environment (i.e., trends or situation) with which they are facing [11]. The requirements in the service, therefore, might be changed depending on the environment. In order to meet such changeable requirements and realize the growth of a service, the key is the continual service improvement adjusted to coincide with the requirements. Within such a service improvement process, the early phase inevitably includes sub-steps for identifying requirements and analyzing the identified requirements to define specific requirements that should be the focus of improvement. The scope of this article is to propose a practical method that is used in the early phase.

In this paper, Section 2 explains a model of service growth and a service improvement over the lifecycle of a service. Based on the service growth model, a framework of requirement-oriented service improvement is illustrated in Section 3. The framework includes value analysis, service evaluation, and service design, and, in this paper, the concentration is on value analysis and service evaluation phases, in which requirements in a service are analyzed to define service elements that must/should be improved. Section 4 presents an outline of the manner in which designers examine and identify requirements, and Section 5 includes a description of a method used to evaluate the identified requirements. The evaluation result provides suggestions for the strategic improvement of a service. Section 6 explains important perspectives that the designers should focus on to obtain the suggestions. These sections, i.e., Sections 4 to 6, are the central argumentation of this paper. Section 7 is a description of how the proposed method was applied to a real B2B service. Section 8 presents a discussion of the result of the case study, and Section 9 presents the conclusion.

2 SERVICE GROWTH

2.1 Service lifecycle

Some researchers have referred to a model of service lifecycle. Aurich et al. examined manufacture and user activities in a product lifecycle and mentioned a model of service lifecycle in the product lifecycle point of view [12]. In the IT system field, ITIL (IT Infrastructure Library), a framework to operate and manage IT systems, provides a model of lifecycle of an IT service [13]. The lifecycle model in ITIL focuses on continual IT service improvement; thus, the model provides us important insights. However, it provides little information about product shares needed for service offering.

We have proposed a service lifecycle model from an objective of realizing a continual service growth. Our lifecycle model is composed of four phases: value analysis, service design, servicing, and service evaluation (Figure 1). Servicing is subdivided into three phases: introduction, operation, and maintenance. To realize service growth by modifying or improving the service, it is essential to check/evaluate the degree of current achievement toward its target value and to identify the service elements that must/should be improved. This is one reason that the model includes an evaluation phase, which is one of the features of our service lifecycle model.

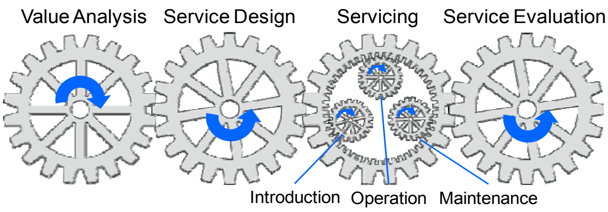


Figure 1: Service lifecycle

2.2 Service improvement

Using the service lifecycle model, service growth is modeled as shown in Figure 2. In this model, service improvement is illustrated as a pair of vertically ordered gears. As the service improvement should be executed on the basis of the result of evaluation, power to activate the upper gear in each pair is transmitted by the evaluation gear.

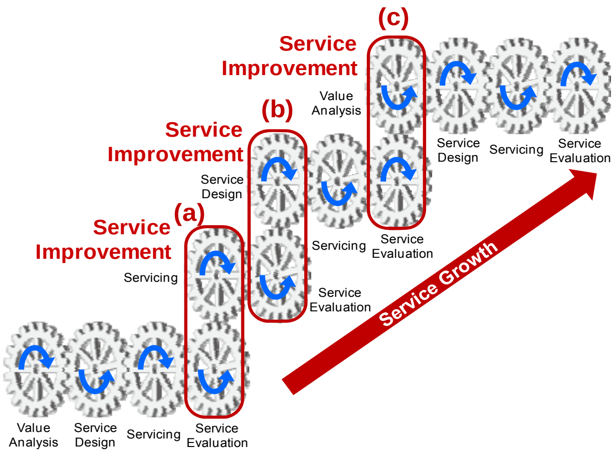


Figure 2: Service growth

Designers have to consider service improvements over the entire lifecycle [14]. Therefore, three vertically ordered gear sets should be considered, (a) Service Evaluation - Servicing, (b) Service Evaluation - Service Design, and (c) Service Evaluation - Value Analysis (Figure 2).

The first, (a) Service Evaluation - Servicing, refers to improvement without changing the current service structure, e.g., reinforcing the education for staffs.

The second, (b) Service Evaluation - Service Design, refers to the re-design of the current service elements, e.g., its functions, business partnerships, service activities, or physical products needed for service realization.

The third, (c) Service Evaluation - Value analysis, is a requirement-oriented service improvement. This improvement requires a re-analysis of customer needs and re-identification of requirements. The service could be modified and improved radically (e.g., by adding new functions to provide new values). As reported in 1.2, the focus of this paper is on requirement-oriented service improvement. Therefore, the next section presents an explanation of the framework for the third set.

3 FRAMEWORK OF REQUIREMENT-ORIENTED SERVICE IMPROVEMENT

A systematic framework of the requirement-oriented service improvement is illustrated in Figure 3. The framework is composed of three service lifecycle phases: service evaluation, value analysis and service design. Squares in each phase indicate sub-steps that should be performed by designers. This framework can be used to “PSS improvement,” since, as mentioned in Section 1, the term service in this study corresponds to PSS.

The next part (3.1) briefly explains each phase of this framework.

3.1 Three phases in the framework

Value analysis

In this phase, designers re-analyze values provided through the service, namely, the purpose of this phase is to identify requirements and analyze the identified requirements. Exhaustive examination and identification of requirements without omission are important.

Service evaluation

The ideal business or solution forms a win-win relation between a service receiver and a service provider in terms of profits, costs, and satisfaction. Service, therefore, must be improved with consideration of the balance of the provider-receiver relation. Service that makes the receiver dissatisfied due to an improvement that ignores customer needs will fail, and, on the other hand, the provider should not lose by forcing himself to meet customer needs completely. Hence, the service evaluation phase should include the perspectives of both the customer and the provider.

With respect to the evaluation from the customer’s point of view, it is important to clarify the degree to which customers are satisfied, i.e., the fulfillment level of each requirement.

On the other hand, from the provider’s perspective, the costs, productivity, and profit of the current service should be evaluated. Some methods for evaluating a service from such criteria have already been proposed, e.g., Activity-Based Costing [15] for cost estimation.

Service design

To find solutions for service improvement, designers must first define the requirements that should be targeted in the improvement. Subsequently, some specific solutions that can satisfy the requirements are conceptualized. The resources needed to realize the solution are then determined. Here, the term resources includes both physical products and human resources. After that, designers select the best solution among them. The

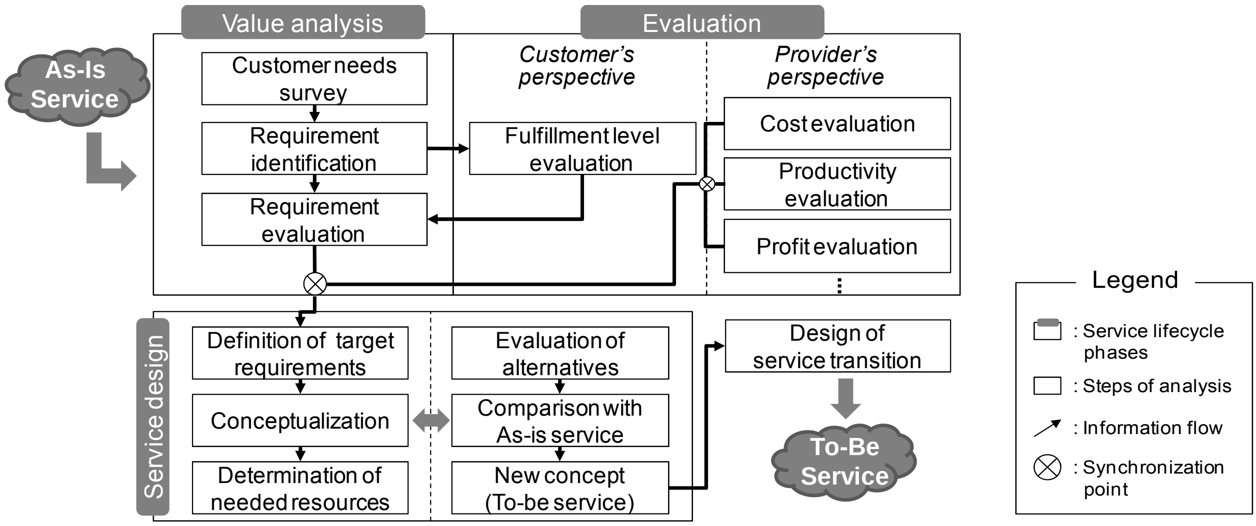


Figure 3: Framework of requirement-oriented service improvement

selected solution is then compared with the current service by some criteria. Only when the solution is better than the current service, it can be regarded as suitable for a new concept, i.e. To-be service. The to-be service should be introduced to the current business field smoothly. Therefore, after the new service concept is generated, designers need to consider how to shift the current service to the new service, i.e., they need to design a service transition [16].

3.2 Scope and challenge

The framework reported above is just an overview of requirement-oriented service improvement. We, therefore, need a more concrete method or procedure to execute each step in the framework.

One of the most important steps in the framework is analyzing the identified requirements to define design targets because this step is a starting point of the requirement-oriented service improvement; thus, the step affect the later steps, e.g., steps in the service design phase. However, it is difficult to determine target requirements due to the fact that, normally, a number of requirements are identified when they are thoroughly examined.

In this paper, our scope is set on the procedure to define the target requirements, namely three sub-steps from a "Customer needs survey" to "Definition of target requirements" in the value analysis phase and "Fulfillment evaluation" in the evaluation phase (Figure 3). The challenge is proposing a concrete and practical method to analyze the identified requirements and to define the target requirements from them.

4 REQUIREMENT IDENTIFICATION

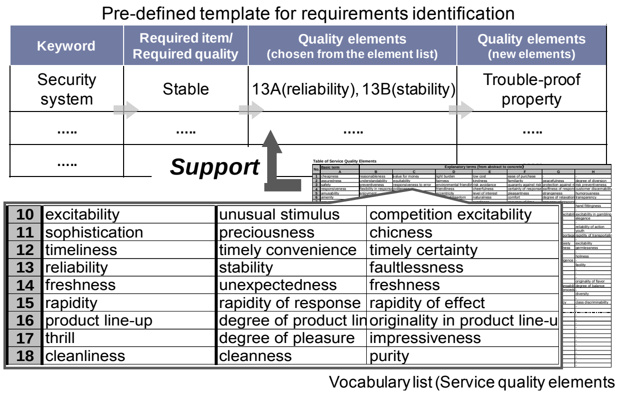
To analyze the customer and to identify requirements in a B2B service, a method called Business process- and Goal-oriented Requirements Analysis has been proposed ([17-18]).

The first step of this method for designers is re-analyzing service receivers to clarify customers and to identify customer needs. Market surveys, interviews, or questionnaires are useful in this step [19].

Based on the collected data, customer's business activities are modeled visually, and goals, which indicate objectives that should be achieved for each business task [20], are identified for each business activity.

The modeled customer's business activities are then translated into a service script. The service script is written in natural language; thus, it enables designers to analyze the customer's behavior in more detail. From the script, designers identify some "key words" that can be considered as important elements for the service.

Finally, each key word is associated with required items/qualities and quality elements using a pre-defined template and vocabulary list (Figure 4). Here, required items refer to what customers want to do, and the required quality is a linguistic expression of customer needs related to the quality of the provided product/service [21], namely, the required items/qualities indicate representations of "customer needs" in a service. On the other hand, quality elements work as criteria for evaluating the quality [22]. Thus, the quality elements are observable and controllable for designers and could be regarded as requirements in a service, since these are elements that satisfy the required items/qualities, i.e., customer needs. (See [17-18] for more details.)



Keyword	Required item/ Required quality	Quality elements (chosen from the element list)	Quality elements (new elements)
Security system	Stable	13A(reliability), 13B(stability)	Trouble-proof property
.....	.....	.....	.....
.....			

10	excitability	unusual stimulus	competition excitability
11	sophistication	preciousness	chicness
12	timeliness	timely convenience	timely certainty
13	reliability	stability	faultlessness
14	freshness	unexpectedness	freshness
15	rapidity	rapidity of response	rapidity of effect
16	product line-up	degree of product lin	originality in product line-u
17	thrill	degree of pleasure	impressiveness
18	cleanliness	cleanness	purity

Figure 4: Requirement identification using vocabulary list

5 REQUIREMENT EVALUATION

5.1 Approach

Each of the identified requirements has its attributes, e.g., whether or not it is fulfilled. Urgency of the need for improving a service is influenced by the attributes of the requirements. For instance, a part of the current service related to an unfulfilled requirement should be improved preferentially compared to a service that already satisfies a requirement. Therefore, "classification" of the requirements is taken as an approach to "evaluate" the identified requirements.

For the classification, four perspectives are introduced as attributes of requirements: fulfilment level, Kano quality [22], and internal and external environments. Each perspective is explained below. The fulfilment level and Kano quality are evaluated by the customer. On the other hand, internal and external environments are evaluated by the provider.

1st perspective: Fulfilment level of the requirements

The first evaluation perspective is the fulfilment level. It refers to the degree to which the requirements are satisfied. In this study, the fulfillment level of the identified requirements is evaluated qualitatively by the customers' use of the terms "fulfilled", "partially-fulfilled" and "unfulfilled". As reported in Section 3, the fulfilment level evaluation is held in the evaluation phase (Figure 3).

2nd perspective: Kano quality

The second one is Kano quality [22], which provides quality categories of features in a product/service.

Kano quality is proposed by Kano et al. in the quality management field and is a model to categorize a quality [22]. According to the Kano model, quality attributes are categorized mainly into three types: attractive, one-dimensional and must-be quality.

Figure 5 illustrates the features of these three types of quality. The horizontal axis indicates the state of physical fulfillment. Attractive quality elements have little influence on customer satisfaction, even when they are unfulfilled. On the other hand, must-be quality elements are recognized as a matter of course, and, if they are unfulfilled, customers are deeply dissatisfied.

In this study, the identified requirements are classified into three Kano quality types.

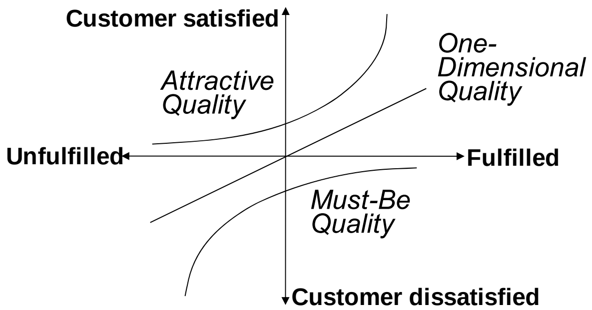


Figure 5: Kano quality model

3rd and 4th perspective: Internal and external environment

The internal environment of a provider affects the decision to define the target requirements for the improvement of a service. For example, if the provider has a specific strength, e.g., a specific skill or knowledge, it is relatively easy to improve a part of service related to such strength. Furthermore, in general, an external environment, i.e. trends or situation, influences a customer and his/her needs. Therefore, to grasp such environment-related requirements, designers have to analyze the external environment of a provider.

SWOT [23-24] analysis is a framework to formulate a business strategy by analyzing the external and internal environments of the business. Table 1 shows a typical matrix that is provided in a series of SWOT analysis studies [24]. As shown in Table 1, in SWOT analysis, the external environment is analyzed by listing the business Opportunities (O) and Threats (T), and the company's internal environment is assessed for its Strengths (S) and Weaknesses (W).

Table 1: SWOT analysis

	Internal Strengths (S)	Internal Weaknesses (W)
External Opportunities (O)	SO strategy	WO strategy
External Treats (T)	ST strategy	WT strategy

In our method, designers judge whether or not requirements are related to internal environments, i.e., internal strengths or weaknesses, and any external environments, i.e., external opportunities or threats.

5.2 Requirements evaluation matrices

Bi-layered matrix

In this study, a bi-layered matrix to evaluate and classify the identified requirements is developed as shown in Figure 6. The upper matrix in Figure 6 classifies the requirements from a customer's viewpoint. Thus, its horizontal axis is the fulfillment level, and the other axis is the Kano classification. The lower matrix is almost the same as the SWOT matrix. However, the lower matrix has nine cells, while the original SWOT matrix has only four cells. This is because all of the requirements, including requirements that are not related to internal or external environments, should be categorized to any cells.

The identified requirements are first mapped to a cell in the upper matrix, and they are then mapped to a cell in the lower matrix. All of the requirements are then mapped onto two matrices respectively.

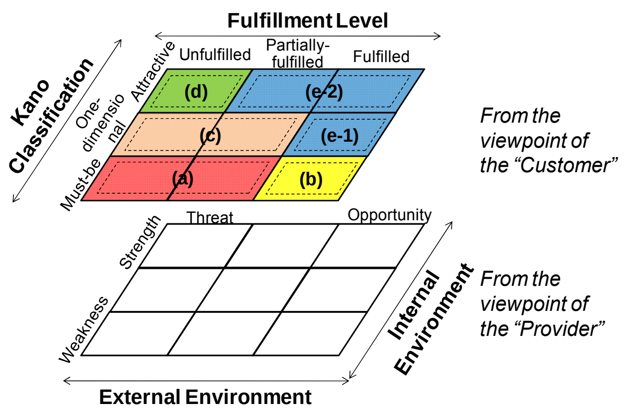


Figure 6: Requirement evaluation matrices

Five important sectors

The nine cells in the upper matrix can be classified into five sectors, (a) to (e), shown in Figure 6.

Referring to the feature of three types of quality noted in the Kano model (Figure 5), sectors (a) and (c) indicate that customers are dissatisfied, that is, the value of the customer satisfaction is negative. On the other hand, sector (e), (e-1) and (e-2), refers to customer satisfaction, namely, the value of customer satisfaction is positive.

Sectors (b) and (d) indicate neutrality, neither satisfaction nor dissatisfaction; thus, the value of customer satisfaction is nearly zero. It is noteworthy that, in sector (b), zero is the maximum, and, in contrast, zero is the minimum in sector (d). Therefore, improving a service related to a requirement in sector (d), the value of customer satisfaction can only move to the positive direction, while that is not possible in sector (b).

6 STRATEGIC REQUIREMENT ANALYSIS

This section is a description of some important points that should be addressed to conduct the strategic determination of target requirements using the requirement evaluation matrices presented in Sector 5.

6.1 Improvement strategy driven by Kano and SWOT

The Kano classification and SWOT analysis are both considered as valuable for developing design and business strategies.

Some researchers in the mechanical design field have suggested that a product's features should be designed in consideration with its Kano quality. Table 2 is a description of the characteristics of design corresponding to each quality [25]. This description can be considered as a kind of design strategy based on the Kano quality.

Table 2: Design types corresponding to the Kano quality

Kano categories	Type of Design
Attractive	**Attractive Design:** A product/service provides extra satisfaction to customers. An example of this kind of design in a laptop computer would be a security system that included a fingerprint scanner.
One-dimensional	**Better Design:** The better a product/service performs for a customer, the more satisfied the customer is. An example of better design in a laptop would be its weight.
Must-be	**Essential Design:** A lack of such a feature would result in customer dissatisfaction, and probably make a product/service not as useful to the customers. An example of this design in a laptop would be a spacebar.

On the other hand, in a relevant study of SWOT analysis, Weihrich proposed four conceptually alternative strategies corresponding to the four columns in the SWOT matrix [24] (Table 1).

Improvement ideas or plans described in the S-O column are called SO strategies. The strategies are means to use internal strengths to take advantage of the opportunities. Thus the company should not hesitate to realize the ideas described as SO strategies.

ST strategies appear in the S-T column. This strategy is based on the strengths of a company that can deal with threats in the external environment. In other words, if a provider can overcome the threats, a differentiated service can be realized.

WO strategies in the W-O column attempt to minimize weaknesses by taking advantage of opportunities. The business plans in the W-O column should be conducted carefully.

WT strategies aim at minimizing weaknesses and avoiding threats. Namely, actions or plans to avoid significant risks are described here.

6.2 Rough strategy for service improvement

The design types corresponding to each Kano quality derive a rough strategy of service improvement with respect to each of the five important sectors. There are two types of service improvement strategies: (i) To reduce or eliminate the potential for customer dissatisfaction, and (ii) To increase the degree of customer satisfaction.

(i). Improvement to reduce or not to make customer dissatisfaction

Sector (a). Improvement to warrant the minimum quality of a service: "- to 0"

The attributes of a requirement mapped to sector (a) are: Unfulfilled/Partially-fulfilled and Must-be quality.

Requirements in this sector must be fulfilled to warrant the minimum quality of the service. Anything less will result in customer rejection.

Sector (b). Improvement to maintain the minimum quality

The attributes of a requirement mapped to sector (b) are: Fulfilled and Must-be quality.

These attributes means that the minimum quality of the service is already assured. However, if a requirement is also related to Treats or Weakness in the lower matrix, designers need to consider and manage several kinds of risks that impede the quality of the service.

(ii). Improvement to increase the degree of customer satisfaction

Sector (c). Improvement to eliminate customer dissatisfaction and increase satisfaction from a negative to a positive: "- to 0/+"

The attributes of a requirement mapped to sector (c) are: Unfulfilled/Partially-fulfilled and One-dimensional quality.

A part of service related to a requirement mapped here is now considered as one reason for customer dissatisfaction. To eliminate the dissatisfaction, therefore, designers should improve the part of a service. When such improvements are made, there is a possibility to change the dissatisfaction into satisfaction.

Sector (d). Improvement to add a new value by the attractive design: "0 to +"

The attributes of a requirement mapped to sector (d) are: Unfulfilled and Attractive quality.

Focusing on the requirements mapped here, a novel service might be created, and then the value of the customer satisfaction will be increased. This occurs because fulfilling an attractive quality element means pleasing the customer, i.e., the attractive design.

Sector (e). Improvement to obtain higher customer satisfaction: "+ to ++"

The attributes of a requirement mapped to sector (e) are: Fulfilled and One-dimensional quality (e-1), or Partially-fulfilled/Fulfilled and Attractive quality (e-2).

The current services related to requirements mapped here have already created relatively high customer satisfaction. Therefore, the provider does not need to modify the services. However, effective improvement of the service can raise the degree of customer satisfaction dramatically and will be an important source of profits.

Here, sectors (e-1) and (e-2) are different in terms of the design type, namely, (e-1) relates to the better design and (e-2) relates to the attractive design. Therefore, improvements concerning requirements in (e-1) are more realistic, whereas those in (e-2) are more creative.

6.3 More precise suggestions to define target requirements

The rough strategies reported in 6.2 are obtained from the mapping result on the upper matrix. It is, therefore, possible to provide more detailed suggestions by combining the mapping result on the lower matrix. In this study, a vector that connects the same requirement between two matrices is descried. The vectors possess four kinds of attributes of the requirement: fulfillment level, Kano quality, and internal and external environments.

Strategies for the vectors are generated by combining the strategies driven by the SWOT matrix with the grand strategies reported in 6.2. A strategy template developed in this study organizes these two strategies, and, thus, it provides suggestions or hints that are more precise to define the target requirements. Namely, the template helps designers define the target requirements for improvement.

7 CASE STUDY

This section discusses how the proposed method was applied to a real B2B service, facility construction and maintenance service, in which a utility company was the service receiver. Figure 7 shows the overview of the service.

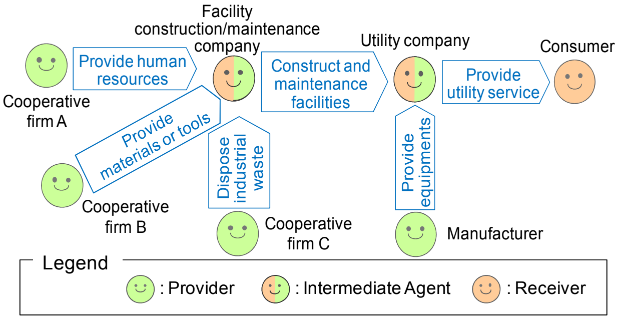


Figure 7: Overview of the case example

In this example, the utility company offers a social infrastructure service and maintains lifelines for the public. Thus, the utility company has to operate its facilities safely. A facility construction/maintenance company constructs and maintains the facilities of the utility company. The utility company purchases the equipment needed to operate its facilities from a manufacturer. Cooperative firms provide human resources, materials, and tools or are entrusted to dispose of industrial wastes.

The focus was to improve the facility construction and maintenance service received by the utility company. Namely, in this case study, requirements in the service were identified, and then the identified requirements were analyzed by using the proposed matrices and strategy template.

Requirement Identification

First of all, the requirements for the service were identified with the Business process- and Goal-oriented Requirements Analysis method. Table 3 illustrates a part of the process to formulate requirements, and the leftmost column in Table 4 shows a part of the result. In this case study, nearly 50 requirements, e.g., “Reliability of an equipment” and “Accuracy of an inspection,” were identified.

Table 3: Requirement Identification

Keyword	Required item/ Required quality	Quality elements (chosen from the element list)	Quality elements (new elements)
Construction / Repair Planning	Valid		Validity
Work situation	At various situations		Without limitation
Quotation	Fast	15D(Rapidity in processing)	
Equipment	Decrease renewal costs	1A(Cheapness)	Long life

Requirement Evaluation: Classifying

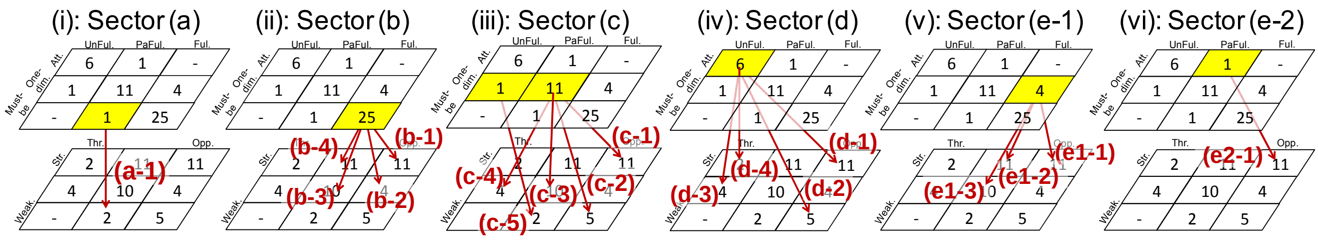
To analyze the identified requirements, the fulfillment level of the requirements was evaluated qualitatively through a discussion with a person involved in the service. The result is shown in Table 4. Secondly, the identified requirements were classified into three types of Kano quality. Questionnaires were adopted for the objective classification. Table 4 illustrates the result.

Thirdly, internal strengths and weaknesses as well as external opportunities and external threats were extracted on the basis of some discussions and data collection.

- The service provider’s internal strength was an advanced technological capability.
- Their internal weaknesses were: more poorly constructed technical training within the company than several years before and relatively-weak relationship with the customer, i.e. the utility company.

Table 4: Requirement evaluation

Requirements	Fulfillment level	Kano Quality	Internal Environment		External Environment	
			Strength	Weakness	Opportunity	Threat
Reliability of *[equipment]*	Fulfilled	Must-be	Unrelated	Unrelated	Related	Unrelated
Environmental friendliness of *[equipment]*	Unfulfilled	Attractive	Unrelated	Unrelated	Unrelated	Related
Long life of *[equipment]*	Unfulfilled	Attractive	Unrelated	Unrelated	Unrelated	Related
Stability of a *[facility]*	Fulfilled	Must-be	Unrelated	Unrelated	Related	Unrelated
Accuracy of *[inspection]*	Fulfilled	Must-be	Related	Unrelated	Related	Unrelated
Stability of *[power supply]*	Fulfilled	Must-be	Unrelated	Unrelated	Unrelated	Unrelated
Degree of handing down of [skills] to younger employees	Partially-fulfilled	Must-be	Unrelated	Related	Unrelated	Unrelated
High capability on self-managing of a *[team]*	Fulfilled	One-dimensional	Related	Unrelated	Unrelated	Unrelated
Small amount of *[waste of materials]*	Partially-fulfilled	One-dimensional	Unrelated	Unrelated	Unrelated	Related
Punctuality of *[work]*	Fulfilled	Must-be	Related	Unrelated	Unrelated	Unrelated
Diversity of *[work techniques]*	Partially-fulfilled	One-dimensional	Related	Unrelated	Related	Unrelated
……	…	…	…	…	…	…



(i): Sector (a)		
Vec.	N. of reqs.	Mapped reqs.
(a-1)	1	Degree of handing down skills to younger employees

(iv): Sector (d)		
Vec.	N. of reqs.	Mapped reqs.
(d-1)	1	Swiftness of modifying a specification
(d-2)	1	Degree of cooperation for building close relationships with other teams
(d-3)	2	Long life of equipment, etc.
(d-4)	2	Possibility of succession of equipment, etc.

(ii): Sector (b)		
Vec.	N. of reqs.	Mapped reqs.
(b-1)	5	Accuracy of inspection, etc.
(b-2)	4	Reliability of equipment, etc.
(b-3)	7	Stability of power supply, etc.
(b-4)	9	Risk preventiveness in work, Punctuality in work, etc.

(v): Sector (e-1)		
Vec.	N. of reqs.	Mapped reqs.
(e1-1)	1	Less limitation on work situation
(e1-2)	2	High capability on self-management of a team
(e1-3)	1	Credibility of a work manager

(iii): Sector (c)		
Vec.	N. of reqs.	Mapped reqs.
(c-1)	3	Diversity of work techniques, etc.
(c-2)	4	Flexibility of work, etc.
(c-3)	2	Cheapness of equipment, etc.
(c-4)	2	Small amount of waste of materials, etc.
(c-5)	1	Degree of understanding about other teams

(vi): Sector (e-2)		
Vec.	N. of reqs.	Mapped reqs.
(e2-1)	1	Exactness of modification of a specification

Figure 8: Distribution of requirements

- The external opportunities for their services were: an increase in disasters caused by climate change and an increase of the difficulty level of construction/repair work because of the complexity of equipments. (The first is a risk factor to maintain facilities for the utility company; thus, for the facility construction/maintenance company, this situation will be a chance for their maintenance business.)
- The external threat for their service was societal demand for the reduction of the environmental burden. (Up to now, the facility construction/ maintenance company has been unconcerned about environmental burden and just focused on safety or output due to the fact that they are involved in public infrastructure.)

Subsequently, the identified requirements were evaluated whether they were related to the above-mentioned S, W, O, and T or not. The results are shown in Table 4.

Based on each result, the requirements were mapped to the bi-layered matrix. Vectors to connect the same requirement were then described. The results are shown in Figure 8. The numbers in each cell indicate how many requirements belong to the cell in the matrices.

Determination of the target requirements

The facility construction/maintenance company, which was a service provider in this case, intended to improve its service toward the two objectives described below.

- Fortifying the basics of their current service.
- Providing new values to the service receiver, where the new values must fit into the customer needs.

Considering the five rough strategies corresponding to the five important sectors, for the first objective, i.e., fortifying the basics of their current service, we analyzed some vectors which start with sectors (a) and (b). As shown in (i) in Figure 8, there was a vector related to sector (a), which represented a requirement "Degree of handing down skills to younger employees." As reported in 6.2, requirements in sector (a) must be fulfilled to warrant the minimum quality of the service, and anything less will result in customer rejection. Therefore, the "Degree of handing down skills to younger employees" was insufficient from the customer's viewpoint; thus, the provider has to improve it by, e.g., reinforcing education or reorganizing work teams. It is noteworthy that concrete solutions should be conceptualized in the "service design" phase. Meanwhile, we could find 25 requirements that were represented by vectors starting from sector (b), e.g., "Reliability of equipment" and "Punctuality of work". These requirements were considered as the must-be quality elements and have been fulfilled. It means that the minimum quality of the services related to these requirements was assured. Furthermore, according to the rough strategies reported in 6.2, there seems to be no significant risks that impede the quality of the service, since the vectors were not headed to Weakness- or Treat-related cells in the lower matrix.

On the other hand, focusing on vectors starting from sector (d) was the most effective way to examine requirements that relate to the second objective, namely, providing new values to the service receiver. Six requirements were found in the sector, and new values might be provided by considering additional services to meet some of these requirements.

Furthermore, observing the mapping result on the lower matrix and using the strategy template helped identify the requirements that deserved attention. In this case, for example, the requirement "Swiftness of modifying a specification," which was translated from customer needs "A specification should be changed or modified swiftly in response to requests," was found in sector (d) in the upper matrix. In the lower matrix, this requirement was mapped to the Opportunity – Strength cell; thus, its vector was headed to the Opportunity – Strength cell. It means that, according to the strategy template, the requirement was easy to fulfill, since the requirement was not related to the internal weaknesses and the external threats. Therefore, when an immediate improvement is needed for the service provider, conceptualizing a service that meets this requirement was the best way. On the other hand, in sector (d), there was a requirement "Possibility of succession of equipment," which means that equipments in a facility should not be disposed of without reusing. This requirement's vector was headed to the Threat – Strength cell. Referring to the strategy template, there may be risks caused by the external threats, when the provider attempts to create a new service that meets the requirement. However, if a provider can overcome the threats, a differentiated service can be realized with providing a new value to the utility company.

8 DISCUSSION

Once requirements in a service are identified, finding out the target requirements from them is the designer's responsibility, and it depends on the capability of the designers. In many cases, this puts a burden on the designers, since designers have to consider or manage a number of requirements; for example, we had to consider nearly 50 requirements in this case.

Concerning this problem, by classifying the identified requirements into the developed matrices and analyzing the classification result, we could obtain some significant suggestions to define the target requirements. For example, in this case, we could find that fulfilling the requirement “Degree of handing down skills to younger employees” was important to warrant the quality of the service. On the other hand, designing a new service that meets the requirement “Possibility of succession of equipment” will be effective to provide novel value for the utility company. Namely, the proposed method provided important suggestions to define the target requirements based on a service provider's strategy.

However, the matrices do not provide sufficient information to determine the target requirements, as they do not deal with the data of cost, productivity, and profit evaluations, which can be regarded as important criteria for a service improvement from a provider's viewpoint. Therefore, future work will include a scheme to combine other evaluation criteria with the proposed method. Namely, we need to clarify the details of the biggest connecting point in Figure 3. Of course, we have to establish a more concrete method for each step in the service design phase.

9 CONCLUSION

In this article, we propose a framework of requirement-oriented service improvement. In this study, we concentrate on the early phase of the framework, which is requirement identification, evaluation, and the definition of specific requirements that should be focused on improvement. As a concrete and practical method for this challenge, the requirement evaluation matrices and the strategy template were developed.

It is difficult for designers to define design targets, i.e. target requirements, in service improvement. To overcome this problem, the proposed method enables designers to obtain some significant suggestions or hints to define the target requirements.

10 ACKNOWLEDGMENTS

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11 REFERENCES

[1] Mont, O., 2002, Clarifying the concept of product-service system, Journal of Cleaner Production, 10: 237-245.

[2] Tukker, A. and Tischner, U., 2006, Product-services as a research field: past, present and future. Reflections from a decade of research, Journal of Cleaner Production, 14/17:1552-1556.

[3] Arai, T. and Shimomura, Y., 2004, Proposal of Service CAD System -A Tool for Service Engineering-, Annals of the CIRP, 53/1:397-400.

[4] Arai, T. and Shimomura, Y., 2005, Service CAD System -Evaluation and Quantification-. Annals of the CIRP, 54/1:463-466.

[5] Fisk, R. P., Grove, S. J., John, J., 2003, Interactive Services Marketing, Houghton Mifflin Company.

[6] Maslow, A. H., 1987, Motivation and Personality, 3rd edition, Harper & Row.

[7] Ericson, Å., Müller, P., Larsson, T. and Stark, R., 2009, Product-Service Systems – From Customer Needs to Requirements in Early Development Phases, Proceedings of CIRP, IPS2 Conference 2009, CIRP, 62-67.

[8] Ulrich, K. T. and Eppinger, S. D., 2008, Product Design and Development, McGraw-Hill.

[9] Gummesson, E., 1998, Implementation Requires a Relationship Marketing Paradigm, Journal of the Academy of Marketing Science, 26:242–49.

[10] Gronroos, C., 2000, Service Management and Marketing: A Customer Relationship Management Approach, John Wiley & Sons.

[11] Peach, R., 2002, The ISO Handbook Forth Edition, McGraw-Hill.

[12] Aurich, J. C. And Fuchs, C., 2004, An Approach to Life Cycle Oriented Technical Service Design, Annals of the CIRP, 53/1: 151-154.

[13] Office of Government Commerce, 2007, Service Operation – ITIL Version 3, The Stationery Office.

[14] Office of Government Commerce, 2007, Service Improvement – ITIL Version 3, The Stationery Office.

[15] Cooper, R., 1988, The Rise of Activity-Based Costing- Part One: What is an Activity-Based Cost System?, Journal of Cost Management, 2/2:45-54.

[16] Office of Government Commerce, 2007, Service Transition – ITIL Version 3, The Stationery Office.

[17] Akasaka, F., Hosono, S., Yamamura, K., Shimomura, Y., and Arai, T., 2009, A Method for Analyzing Customer Requirements in a B2B Service, In Proceedings of the 9th Japan Korea Workshop on CAD/CAM -Design Engineering Workshop-, 7-12.

[18] Kimita, K., Akasaka, F., Ronnback, A., Sakao, T. and Shimomura, Y., 2009, Requirement Analysis for User-Oriented Service Design, In Proceedings of the 42nd CIRP Conference on Manufacturing Systems, CIRP, CD-ROM.

[19] Gough, I., 1994, Economic Institutions and the Satisfaction of Human Needs, Journal of Economic Issues, 28/1, 25-66.

[20] Dardenne, A., Lamsweerde, A. V. and Fickas, S., 1993, Goal-Directed Requirements Acquisition, Science of Computer Programming, 20:3-50.

[21] Akao, Y., 1990, Quality Function Deployment, Productivity Press.

[22] Kano, N., Seraku, N., Takahashi, F. and Tsuji, S., 1984, Attractive Quality and Must-Be Quality, Quality, 14/2: 39-48, the Japan Society of Quality Control.

[23] Hill, T. and Westbrook, R., 1997, SWOT Analysis: It's Time for a Product Recall, Long Range Planning, 30/1, 46-52.

[24] Weihrich, H., 1982, The TOWS Matrix --- A Tool for Situational Analysis, Long Range Planning, April, 60.

[25] MacDonald, E. F., Gonzalez, R. and Papalambros, P. Y., 2009, Preference Inconsistency in Multidisciplinary Design Decision Making, Journal of Mechanical Design, 131/3, 1-13.

SysML for the Analysis of Product-Service Systems Requirements

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Abstract

In this paper, the Systems Modelling Language (SysML) is introduced as a technique for the design of a product-service system (PSS). In examples of the requirements diagram in SysML, this paper shows that: (1) a PSS can be analysed by the SysML technique, and (2) the SysML can model the requirements of a PSS in orientations according to product, use or result. Recommendations based on the example will then be used to suggest improvements in the design of a PSS.

Keywords

Product-Service Systems, SysML, Conceptual design, Requirements, Traceability

1 INTRODUCTION

The design of a product-service system (PSS) involves three main stages: analysis, concept and execution [1]. The analysis phase captures specific customer needs and *the requirements to fulfil them*. The concept phase identifies structural, physical and behavioural characteristics for the PSS. The execution phase involves planning, scheduling, prototyping, simulation and any other design process required for PSS realisation.

For systems design in general, the analysis and concept stages are areas of design that lacks efficient support [2]. The problem centres on how to efficiently develop methods to deal with difficulties in converting customer needs into functions/use cases and to realise a clear vision of the system to ease system integration and communication among team members.

Recently, a modelling technique known as the Systems Modelling Language (SysML) has been proposed to support the analysis and concept phase of systems design. SysML is based on the Unified Modelling Language (UML) and was developed by the Object Management Group (OMG) consortium and the International Council on Systems Engineering (INCOSE) [3]. The SysML approach has been applied in areas such as requirement modelling, describing physical systems connectivity and modelling the frameworks of organisations [4].

The focus of this paper is to show an example of the SysML requirement diagram for the conceptual design of a PSS. It seeks to contribute to PSS research by assessing the benefits of the technique for the analysis phase of PSS design.

This paper begins with an overview of product-service systems. The SysML approach will then be introduced as technique for the analysis phase of systems design. The focus of the technique is to support systems designers in identifying the requirements to fulfil customer needs. Recommendations based on worked examples of the SysML requirements diagram for a PSS will then be used to suggest improvements in the design of a PSS.

2 PRODUCT-SERVICE SYSTEMS

According to the United Nations, a Product-Service System (PSS) is 'a competitive system of products, services, supporting networks and infrastructure' [5]. It is an approach to production that shifts focus from 'product thinking' to 'systems thinking' [6, 7].

In principle, a PSS involves intermixing product and service components for added customer value [6]. Added value for customers is realised by delivery systems that offer value propositions that utilise PSS granularity i.e. the level to which a PSS is broken down into subsystems and components to aid flexibility and customisation.

2.1 Delivery systems for a PSS

Delivery systems for a PSS are realised in various orientations according to product, use or result [7, 8] as shown in Figure 1.

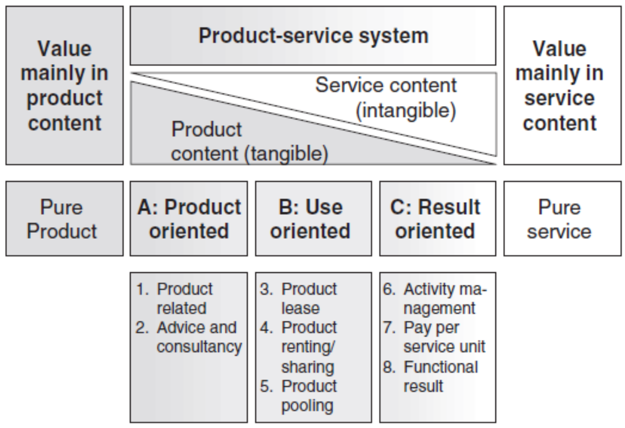

Figure 1: Product-service system configurations [8]

In the *product-oriented* approaches, the provider offers the sale of products and also opens service channels for additional product related services such as repairs, upgrades as well as professional advice / consultancy [8].

For the *use-oriented* approach, the provider maintains the rights to a product. This product is made available for use in a service environment via services such as product leasing, sharing, pooling and renting.

The result-oriented approach involves a provider delivering service content independent of product choice. This approach is based on pay-per-service-unit schemes that delivers functional results, and on activity management approaches.

2.2 Modelling for PSS delivery

Various models for product-service systems have been proposed, but as yet there is no final definition of a standard model. This is because a company seeking to deliver a PSS needs to consider business requirements such as: *life-cycle of a product* from its engineering through to its decommissioning (recycling and disposal), *close knitting* of products with services and services with products, and *establishing links* and networks (with customers and other manufacturers) to aid PSS delivery.

Function-oriented modelling, object-oriented modelling, conceptual modelling and service modelling are some approaches to modelling the business requirements for a PSS [9].

Given the variety of possible contexts, achieving a comprehensive standard model can be a very difficult goal [10]. It is likely that bespoke models need to be developed for each PSS context [11].

It then becomes worthwhile to consider contributions from the field of systems engineering as a starting point for any model being developed. Systems engineering has always had to deal with complex, dynamic, and multidisciplinary systems, so that a systems engineering tool such as SysML may be useful at some level in any PSS context, possibly as an initial PSS model. The SysML approach benefits system engineers because the approach identifies the minimal set of the popular UML technique required to specify, analyse, design, verify and validate a wide range of systems (such as PSSs) [4].

3 SYSML AND THE REQUIREMENTS DIAGRAM

3.1 Overview

SysML is a general-purpose graphical modelling language for representing systems that may include combinations of products, data, people, facilities, and natural objects [12]. In software engineering, the use of modelling is increasingly being adopted through the Unified Modelling Language (UML). SysML was developed by starting with a subset of UML, which was then extended with some new diagrams. SysML consists of nine diagrams (Figure 2) that are classified into:

1. Structure diagram, consisting of Block Definition, Internal Block, and Package diagrams, which represent structural elements and their organisation and interconnection; and parametric diagram, which represents real-world constraints on property values.
2. Behaviour diagram, consisting of Activity, Sequence, State Machine, and Use Case diagrams. These diagrams represent behaviour and functionality of entities within the model.
3. Requirement diagram, which represents individual requirements and their relationship with other requirements, design elements, and test cases to support requirements traceability [12].

Each diagram utilises a different viewpoint, with different abstraction and notation; each diagram thus represents partial views of the complete model. The complete set of diagrams provides a complete, coherent description of the model of the system being developed. This model can then be used to support analysis, specification, design, and verification of the system.

The system model is generally created using a modelling tool and stored in an on-line model repository. This facilitates collaboration and provision of useful capabilities such as automatic updating of other diagrams when details are changed in one diagram. For example, because requirement diagram dependencies to constructs in other diagrams are tracked automatically, the design team will be alerted when a design change compromises a requirement.

In SysML, the requirements diagram documents what the system must accomplish and provides many useful features for a PSS design team. The rest of this paper will focus on the requirements diagram and how it can be applied in a PSS context.

The reader is referred to reference [2, 3, 4, 12] for the detailed explanation and description of the SysML approach, diagrams and the arguments which underlie this technique.

3.2 The Requirements Diagram

By introducing the requirement diagram, SysML offers an opportunity to:

1. Trace initial requirements during the design and development of a system,
2. Capture design rationale in terms of how design decisions were made, and
3. Generate test cases during the verification stage of a design process [4].

It is for this reason that the requirement diagram is vital to the SysML technique.

Requirement diagrams contain three main diagrammatic

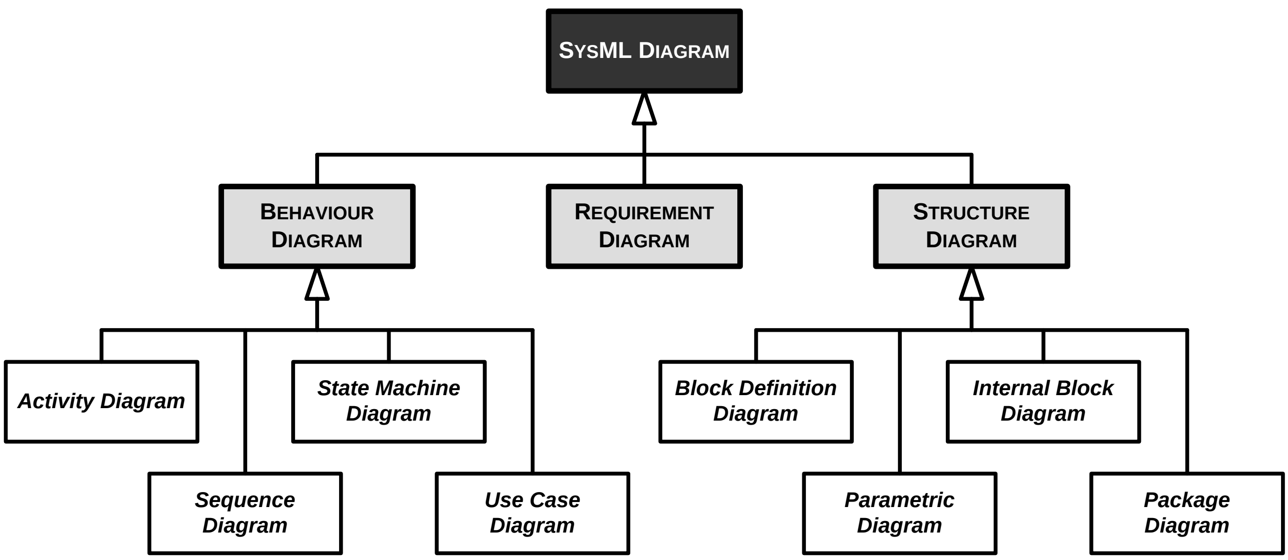

Figure 2: Systems modelling language (SysML) diagram types

modelling components: *boxes* to represent requirements, *rationale* to represent design rationale and to track changes to requirements and *arrows* to represent relationships between requirements [3, 13] as shown in Figure 3.

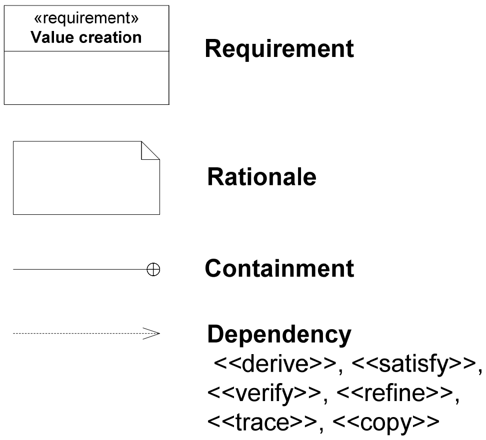

Figure 3: Requirement diagram symbols

The term 'requirement' is used to specify 'a capability or condition that must (or should) be satisfied' [3]. In real life systems, a standard requirement is also defined by a unique identifier, textual description and extra explanations such as verification status and requirements consistency checks.

The rationale construct is a general-purpose construct that can be used by a systems designer to provide explanations for decisions made during system analysis and conceptualisation. For example, a PSS delivery system requirement to 'reduce waste generation' could be supported by a design rationale containing textual descriptions such as 'new environmental regulations' or 'motivated by a customer survey conducted on …'.

Within the context of SysML, a requirement may be related to several sub-requirements as defined by relationships of containment or dependencies [3].

The containment relationship is used to show how a complex requirement can be decomposed into a set of child requirements.

SysML also recognises five main dependencies between requirements and between other requirement diagram elements: derive, satisfy, verify, refine, trace and copy. The <<derive>> relationship defines the link between derived requirements and source requirements whereas the <<satisfy>> relationship shows links for satisfying requirements. The <<verify>> relationship shows how test cases are used to verify a requirement. The <<refine>> relationship is applied to explain how one element refines another element whereas the <<trace>> relationship can be used to describe a general-purpose link between requirement diagram elements. The <<copy>> relationship creates a copy of a requirement.

4 PRODUCT-SERVICE SYSTEM REQUIREMENTS

William [13] captured and discussed cases of business-to-customer (B2C) type product-service systems in the automotive industry. A B2C automotive PSS sells (or delivers) cars, vans, trucks, buses and other forms of commercial vehicles to end consumers. The B2C type business lies at the spectrum of a supply chain where a business delivers products and services to end users or consumers. A barbershop and a laundrette are common examples of B2C for end consumers.

This section makes use of the PSS orientations identified in [13] to demonstrate the possible use of the requirements diagram for a PSS. The first sub-section presents the requirements for a PSS in the automobile industry based on product-orientation whereas the second and third sub-sections present the requirements for a PSS in the automobile industry based on use-orientation and result-orientation respectively.

4.1 Product-oriented requirements

In Figure 4, an example of a requirement diagram has been produced for an automotive company that delivers a product-orientated PSS for product related services and professional advice and consultancy.

In this configuration for a PSS, a company sells and transfers ownership of a product to a customer. When ownership of a product is transferred from the company to the customer, the responsibility of dealing with the risks and costs associated with after sales is also transferred. These risks and costs include product failure, maintenance costs and availability of spares. In the product-orientated PSS the business offers product-related services as well as professional advice and consultancy to alleviate some of these risk and costs. These services are also provided to create more business.

Delivery system requirement

The clear vision or main requirement of the delivery system in this example is customer mobility. This main requirement is satisfied in requirements for affordable customer solutions (customer requirement) and profitable business operations (manufacturer requirement). It is also determined (i.e. refined) by the choice of automobile that delivers the product-orientated PSS (provision requirement). Consequently, the automotive company will need to deliver a selection of automobiles to meet the main requirement of customer mobility.

For this example, automotive (i.e. the product) functions are contained in the sub-requirements for reliability and performance.

Services offered in this orientation as shown in Figure 4, are required to satisfy customer and manufacturer requirements of affordability and profitability. To satisfy the requirement for affordable customer solutions, the manufacturer offers cheap repairs and maintenance for automobiles whereas for profitable operations, the manufacturer provides automobile data and advice to customers. In addition, the manufacturer collects services data about automobile use and life to refine the services offered to customers.

Value proposition

For the example of a product-orientated PSS in Figure 4, the main requirements of the value propositions for the automotive company include: initial warranty for automobile, zero interest financing and take back scheme at automobile end-of-life.

The initial warranty is a scheme that the manufacturer offers to the customer to guarantee repairs, maintenance and replacements service for a fixed duration. In other words, the automotive company closely links automotive services to an offered automotive to deliver affordable customer solutions. The terms and provisions of the warranty are derived from customer contracts for service provision.

Zero percent interest is an initiative that the automotive company offers to customers to promote sales. It offers customers a fixed period during which the manufacturer expects no payment for the purchased automobile (and the closely linked services).

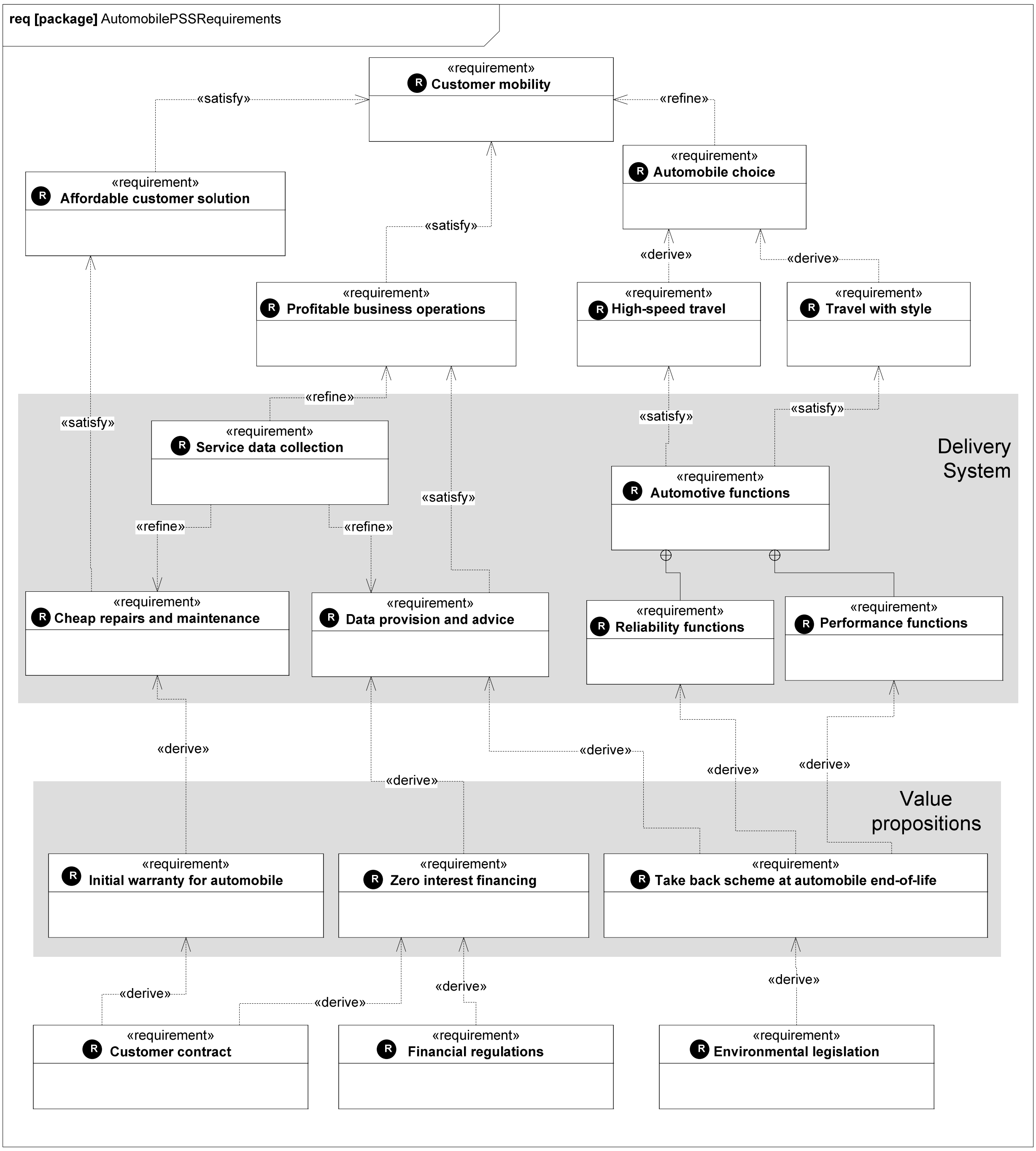

Figure 4: Requirements diagram for a product -oriented product-service system in the automotive industry

Following the completion of the period, the manufacturer may then request full payment, instalment payments or extend the period for zero interest financing. The stipulations of the zero interest financing are determined by the customer contract and financial regulations defined by institutions such as the Financial Services Authority (FSA) in the United Kingdom, the Securities and Exchange Commission (SEC) in the United states and Finansinspektionen in Sweden.

Take back schemes are motivated by environmental legislation within the automotive industry that encourage companies to improve the environmental impact of actors associated with automotive lifecycles [13].

These legislations require companies to be more active and responsible for taking back automotives at the end-of –life stage (i.e. when automotives are no longer functional or required by the customer). The take back scheme may include assuring customers that end-of-life automotives will be taken back and recycled. It may also involve recovering or salvaging materials and components from end-of-life vehicles for use as spare parts.

To derive the take back schemes, the company must consult appropriate environmental legislation to capture requirements relating to the laws that govern aspects such as: material recovery from vehicles, automotive disassembly, recycling and garages.

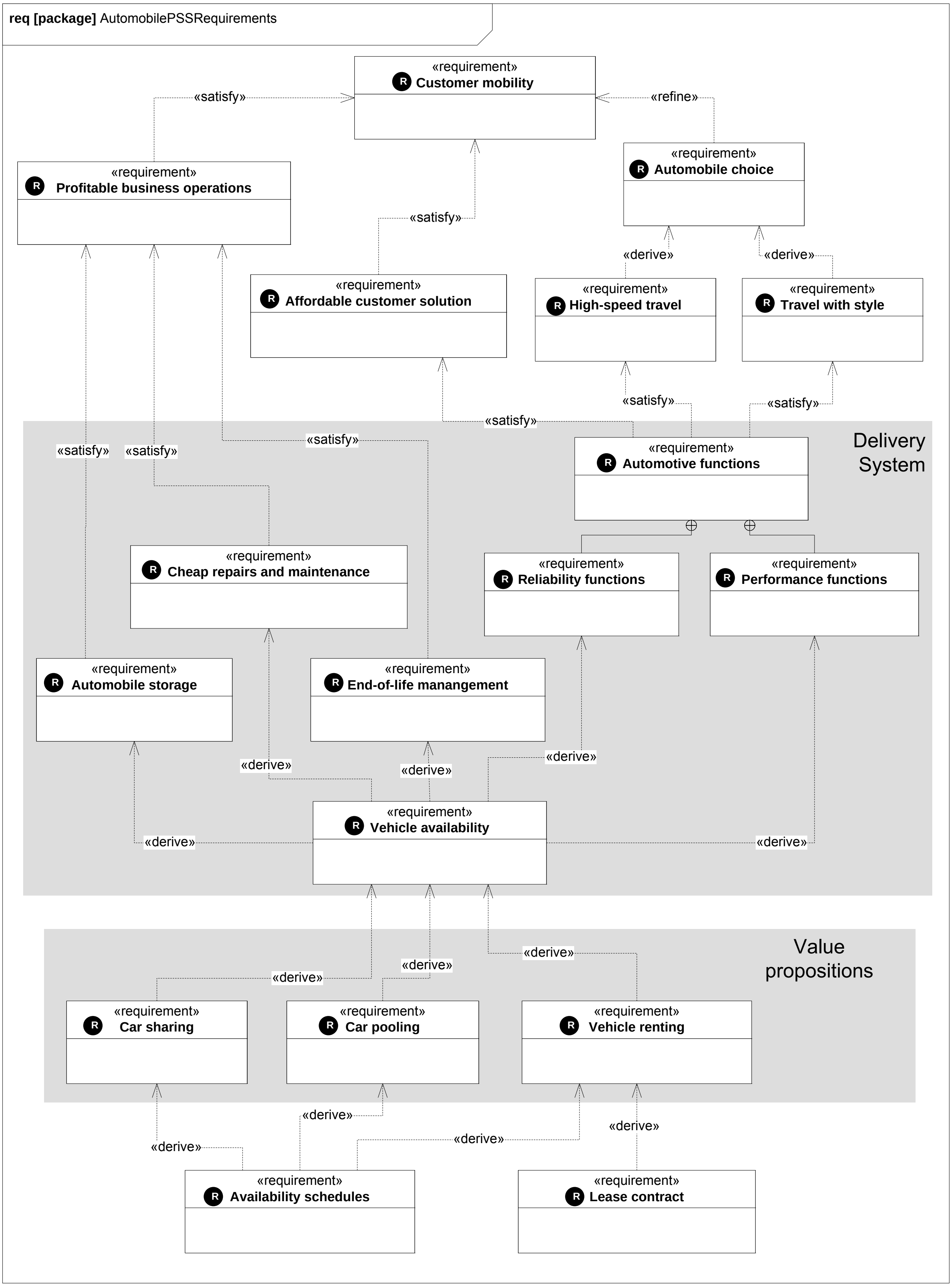

Figure 5: Requirements diagram for a use-oriented product-service system in the automotive industry

4.2 Use-oriented requirements

A second example of the requirements diagram is highlighted in Figure 5. The figure shows how the requirements for a use-orientated PSS can be captured by SysML.

For this configuration of a PSS, the automotive company in the B2C automotive business retains ownership of vehicles. These vehicles are then made available to customers for leasing, sharing or pooling. As a result, the automotive company assumes the risk and cost of vehicle maintenance, repairs, upgrades and replacement.

Delivery system requirement

As in the product-oriented PSS, the clear vision or main requirement of the delivery system in this example is customer mobility. Since the customer is given the option to choose the type of vehicle for mobility, the company must also deliver a selection of automobiles. The customer requirement for affordable customer solutions and the company requirement for profitable business operations are maintained.

The main service requirement offered by the automotive company is vehicle availability. This requirement is dependent on how the automobile is stored to enable access by customers, repairs and maintenance for conditioning the vehicle and end-of-life management for recovering spares from vehicles.

Value propositions

The main value propositions for the example of a use-orientated PSS (Figure 5) offered by the automotive company include: car sharing, car pooling and vehicle renting.

For car sharing, the customer is required to make a regular payment for the use of a vehicle that is shared by multiple customers at different times. The same condition applies for car pooling but customers are required to access the vehicle concurrently.

For vehicle renting, multiple vehicles are made available by the automotive company for customers to lease based on a regular subscription. In car sharing and car pooling schemes, a lease contract and availability schedule is required for defining how customers can use the vehicle availability service requirement. For the vehicle renting, the main requirement is the lease contract that defines the terms of vehicle use.

4.3 Result-oriented requirements

Figure 6 shows a third example of the requirements diagram for a result-orientated PSS. In this configuration for a PSS, the automotive company in the B2C automotive business also retains ownership of vehicles. Similarly, the automotive company assumes the risk and cost of vehicle maintenance, repairs, upgrades and replacement. Unlike the use-oriented PSS, the result-oriented delivers functionality independent of vehicle type, pay-per-travel schemes and outsources elements of business operations such as maintenance and service data collection.

Delivery system requirement

As in the previous examples, the customer, manufacturer and provision requirements are reused. For the result-oriented PSS in this example, the clear vision or main requirement of the delivery system for customer mobility is maintained. Similarly, customer requirement for affordable customer solutions and the company requirement for profitable business operations are maintained. A range of automobiles as suggested in [12] is also required to offer options for customer mobility. For instance, automotive companies may offer human-powered/electric vehicle, taxis or environmentally friendly car-ferry designs for variety in customer mobility.

Value propositions

In the example of the result-oriented PSS offered by the automotive company, three main value propositions are captured as requirements: pay per time, pay per output and mobility system.

In the pay per time and pay per travel schemes, a customer pays a flat fee for travel to destinations covered by the automotive company. For the pay per time scheme, the flat fee depends on travel duration (such as hourly, daily or weekly) whereas for pay per travel the customer pays for each trip or functionality provided by the vehicle. The mobility system is an initiative that allows customers such as locals and visitors to select travel means best suited to their needs.

5 DISCUSSION

As shown by the examples in this paper, for a PSS, with a clear vision of a delivery system that offers customer value, a requirements diagram can be generated. Engineers, designers, managers and other key company personnel may collaborate for the realisation of this requirements diagram.

For the analysis and conceptualisation of a PSS, a company captures customer, manufacturer and provision (product and service) requirements. These are then implemented to offer value propositions based on enhancing a product, making a product available or making the function of the product available to the customer.

5.1 SysML applications for product-service systems

Applying a systems modelling tool such as SysML for the design of a PSS can be beneficial in terms developing models to aid system collaborators in transforming customer requirements into functions and components. This is done to support systems development and to promote a common and clear vision of a system among system collaborators. The requirements diagram, an integral part of SysML can be used to models the requirements of a PSS as demonstrated by the examples in Section 4.

Furthermore, a major consideration for collaborators during PSS design involves designing the links and networks (with customers and other manufacturers) to aid PSS delivery, and the close knitting of services with products [11]. As a result, companies seeking to apply product-service systems will need to carefully analyse a PSS to capture key requirements to aid communication among PSS collaborators during development and delivery of a PSS. The requirements diagram offers a standardised notation that could be used to standardise communication of a PSS across departments or companies that collaborate to deliver a PSS.

In addition, the constructs of the requirements diagram are measures that SysML introduces to maintain traceability of requirements during systems design and development, to understand decisions made during design and to guide systems testing by creating test cases.

The requirements diagram is also a diagrammatic tool for maintaining traceability during the reconfiguration of a PSS. This is because it offers constructs that could enable PSS designers to explain the rationale for their decisions during the design process. Individuals are accountable for actions and can be consulted or contacted for further clarification on decisions.

5.2 Limitations of SysML

Developed recently, SysML is a new approach to systems modelling that is currently supported by relatively few tools and has not been accepted widely within the research community [14]. The approach also requires modifications and updates to enhance the use of the contained diagrams in industry. SysML like UML is developed as a notation for systems – not a methodology. Consequently, the use of SysML requires the study of the system to be modelled with the intention of: (1) understanding the characteristics of the system to be modelled, and (2) deciding on the level at which to model the system.

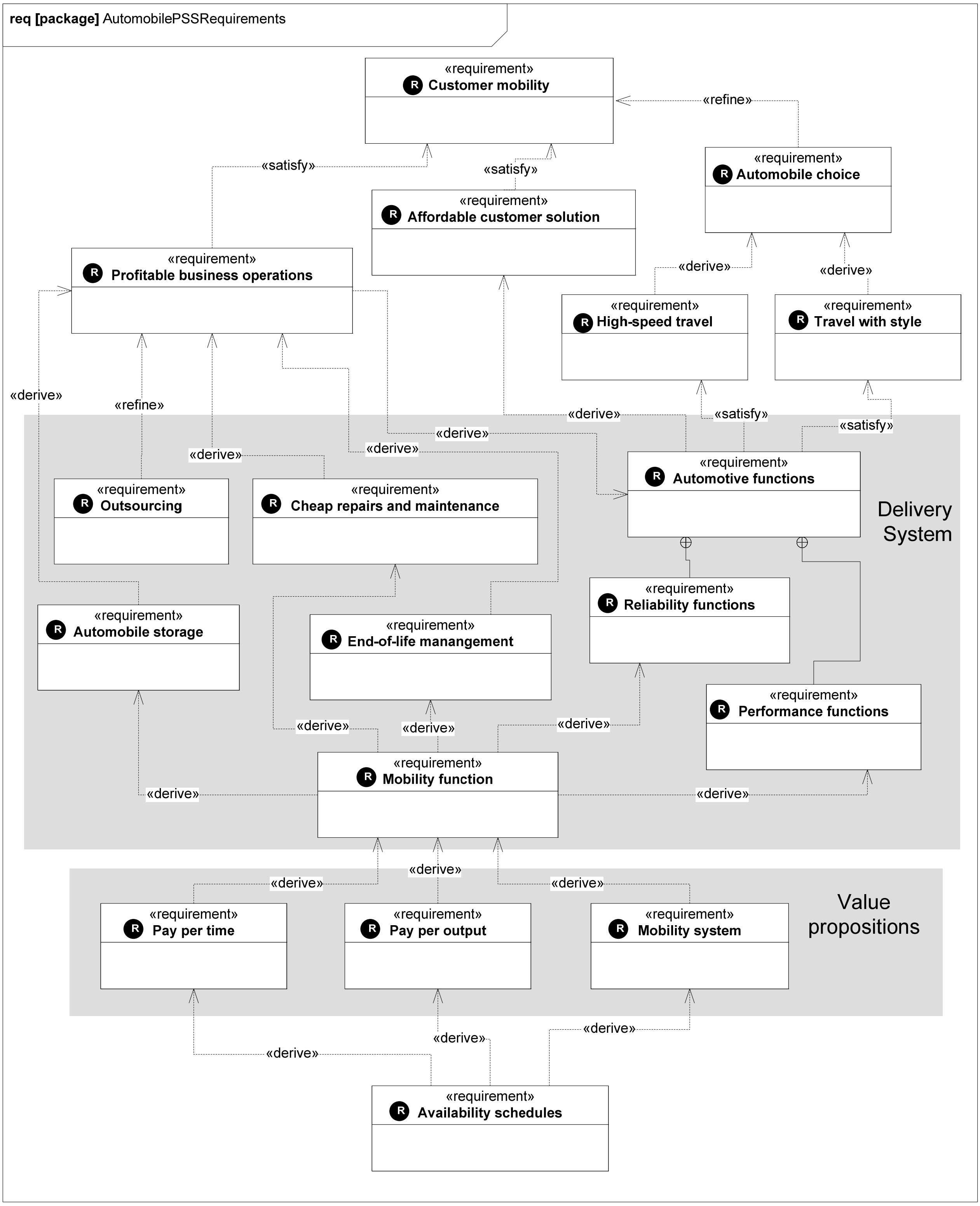

Figure 6: Requirements diagram for a result-oriented product-service system in the automotive industry

Nonetheless, SysML provides *visual representations* that are useful for modelling systems and *semantics* that show different aspects of a system such as structure, behaviour and requirements.

6 SUMMARY

A product-service system (PSS) is delivered as a system made up of intermixed product and service components for added customer value. The design for PSS delivery involves analysis, concept and implementation phases for realising value propositions based on product-, use- and result- orientations. As shown by the examples in this paper, the requirements diagram can be used to analyse the three orientations of a PSS. The requirements diagram is an integral part of SysML that can be used to trace initial requirements during the design and development of a system and capture design rationale in terms of how design decisions were made. SysML for PSS design provides standardised language for design, traceability of requirements, and the support for communication among PSS collaborators during development and delivery of a PSS.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Aurich JC, Fuchs C and DeVries MF, 2004, An Approach to Life Cycle Oriented Technical Service Design, CIRP Annals - Manufacturing Technology, 53(1), pp. 151-154.

[2] Balmelli L, 2007, An Overview of the Systems Modeling Language for Products and Systems Development, Journal of Object Technology, 6(6), pp. 149-177

[3] Object Management Group, 2009, OMG Systems Modeling Language (OMG SysML™) Version 1.1, online at: http://www.omg.org/spec/SysML/1.1, accessed 15 October, 2008

[4] Holt J and Perry S, 2006, SysML: Describing the system, Information Professional, 3 (4), pp. 35-37.

[5] United Nations Environment Programme, 2001, 'The Role of Product Service Systems in a Sustainable Society', online at:

http://www.uneptie.org/pc/sustain/reports/pss/pss-brochure-final.pdf, accessed 19 October, 2008

[6] Durugbo C., Tiwari A., Alcock J.R., 2009, An Info-dynamic Engine Approach to Improving the Efficiency of Information Flow in a Product-Service System in Proceedings of the 1st CIRP IPS2 Conference, pp. 107-112

[7] Baines T, Lightfoot HW, Evans S, Neely A, Greenough R, Peppard J, Roy R, Shehab E, Braganza A, Tiwari A, Alcock JR, Angus JP, Bastl M, Cousens A, Irving P, Johnson M, Kingston J, Lockett H, Martinez V, Michele P, Tranfield D, Walton IM, & Wilson H, 2007, The state-of-the art in Product Service Systems, Proceedings of the I MECH E Part B Journal of Engineering Manufacture, vol. 221, no. 10, pp. 1543-1552

[8] Tukker A, 2004, Eight types of product-service system: eight ways to sustainability? Experiences from SusProNet, Business Strategy and the Environment, vol. 13, no. 4, pp. 246-260

[9] Durugbo C., Tiwari A., Alcock J.R., 2010, A Review of Information Flow Diagrammatic Models for Product-Service Systems. International Journal of Advanced Manufacturing Technology (*Accepted for Publication*).

[10] Morelli N, 2006, Developing new product service systems (PSS): methodologies and operational tools, Journal of Cleaner Production, vol. 14, issue 17, pp. 1495-1501.

[11] Becker J, Beverungen DF and Knackstedt R, 2009, The challenge of conceptual modeling for product-service systems: status-quo and perspectives for reference models and modeling languages, Information Systems and e-Business Management, pp. 1-34.

[12] Friedenthal S, Moore A and Steiner R, 2008, Practical Guide to SysML: The Systems Modeling Language, Morgan Kaufmann.

[13] Williams A, 2007, Product service systems in the automobile industry: contribution to system innovation?, Journal of Cleaner Production, 15 (11-12), pp. 1093-1103.

[14] Vanderperren Y and Dehaene W, 2005, SysML and Systems Engineering Applied to UML-Based SoC Design in Proceedings of the 2nd UML-SoC Workshop at 42nd DAC, Anaheim (CA), USA.

Prioritizing Service Functions with Non-Functional Requirements

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Abstract

The early stage of service development primarily has two design phases: acquiring demands/constraints and determining delivering functions. The latter phase is significant in bridging the gap between design and implementation, as service providers in the IT industry have struggled in determining an appropriate combination of functions: IT-enabled functions and practitioners' activities. This paper focuses on non-functional requirements (NFR), and quantifies the value of respective combination of service functions from NFR perspectives by clarifying the relationships between NFRs, qualities and functions. Case studies on educational services show that the approach will provide us with a basis for determining respective function priority.

Keywords

PSS design, Service engineering, Non-functional requirements

1 INTRODUCTION

1.1 Gaps between design and implementation

Transformation from product-based business to service-based business is a trend in the manufacturing industry. Service is designed as an additional value for products: manual, maintenance, or providing communities for users. Service is also designed as an alternative value of products themselves: car sharing or rent-a-car provides a transportation function which automobiles have. Therefore, manufacturers will pursue design of products and services not from the viewpoint of superficial functions, but from values which deliver solidly to customers.

The IT system industry has also been following a service trend. Companies strive to increase efficiency in IT systems, and their investment will focus on outsourcing services or software as a service (SaaS) which replace the IT software and hardware platforms maintained by them. Due to this, there is an ongoing trend of shifting to services in various sectors of conventional software and hardware products.

However, vendors in those sectors have tried finding the most beneficial structure in service systems and designing functions in products and/or services by trial and error. This is attributable to the fact that service systems are composed of quantitative and non-quantitative functions. They are composed of visible functions delivered through software or hardware, and support human activities conducted by help-desk operators or maintenance engineers. However, service designers have mainly focused on realization of visible functional requirements because it is hard to determine the relationship between each functional requirement and the activities. As a consequence, they subsequently notice some non-functional requirements (NFR) are left abandoned and they face the necessity of realizing them. Then, they are forced to reassess requirements and functions to be delivered at the time of implementation.

1.2 Related work for bridging the gap

The study of PSS (Product-Service Systems) has discussed the functional values in products and service systems and how to redesign product functions as service functions [1]. Service Engineering have tried systematizing the ways to design functions to meet the customers' expectations [2, 3]. These approaches decompose the products into functions notionally as a service design framework. However, the decomposition starts from indentifying products' intrinsic functions, so attributes derived from the functions, such as supporting activities may be overlooked.

In Requirements Engineering, requirements elicitation and management have been discussed, and triaging requirements have become issues recently. Sankar and Venkat have focused on bridging the gap between requirements and design for products [4]. Herrmann and Daneva have instituted and contemplated the research area more clearly; how to prioritize requirements based on benefits and cost for the early phase of the software lifecycle [5]. Their classifications are 'fixed importance', 'requirements grouping', 'using relative values instead of absolute ones', 'determining relative values by pair-wise comparison', 'using discrete values instead of a continuous scale', and 'building benefit intervals instead of using one value only'. As these research projects still focus on software/hardware products and classifications are domain specific, further research on standardizing the process should be done by shifting the focus to services.

Therefore, this paper focuses on NFRs for service development, clarifying the relationship between NFRs and degree of quality factors, and the relationship between NFRs and functions. The relationships enable quantification of the value produced from the combination of functions, and they are to provide the basis for prioritizing functions to be delivered.

2 NON-FUNCTIONAL REQUIREMENTS (NFR)

NFRs are essentially requirements which cannot be described in the normal functional description. They are qualitative requirements which contribute to the maturity of the system: performance of response speed, reusability, reliability, or availability of the system. Usually, functions are designed for realizing requirements because system developments are recognized to be as successful only if such functional requirements are clearly defined. However, unless the goals and background of the system development are written and shared among stakeholders, some functions may not be utilized when they are delivered. Furthermore, if some attributes of the functions are not clearly defined, the system will not attain expected levels of performance or usability and such functional design would have to be reassessed. Defining NFRs in the early design phase will address a large number of problems in the ensuing phases. Although, industries have, through their experience, developed a body of knowledge about NFRs, the academia has been trying to establish a model to explain the value of NFRs and the impact or role of NFRs.

2.1 NFR Standardization

As a yardstick among stakeholders, classifications have been specified mainly in software development. IEEE std 830-1998 was established to specify NFRs for software products to prevent oversight [6]. Their NFRs are performance, safety, security and other quality attributes. ISO09126 also defines items to measure the quality of software [7]. These items are composed of quality attributes and their detailed elements. The quality attributes are functionality, reliability, usability, efficiency, maintainability and transitivity.

2.2 NFR Management

On the other hand, goal-oriented approach has been discussed in academia to comprehend NFRs in system development. The approach enables us to identify not only the basis for users needs, but also to specify the respective functions or activities that will satisfy the needs or expectations [8]. A goal-oriented model provides and overviews of the objectives and the alternatives to achieve the goals. The approach may uncover constraints which may have been disregarded.

The standardization targets on developing a body of knowledge but does tell you how to utilize it whereas as a goal-oriented approach attempts to elicit various requirements from stakeholders to reduce the risks of development reassessment, although decisions on choosing functions differ according to managers' experience.

The approach we propose provides objective design assessment by accommodating good aspects of these activities. As an initial part of our proposed methodology, the next sections describe the way to determine the service boundaries and estimate benefits of service functions within the boundary. The preliminary section of our methodology begins by establishing users' behaviour.

3 IDENTIFYING SERVICE FUNCTIONS AND SYSTEM BOUNDARIES

Unlike with product, service has unique features: intangibility, simultaneity, heterogeneity and perishability. These evanescent features make us realize again that introduction and aftercare of a service are important factors for customer satisfaction. In order to perceive these circumstances in user-oriented way, the authors have proposed a methodology of persona-centric service design [9]. The methodology denotes all stakeholders involved in a service system as personas. Persona is defined in two ways. One is the 'User Persona', who will be the final user of the service. The rest of the stakeholders are denoted as 'Role Personas', who have missions in their organization. A user persona has an 'important value list' and 'use cases for each phase'. A use case divided by each phase of service encounter is a combination of 'scenario' and 'degree of importance'. A role persona has a 'function list', which denotes each function provided to other personas.

The following are persona-oriented methodologies to clarify service system boundaries for business to business (BtoB) and business to customer (BtoC) services.

3.1 System Modelling for BtoC Service

First, personas on the receivers' side are modelled as follows:

1. Collect a mass of individual information on services - how much importance they put on quality - through questionnaires to target a user group.
2. Cluster these collected data and choose an arbitrary group that has characteristics suitable to the target based on business decision-making.
3. Extract important value data from information on quality importance degree by methods such as multivariate analysis. Then, list the extracted results as an important value list.
4. Interview some individuals who are in the group mentioned above and make a list of important values.
5. Compute a degree of similarities with the important values, and identify the person with the highest similarity. Then, complete user persona information by using the use case as supplementary information for the user persona.

   Then, personas on the providers' side and the whole service system are modelled in the following steps.

6. Nominate stakeholders in service providers and receivers, and nominate functions that each persona gives to other persona. Then, make role personas. With interview results, put importance on each function and complete role persona information.
7. Correspond between each use case and a function in role persona one-to-one.
8. Confirm whether each use case based on the process of user persona is at all related to any function of role persona. When there is no corresponding function in role persona, analyzing and extracting role persona would be inappropriate. In this case, extract functions in provider again until they correspond to both sides perfectly.

3.2 System Modelling for BtoB Service

As the behaviour of receivers of BtoB services follows business roles, [10] refines the persona elicitation phase (steps 1-6) and substitutes them with the following steps. The steps add business process-oriented ways to indentify stakeholders and their requirements.

1. Draw the target business process as a set of business activities. Identify groups which are in charge of doing the activities. The groups are usually equivalent to each division in their organization.
2. Draw business goals and categorize them according to balanced score cards (BSC) which have four points of view: financial, process, customer and learning views. Then, set the degree of importance to each sub-goal, and find groups which are related to the goals in the category of business processes. The identification follows the degree of relevance which is calculated from the degree of importance of each goal, using something like an arithmetic-geometric mean alogrithm.
3. Nominate role personas from step 1 which identifies directly related stakeholders and step 2 which identifies indirectly related stakeholders.

Necessary and sufficient stakeholders with functions will be extracted from these steps. As a result, flows of service functions between provider and receiver are clarified as shown in Figure 1, and the service system boundary is identified in persona centric ways.

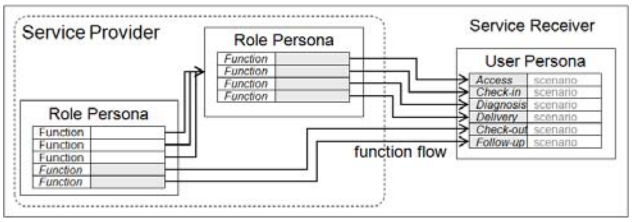

Figure 1: Service Function Flows

The next section shows the latter part of the method: how to acquire hints to optimize service design by assessing the benefit of service systems in various aspects through reframing functions.

4 DESIGN ASSESSMENT

Innovative services will be realized through unbundling and re-bundling service functions in service systems to maximize the total benefit. The NFRs are classified as ‘quality requirements’ and ‘technical requirements’ (Figure 2). NFR and quality requirements are treated on an equal basis in some classifications. However, this paper regards technical requirements as equal to functional requirements, so the NFRs are regarded as a superset of functional requirements (FR).

4.1 Relationships between NFR and Quality

Quality contributes to customer satisfaction directly, so qualities are described as metrics which describe personal sensitivity, perception, or tastes. Service qualities in BtoC services are quite sensitivity oriented, though qualities of BtoB services are productivity oriented. So, the relationships are defined as follows.

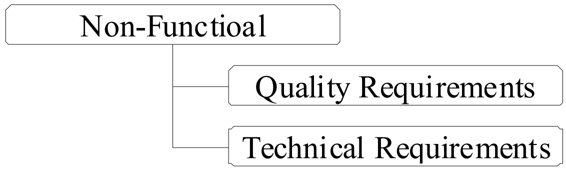

Figure 2: NFR elements

NFR-Quality Requirements for BtoC

The human sense of values has been classified in lexicons and lists [11, 12]. These values will come to the surface as qualitative requirements. In software development, qualitative requirements are classified as non-functional requirements: ‘usability’, ‘security’, ‘reliability’, ‘performance’, ‘portability’, and ‘customizability’ [6]. To some extent, relationships were found between the quality vocabulary and non-functional requirements. Most of the quality elements can be associated with non-functional requirements which regard to their concept. The NFR-quality list is then defined. A part of the list of representing factors is shown in Table 1.

NFR-Quality Requirements for BtoB

Qualities of BtoB services will be described as metrics which directly indicate productivity in their business. For business purposes we introduce NFR categories for BtoB: ‘availability’, ‘performance’, ‘maintainability’ ‘assimilation’, ‘security’, and ‘environment’. The elements in the table are defined by referencing the guidelines and grades of NFRs which are developed under the consortium of IT vendors [13]. Then, quality factors for BtoB are defined. A part of the list is shown in Table 2.

4.2 Relationships between NFR and Function

From a view of realizing NFRs, NFRs will be visible functions, though some functions will have to be delivered as human activities. The NFRs are then denoted as physical and non-physical functions in Figure 3.

Table 1: Part of NFR – Quality Factors for BtoC

NFR	Quality Factor				
1. usability	low cost	reasonable price	value	low cost	low expenses
2. performance	comfort	refreshment	enjoyment	freedom	carefree
3. security	safety	ease to understand	fairness	justice	kindness
4. reliability	certainty	certainty to complete	processing certainty	source certainty	appropriateness
5. portability	easiness	coziness	comfort	optimism	agility
6. customizability	uniqueness	individual identity	uniqueness of time	locality	originality
	...	...	...	...	...

Table 2: Part of NFR – Quality Factors for BtoB

NFR	Quality Factor				
1. availability	business continuity	fault tolerance	contingency planning	recovery performance	maturity
2. performance	business performance	response performance	performance throughput	resource extensibility	performance guarantee
3. maintainability	operation time	back up	monitoring	recovery method	precaution
4. assimilation	integration schedule	deployment method	data volume migration	medium for migration	rehearsal
5. security	compliance	risk analysis	authentication	device limitation	encryption
6. environment	conformance	place, location	system prerequisite	system characteristics	disaster recovery
	...	...	...	...	...

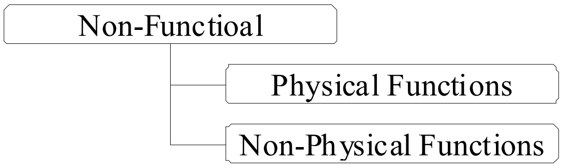

Figure 3: Elements of realizing NFRs

4.3 NFR-Quality and NFR-Function

Using each NFR as a common denominator of 'NFR-Quality' and 'NFR-Function', NFR, quality elements and functions will be associated. Though technical requirements obviously presume specific service functions or activities, quality requirements will be realized in combinations of these functions and activities. Therefore, the relationships are denoted in the model in Figure 4. The relationships are the model which integrates the elements classified in Figure 2 and Figure 3.

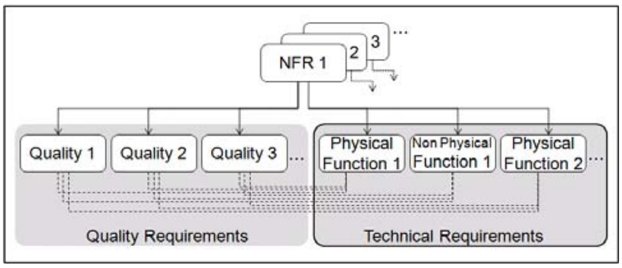

Figure 4: NFR-Quality-Function Relationships

Quantifying Service Values

The effects of service can be evaluated from various perspectives. When service providers promote and propose their services to possible customers, they need to demonstrate those effects, not only the cost value but also other values for customer satisfaction. The factors for customer satisfaction can be dealt with by NFRs, i.e. safety for 'reliability' and speed for 'performance'.

In order to quantify the effectiveness of designed service systems, two attributes are to be set to quality elements and functions respectively in the NFR-quality-function relationships. Degree of importance is an attribute for each quality element, as it contributes to customer satisfaction. In the same way, the second attribute - delivery cost is an attribute for each function will determine the price of the services which may also affect customer satisfaction.

4.4 Design Assessment

Using the models mentioned above, a system is designed through assessment steps which incorporates the procedure identified in Section 3. The respective steps are listed as follows.

1. Use the NFR-quality list, and reconfirm any overlooked quality elements which have to be considered.
2. Define the relationships between quality and function. First, link behaviour/activity of each phase of service encounters and important quality factors in the NFR-quality list. Second, identify service functions which correspond to these behaviour/activities, and match the quality factors and the service functions.
3. Review each relationship by confirming whether the quality factors and the functions are in the same NFR category. Separate the relationship into ones for every NFR, when they are in different NFR categories. (e.g) Increasing performance level may lead to decreasing security level.
4. Set the degree of importance to each quality element and set the delivery cost for each function in the relationships.
5. Select service functions to deliver using the relationship. The selection will quantify the satisfactory quality level and the delivery cost in total. Then, bundle the quality elements with each NFR category to make the expected effects comprehensible. Then, compare the results by changing selection of service functions. This will review redundancy, scarcity and feasibility of delivering service functions from both providers' and receivers' viewpoints.

Modelling and Assessment Tools

In order to assist these steps, the authors have implemented modelling and assessment tools as a part of the value co-creation framework [14]. The framework shown in Figure 5 has modelling tools for service objectives, stakeholder comprehension, relationships of quality and function, and design tools for structure of service systems and assessment tools for the values of service systems. Figure 6 is a screenshot of the NFR-quality-function modelling tool. The tool depicts function flows with usability perspective. Users' scenarios are inserted into the diagram to depict the relationships between users' behaviour and service functions in detail. It explains what quality elements are associated with non-functional requirements, and what outcome is to be expected when patterns of combinations are changed. The middle layer consists of quality elements (or receivers' state parameters: RSPs) which are linked to activities will affect customer satisfaction. The quality elements affect it positively or negatively, when new functions substitute for users' activities. They may improve customer satisfaction if the delivering functions have links to the qualities which target users think important and if these functions are delivered at reasonable cost. They may reduce the customer satisfaction if the delivery functions exert a harmful influence upon other quality factors or if the delivering functions result in an unreasonable high price of services. These assessments, through reframing functions, are exemplified in the following case study.

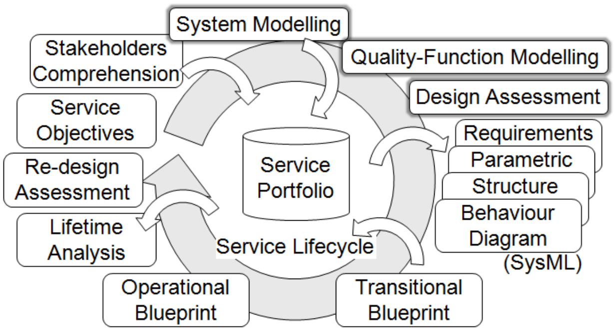

Figure 5: Lifecycle Management Framework

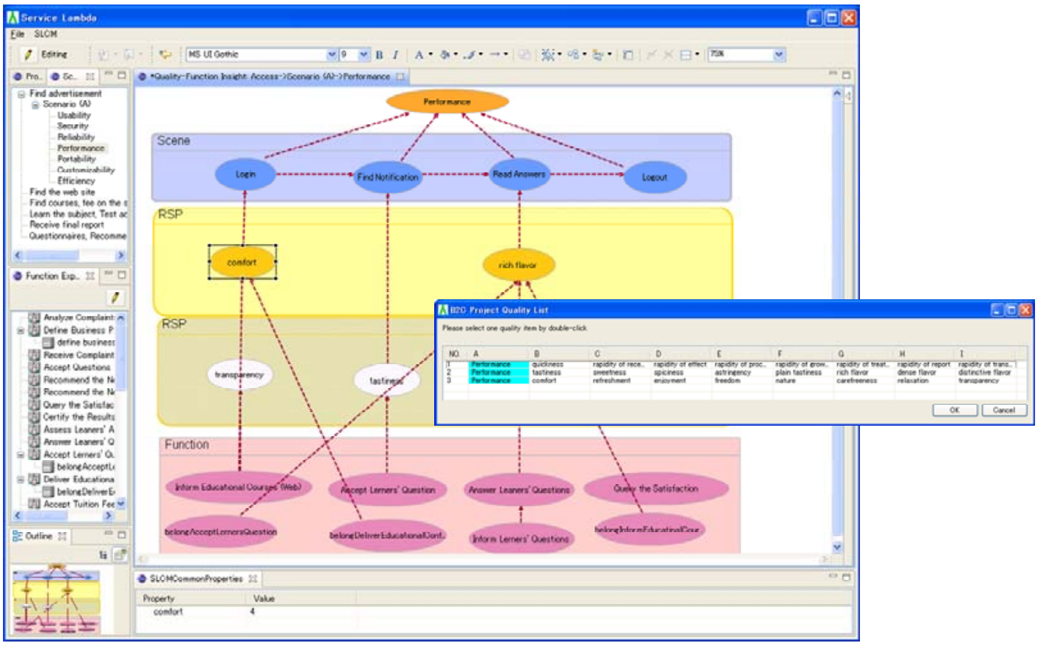

Figure 6: Quality-Function Modelling

5 CASE STUDY

5.1 Software as a Service

The first case study is about e-learning service design as a BtoC service. E-Learning services have replaced conventional classroom education with virtual class, and the electronic material are used instead of text book, although essential functions delivered are the same in both services. The electronic materials are not sold as software product, but as a form of software service. The service will be re-utilized by different clients and delivered as an online service.

Identifying System Boundary

From the list of the users' activities (Table 3), service functions of the provider will be ascertained. In the process of modelling user personas and role personas, the system boundary will be established.

We have applied the methods and tools to different education services in both BtoC and BtoC domains.

Table 3: Users' Activities

Phase of Service Encounter	Users' Activity
1. access	(1) being aware of services
2. check-in	(2) finding popular courses
3. diagnosis	(1) experiencing free-trials (2) comprehend course outline (3) applying for course
4. delivery	(1) logging in/out of the system (2) reading the content (3) taking the tests
5. check-out	(1) asking questions
6. follow-up	(1) considering taking next courses

Then, scope of the service system - the service boundary – is determined as shown in Figure 7, and this scope is to be optimized through reframing service functions.

NFR – Quality Requirements

The user persona's characteristics were established based on the results from questionnaires in Table 4 and in-depth interviews. The target user personas - self-motivated person - are thought to have the ability to study by themselves to some extent. Therefore, they put a high degree of importance on 'usability', 'speed' and 'low price' for activities. Other significant factors are also elicited from the gaps between importance and expectation. Table 5 shows the factors elicited with these steps.

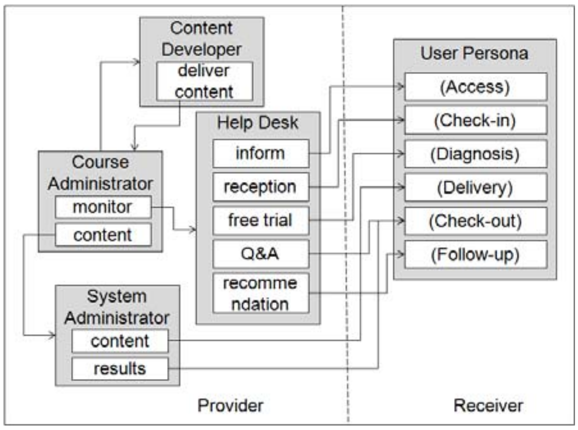

Figure 7: E-learning Service System

Table 4: Quality Factors for the Target

	(high) importance (low)					(high) expectation (low)				
	5	4	3	2	1	5	4	3	2	1
ease	32%	41%	20%	3%	3%	15%	43%	33%	7%	2%
credibility	20%	49%	24%	4%	2%	5%	35%	47%	10%	3%
quickness	21%	42%	31%	3%	3%	10%	36%	45%	8%	2%
appeal	22%	41%	29%	5%	2%	7%	30%	48%	12%	3%
intellectuality	16%	39%	41%	2%	2%	5%	33%	54%	6%	2%
low price	27%	38%	28%	4%	3%	6%	29%	48%	12%	5%
certainty	14%	45%	34%	4%	2%	5%	27%	54%	12%	3%
sincerity	15%	41%	36%	6%	2%	4%	27%	53%	13%	3%
trend	17%	39%	35%	6%	2%	8%	30%	53%	6%	3%
gainfulness	14%	36%	43%	5%	2%	5%	27%	59%	7%	3%

Table 5: Important Quality Requirements

usability	
low cost	reasonable price
performance	
speed	quickness
portability	
easiness	ease

NFR – Quality – Function Modelling

Then, find services function, and find quality factors from the important factors for the user for each activity in Table 3, and link between them as shown in Figure 6.

Design Assessment through Reframing Functions

With these design information, we could estimate changes of the effects of service functions in each non-functional requirement and cost. ‘Quick response’ scored the same, but ‘courteous response’ scored much higher in the provider side. Therefore, the function which corresponds to them could include redundant or excessive features to the users. Figure 8 shows the results of not providing the function: comments and reviews for the learners’ final tests. This simulation will help to establish the appropriateness of the design and assist in prioritizing requirements in the service systems.

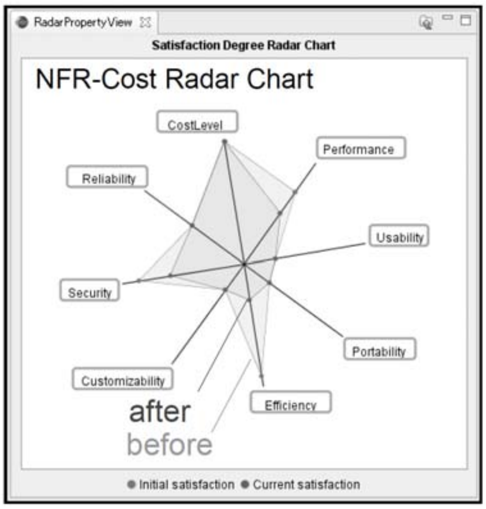

Figure 8: Design Assessment on SaaS Service

5.2 Business Process Outsourcing Service

The second case study is about a business process outsourcing (BPO) service as a BtoB service. Many companies in Japan welcome newly recruited businessmen in April. They take training courses for basic business skills for a month. The courses are not specific to the company, but consist of common skills on business occasions: business manners, skills of PC software/hardware, presentation, or reporting. The instructions are ordinarily instructed by the managers in HR divisions.

Identifying System Boundary

The business process of the training courses consists of the activities in Table 6.

Education vendors can customize the contents or course schedules, and provide these training courses to their clients to replace the client business process.

NFR – Quality Requirements

These activities in the business process are the base determining the service boundary. The NFRs and quality factors were elicited within it. The Table 7 lists some NFR and quality characteristics which are elicited utilizing the Table 2. They are not directly implemented as physical functions. These functions will be realized with functions provided as activities.

Table 6: User-*to-be*’s Activities

Phase of Business Process	Users’ Activity
1. plan	(1) training planning (2) post planning
2. grand design	(1) WBS development (2) schedule planning (3) cost planning (4) quality planning
2. grand design	(5) cultural fit (6) best practice benchmarking (7) human resource planning (8) communication planning (9) risk management (10) security/privacy management (11) compliance (12) procurement planning (13) kick-off scheduling
3. procurement	(1) instructors (2) classrooms (3) equipment (4) teaching materials
4. pre-delivery	(1) distribution planning (2) distribution arrangement (3) class guidance (4) place guidance (5) class/member partitioning
5. delivery	(1) checking just before class (2) attendance checking (3) comment on daily report (4) troubleshooting (5) report on class (6) comment on class (7) intermediate report (8) course modification management
6. evaluation	(1) writing final report (2) final report arrangement
7. improvement	(1) budget evaluation (2) employees' performance evaluation

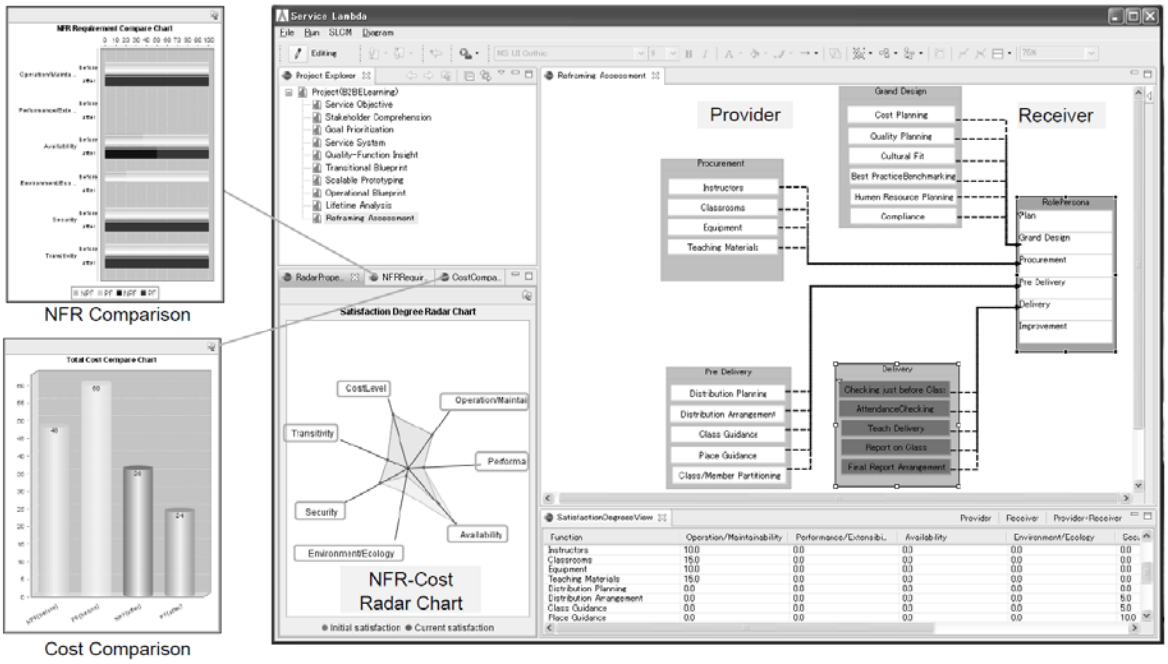

Figure 10: Design Assessment on BPO Service

Table 7: Important Quality Requirements

Availability	
operation schedule	all work days in April
business continuity	providing training classes
business continuity	risk of losing instruction skills
operation/maintainability	
Monitoring	ease of checking attendance
Assimilation	
migration equipment	replacement of classrooms
migration medium	update of vendors' textbook
migration work allotment	ease of task transfer
security	
compliance	compliance
security risk	data leakage risk
access control	management of employees information
data security	management of internal information
environment	
place	convenience of transportation

The degree of importance is set for each quality and delivery cost is set for each function according to the functions and qualities are identified going through respective step by step. Then, we are able to quantify the value of service systems. The following demonstration will assist in reaching a consensus between providers and their expected client.

NFR – Quality – Function Modelling

As shown in the BtoC case study, the relationships between quality factors and functions were established every NFR perspective, using the tool in Figure 6.

Design Assessment through Reframing Functions

Then, the benefits of delivering functions can be assessed. All or parts of the activities from 2 to 6 in Table 6 can be outsourced as shown in Figure 9. For example, activity 5 will not be outsourced when employees from a user's company act as instructors. The outcome of this simulation example is illustrated in Figure 10. The visualized form will contribute for reaching consensus between the education course provider (outsourcer) and the receiver (user company) in when proposing the services.

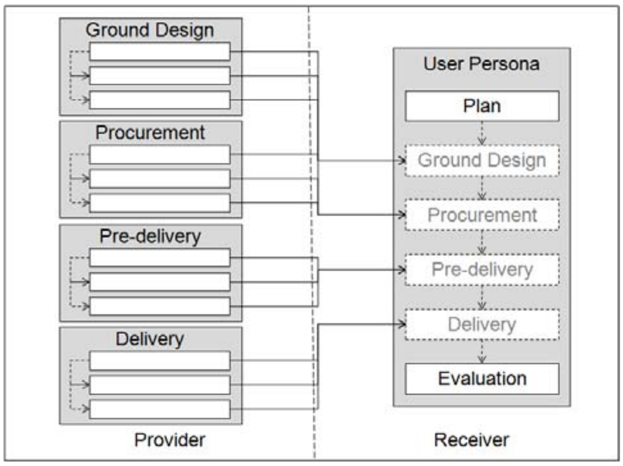

Figure 9: Fully Outsourced Functions

6 CONCLUSION

This paper establishes a framework, which identifies the respective priorities to be delivered. The framework introduces:

(1) the NFR-quality factor lists for BtoC and BtoB, which will reduce the risk of overlooking users' requirements.

(2) the integration models of quality requirements and realizing functions, establishing relationships between users' quality/price requirements for functions and providers delivery costs for them.

Although service decomposition produces a certain number of functions with its diverse relationships pertaining to quality and costs, the NFRs enable categorization of such functions into simple comparative models. In consequence, the framework enables the consideration of both providers' and receivers' demands and the design of feasible service systems.

The case study on SaaS and BPO services are totally different business domains but they show that the approach is applicable to both BtoC and BtoB services.

Decision making has traditionally relied on experience and perceptiveness in many cases. However, the framework will provide the way to a quantitative and objective approach to the value of the respective services and assist in better decision making.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J. R., Angus, J. P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I. M., Wilson, H., 2007, State-of-the-art in Product Service Systems, IMechE, Part B: Journal of Engineering Manufacture, 1543-1552.

[2] Arai, T., Shimomura, Y., 2004, Proposal of Service CAD system – A tool for Service/Product Engineering -, Annals of the CIRP, 53(1), 397-400.

[3] Arai, T., Shimomura, Y., 2005, Service CAD system – Evaluation and Quantification-, Annals of the CIRP, 54(1), 463-466.

[4] Sankar, K., Venkat, R., 2007, Total Requirements Control at Every Stage of Product Development, Proc. of 15th IEEE Int'l Conf. on Requirements Engineering, 337-342.

[5] Herrmann, A., Daneva, M., 2008, Requirements Prioritization Based on Benefit and Cost Prediction: An Agenda for Future Research, Proc. of 16th IEEE Int'l Requirements Engineering Conf., 125-134.

[6] IEEE std 830-1998., Available at: http://standards.ieee.org/reading/ieee/std/se/830-1998.pdf (accessed 10th Nov. 2009).

[7] ISO, ISO/IEC 9126-1:2001, Available at: http://www.iso.org/iso/iso_catalogue/catalogue_tc/ca catalog_detail.htm?csnumber=22749. (accessed 10th Nov. 2009).

[8] Yamamoto, S., Kaiya, H., Cox, K., Bleistein, S., 2006, Goal Oriented Requirements Engineering: Trends and Issues, IEICE Transactions on Information and Systems, 2701-2711.

[9] Hosono, S., Hasegawa, M., Hara, T., Shimomura, Y., Arai, T., 2009, A Methodology of Persona-centric Service Design, CIRP Design Conference, 541-546.

[10] Kuno, A., Hosono, S., 2009, A Method to Identify Stakeholders and Their Requirements at Early Stage of Service Development, Forum on Information Technology, 327-332 (In Japanese).

[11] Murakami, Y., 2002, A collection of basic personality trait words, The Japanese Journal of Personality, Vol.11, 35-49.

[12] The University of Tokyo, 2008, Report on Service Engineering Methods Toward Increasing Customer Satisfaction and Productivity, Investigation Project to Increase Productivity in the Service Industry (In Japanese).

[13] NTT Data Corp., Fujitsu Ltd, NEC Corp., Hitachi Co. Ltd., Mitsubishi Information Systems, Oki Electric Industry Co., Ltd., 2009, Consortium of Standardizing Grades of Non-Functional Requirements, Available at http://www.nttdata.co.jp/nfr-grade/result.html. (accessed 10th Nov. 2009, In Japanese).

[14] Hosono, S., Kuno, A., Hasegawa, M., Hara, T., Shimomura, Y., Arai, T., 2009, A Framework of Co-creating Business Values for IT Services, Proc. of IEEE 2009 Int'l Conf. on Cloud Computing -CLOUD-II, 167-174.

Understanding Information Requirements in Product-service Systems Design

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Abstract

Service information is the information that is required to support the taking of decisions and actions in a service environment. In product-service systems (PSS) this information includes both information to support the lifecycles of physical products and associated services and information to support the management of services. Service blueprinting techniques have been used for visualising and mapping service activities. Effective delivery of service demands access to high quality service information (i.e. complete, correct, minimal and available to the right people at the right time). In this paper we extend the concept of the traditional service blueprint to include service information needed to deliver PSS. Three types of service information are considered: input information, process information and output information. The result is a Service Information Blueprint. In this paper we demonstrate, using a case study, how the service information blueprint is influenced by changes in service definition and contract type.

Keywords

Service Information, Service Blueprint, Information Requirements, Product-Service Systems, Computer-Aided Design

1 INTRODUCTION

In the move to product service systems, the delivery of engineering excellence demands the delivery of excellence in both physical products and associated through-life services. Emerging service products strive to deliver availability and capability to customers. As with physical products, the delivery of service excellence begins in the very early stages of the service lifecycle when contracts are developed and agreed. A key to the delivery of service excellence lies in defining contracts that are feasible and affordable for delivery. Once a contract has been agreed the service product is developed and then delivered. Access to high quality information (complete, correct, minimal and available to the right people at the right time in a form that they are able to use effectively) is key at each phase of service development and delivery: contract definition, service definition and service delivery.

This paper highlights the importance of service design representations including service information needed for the delivery of the product-service system. The concept of traditional service blueprint has been extended to introduce the concept of Service Information Blueprint. Section 2 provides a literature review on key tools and techniques for defining product-service systems. Section 3 focuses on service information requirements in product-service systems. Section 4 introduces the Service Information Blueprint model and a software prototype built on this model. Section 5 presents a case study on a coffee making machine repair service and applications of this case study data to the Service Information Blueprint model for availability type contract. Results from the research are presented in Section 6 and discussed in Section 7.

2 TOWARDS THE DEFINITION OF PRODUCT-SERVICE SYSTEMS

2.1 Definitions of physical products and service products

A product-service system is a system composed of a physical product and associated services that support the product through its life [1]. Current thinking on the dual nature of technical artefacts argues that technical artefacts have both designed physical structure and intended functional structure. On intended functional structures, Vermaas and Houkes, in their ICE (Intentionalist, Causal-role, Evolutionist) theory [2], assert that when engineers ascribe functions to artefacts they have to consider explicitly the goals for which agents use artefacts and the actions that constitute their use; the agents' actions are captured in a "use plan". A number of papers resulting from this work [3] include discussions on the distinction between function, behaviour and capacity of physical artefacts. The service element of a product-service system might be usefully regarded as a form of use-plan for the product; as such, it can be argued that product designers (when designing products for product service systems) need an awareness of the service requirements in addition to traditional usage requirements.

If services are regarded as products, or parts of product-service systems, then the following questions arise:

- What are the intended functional structures of service products and how might they be represented?
- How might product definitions for service products be formulated?

An initial analysis of product definition for goods and services is provided in Table 1.

2.2 Service definition tools and techniques

Over the years a number of tools and techniques have emerged for defining services that deal with complex systems. These are taken from the fields of social and behavioural sciences, business, design and information technology. They are often tailored to aid designers in a

Product (artefact – goods) definition	Product (service) definition parallels
Product definitions include data related to specification, definition, actuals [4], i.e., what is required, what has been designed and what was actually delivered.	There are differences in the detail of how the data is represented but the high level concepts of specification, definition and actuals appear relevant to services.
Product specification – requirements and links to stakeholder needs [5]	For services, Service Level Agreements seem to constitute a service specification.
Product definition – what is defined depends upon the kind of product and the Product Development Process being used, specifically, the information required at each stage gate and through key process steps	To understand parallels, we need to understand more about the Service Development Process. For ABB(Asea Brown Bovery) Full Services, this is the Full Service process phases (and decision points).
Actual products – these are the physical artefacts that are delivered to customers	A key difference between goods and services is that the "manufacture" and delivery of services are done at the same time, and services are transient.
Product definition/representation: structure and relationships to capture are key [6]	Product definition includes shape and constitution whereas service definition includes a process definition. The detail of this will form a part of the case study.

Table 1: Initial analysis of product definition for goods and services (reproduced from [1])

variety of ways throughout the service definition process in the projects they work on. Tassi [7, 8] presented a collection of these tools and techniques according to: (i) the design activities they are used for (e.g. envisioning, designing/co-designing, testing and prototyping, implementing); (ii) the kind of representation they produce (e.g. texts, graphs, narratives, models, games); (iii) the recipients they addressed to (e.g. stakeholders, professionals, service staff, users); and (iv) the contents of the project they can convey (e.g. context, system, offering, interaction). Further tools and techniques can be found in [9].

Service blueprinting approaches have traditionally been used to capture service-only products (e.g. services in hospitality and financial sectors). The research reported in this paper explored the application of the service blueprinting technique to define technical services associated with repair and maintenance activities (e.g. of a coffee making machine). Key aspects of a service blueprint are summarised below.

A service blueprint is built around the principal stages (i.e. key process steps) of the service and two axes: (i) a horizontal axis representing the chronology of actions conducted by the service customer and the service provider and (ii) a vertical axis that distinguishes between different areas of actions - these areas of actions are separated by different 'lines'. Each principal stage has its own service standards, scripts and guidelines which relate to the target performance levels of the service. The association of physical evidence with principal stages of the service addresses the intangibility of the service itself. Two kinds of process are associated with the principal stages: principal actions and support processes. Principal actions can be three types: onstage principal actions by the customer, onstage and backstage principal actions by the service provider's customer contact personnel. A service provider's principal actions and support processes interact with IT resources. For technical services these could include engineering information systems. The visibility of the sub-processes that form processes in the service definition is governed by their positioning on the blueprint relative to a number of visibility and interaction lines. If the enactment of a service blueprint is seen as a simultaneous production and consumption of the service then these lines govern who sees which parts of the delivery of the service.

3 INFORMATION REQUIREMENTS IN PRODUCT SERVICE SYSTEMS DESIGN

3.1 Service information

Information has been described as 'the lifeblood of the organization' [10] and 'the most valuable resource in industry today' [11] but it is also recognized that information is an often undervalued resource and difficult to manage. However, if properly managed, the value of information can grow over time. Information is important in service development and delivery as a means of enhancing decision-making processes. Information per se has no direct value but the impact of improved information quality can both reduce costs and enhance service performance. In the context of product servicing, information can provide details about the condition and usage of the product. In a service delivery context, on the other hand, information provides the contractual requirements of the customer to enable service delivery decisions to be made.

For this paper, service information refers to all the information that is required to support the taking of decisions and actions in a service environment. A service information system is a system (which may itself be a collection of systems) which provides the information required to take key decisions and actions in a service environment [12].

3.2 Service information requirements

Zeithaml et al. [13] identify five quality gaps in service delivery that may result in service failure. Recommended by Zeithaml et al. [13] and distilled by Lovelock and Wirtz [14] are a number of managerial strategies that should be taken to close the service quality gaps. Several of them are related to improving the management of service information. Effective delivery of service demands access to high quality service information (i.e. complete, correct, minimal and available to the right people at the right time).

McFarlane [15] asserts that the information requirements for support service solutions are multifaceted and highly dependent on the nature of the offering and the underpinning service agreement. Defining information requirements is perhaps the most neglected aspect of the information management process. Berkeley and Gupta [16] survey information required to deliver quality services involving high customer contacts. In high customer contact services, a firm's ability to deliver a quality service depends on its capacity to collect, process, distribute and use information. According to Berkeley and Gupta [16], service-delivery process can be broken down into input, process and output stages. They classify information required for delivering quality services into three broad categories: input information, process information and output information.

Input information refers to the information needed before the service is actually being delivered. This includes but is not limited to information related to: (i) identification of customer requirements and/or expectations; (ii) service provider's perception of customer requirements and/or expectations; (iii) definition of service specifications and standards; (iv) service definitions; (v) service history/records; (vi) demand and capacity planning; (vi) customer instructions. Process information is the information actually required by the service provider and the service recipient while the service is actually being delivered. This includes but is not limited to information related to: (i) knowledge to perform the service; (ii) job status; (iii) security and safety; and (iv) quality control/assurance.

Output information refers to information that is available after the service is delivered and as results of the service. Output information can be exploited for future use (e.g. as input information for the next cycle of service delivery, to judge the extent to which the service met customer expectations and needs or to inform the design of the next generation of services) [16]. This includes but is not limited to information related to: (i) internal quality measures; (ii) external quality measures; (iii) customer feedback (suggestions, complaints and compliments); (iv) service recovery; (v) service actually delivered; and (vi) changed state of the service recipient (as a result of the delivered service) [17].

A key aspect of product-service system lies in the need to support through-life product information. Kundu et al. [18] observe that the transition from product to product-service system delivery requires that engineering information systems change to meet new demands to support product data needed for the effective delivery of lifecycle services, including data generated through the whole life of the product, and the rationale behind decisions that were made through life. This is because over the extended time-span of a product's lifecycle, as opposed to its realisation, the people who created this information are increasingly likely to be unavailable to provide comparable support for the both service as well as physical product.

At each stage of the lifecycle of a complex engineering product, the needs of the various stakeholders involved are different and distinct. Designing, servicing, maintaining and upgrading a product are all knowledge intensive activities. Each of the different stakeholders (with different sub-problems and goals) in these stages has different knowledge requirements [19]. Also, since these stakeholders have a variety of information needs, it is likely that they would make different demands of a knowledge and information management system, such as Product Lifecycle Management (PLM) [19]. In order for knowledge management systems to provide efficient lifecycle support it is necessary to understand their knowledge requirements and the information flows between different stakeholders. McKay et al. [20] argue that the strategy of establishing future-proofed product information to support future lifecycle processes will fail in situations where the information requirements of the processes are not anticipated far enough in advance. To address this weakness, McKay et al. [20] propose an integrated product, process and rationale model that allows the definition of multiple product structures for a given artefact. The product structures can be created to suit the lifecycle stage and people (i.e. users) concerned. The inclusion of process, enterprise and rationale information allows the context within which information was created to be captured.

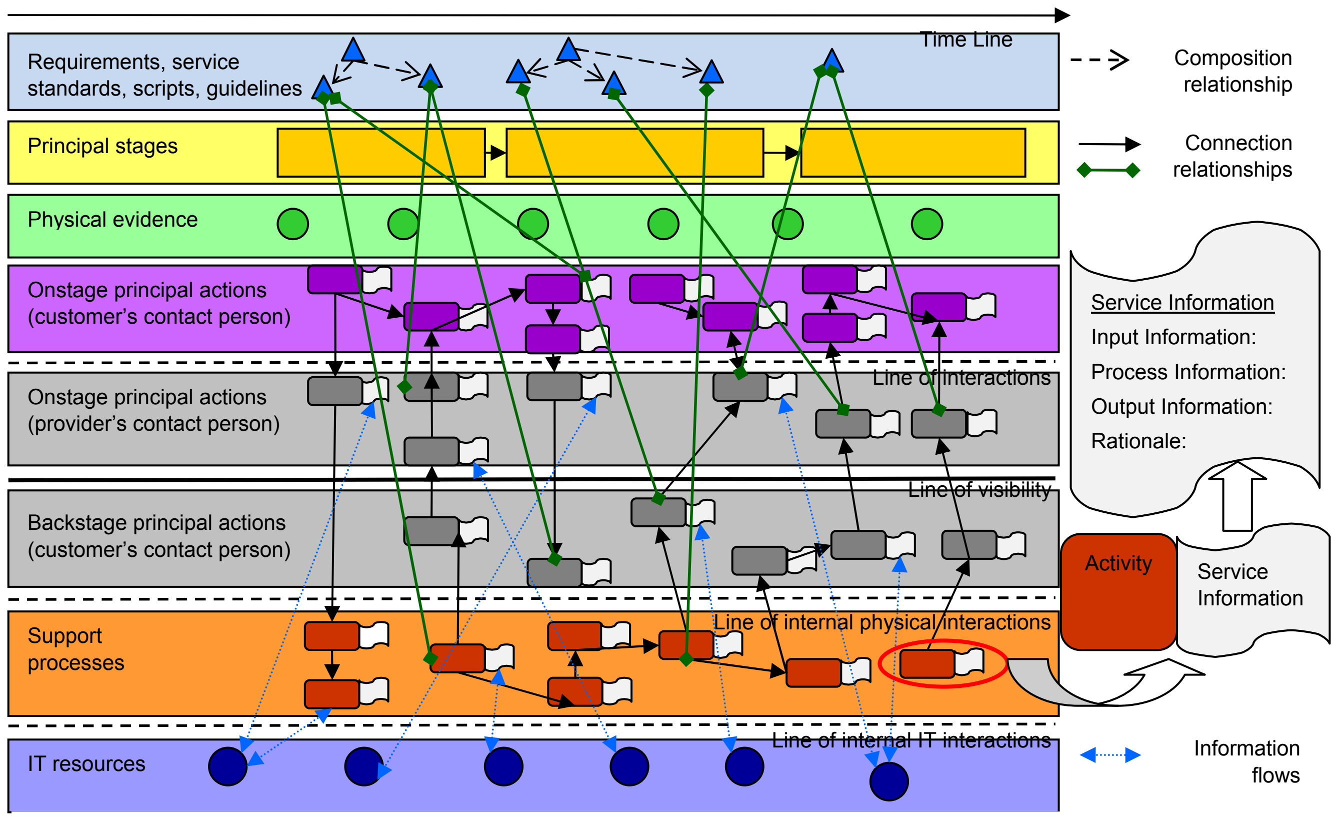

Figure 1: Key elements of a service information blueprint.

4 SERVICE INFORMATION BLUEPRINT

4.1 Service information blueprint

Product service systems (such as Rolls-Royce's 'Power by the Hour') are often designed and developed with aims to improve performance in a number of areas such as: reduce time, reduce cost, improve quality, improve responsiveness, and maintaining a sustainable business. Effective delivery of services with improved performance demands access to high quality service information (i.e. complete, correct, minimal and available to the right people at the right time). This is pertinent throughout the lifecycle (which typically include definition, development, delivery and evaluation) of the product-service system. To address this there is a need to capture service information requirements while defining services.

Service blueprinting techniques have been used for defining (basically visualising and mapping) services. This traditional framework of the service blueprint can be extended by including service information requirements for each service activities (done by the provider and customer to deliver the defined service) in the blueprint. The authors of this paper termed this resulting extended version of blueprint as 'Service Information Blueprint'. This is shown in Figure 1.

Scope: The Service Information Blueprint aims to support service designers in answering the questions: (i) What information is needed? (ii) Does the information exist? (iii) If so, where is it? (iv) If not, where might it come from?

Key Features: In the Service Information Blueprint, service information is categorised according to the swim lanes of the service blueprint: namely, 'requirements, service standards, scripts and guidelines', 'principal stages', 'physical evidence', 'onstage principal actions by the customer', 'onstage principal actions by the service provider's customer contact personnel', 'backstage principal actions by the provider's customer contact personnel', 'support processes', and 'IT resources'). The term and concept of 'swim lanes' have been adopted from the Business Process Modelling Notation (www.bpmn.org). However, the names, concepts and functionalities of all other key elements of the service blueprinting model remain the same.

For each of the service activities (done by the service provider and/or customer to deliver the defined service), three types of service information are considered: input information, process information and output information. This has been adopted from the service information classification scheme proposed by Berkeley and Gupta [16]. However, the definitions and concepts (of the input, process and output information) have been slightly changed and adapted to make them applicable for service activities (rather than the whole service which is composed of a collection of service activities or service process steps). For the Service Information Blueprint, input information refers to the information that are needed before actually performing or carrying out the service activity; process information is the information actually required by the actor while actually performing or carrying out the service activity; output information refers to information that is available after and results of a service activity is been carried out.

The Service Information Blueprint captures information associated with relationships:

- across the swim lanes of a service blueprint (e.g. between KPI-1 defined in the 'Service Standards, Scripts and Guidelines' swim lane and Activity2 of the 'Support Processes' swim lane); and
- between two elements within a swim lane of a service blueprint (e.g. between Activity1 and Activity2 of the 'Support Processes' swim lane). Relationships can be two types: connection and composition.

The Service Information Blueprint also captures or refers to rationale for any service activity definition or any defined relationship. In addition to capturing service information requirements, it also includes sources of that information or refers to that sources (if they already exist in external repositories).

4.2 The 'FSIB' software prototype

A software prototype, called 'FSIB', was developed based on the Service Information Blueprint model (proposed in Section 3.3 and depicted in Figure 1). In the FSIB, an instance of a service definition is termed as a service 'scenario'. In the FSIB, in a service definition 'scenario', the swim lanes of a blueprint are represented as 'canvases' or 'contexts'. The key elements in a swim lane are represented as nodes and arcs. The nodes represent: *definitions* in the 'Requirements, Service Standards, Scripts and Guidelines' swim lane; *stages* in the 'Principal Stages' swim lane; *descriptions* in the 'Physical Evidence' swim lane; *resources* in the 'IT Resources' swim lane; and *activities* in all other swim lanes capturing customer's and provider's activities. The arcs represent relationships among nodes within and across swim lanes. Relationships can be two types- connection and composition. The connection relationships are also classified to represent: materials flows or chronological sequences (in the arrow direction) or information flows or statements (for example to represent dependency links). In the FSIB, for each nodes service information requirements are captured in a separate dialog box. In this dialog box, service information (i.e. input information, process information, output information, and rationale information such as design rationale) for each service activity can be explicitly captured and/or implicitly referred to a hyperlink (if they already exist in external files or URLs or network addresses). A screen dump of the FSIB software prototype is depicted in Figure 2.

5 CASE STUDY – APPLICABILITY OF SERVICE INFORMATION BLUEPRINT TO COFFEE MAKER MAINTENANCE AND REPAIR SERVICE

The Service Information Blueprint model introduced in this paper was applied to a Coffee Maker maintenance and repair service case study (using the FSIB software prototype) for two types of contracts- availability type and spare only type. However, this paper reports in detail application of availability type contract only. The typical scenario is described below.

The Coffee Maker Manufacturer supplies Coffee Maker machines to its customer and takes responsibilities for their maintenance and repair in an availability type contract. The service level agreements (SLAs) and key performance indicators (KPIs) for the contact are as follows:

KPI 1: Call-to-Repair response time- 24 hours (max).

SLA 1: Provider to supply, install, maintain, repair and support spare parts and the whole machine.

SLA 2: Service package include planned preventive and predictive maintenance, and unplanned breakdown maintenance.

SLA 3: Provider is responsible for customer training and to show how to use the Coffee Maker.

SLA 4: Provider to supply user manuals / training materials to the customer.

SLA 5: Customer to pay annual fixed price to the provider for availability of the product (Coffee Maker) and services.

SLA 6: The price includes both spares and services (i.e. complete availability and ready for use).

SLA 7: 24 months minimum contract period (which can be extended after end of the contract).

SLA 8: Services are provided both as-planned and on-demand basis for the duration of the contract.

The contract includes planned preventive and predictive maintenance twice a year by the service provider. Besides, whenever there is problem (i.e. breakdown) with the Coffee Maker, the customer contact (by telephone) the service provider and report about the problem, and also schedules an appointment for engineer's visit. The service engineer is expected to visit the customer within 24 hours of reporting the problem. The service engineer diagnoses the root cause for the problem and try to fix the problem onsite. If for any reasons, the problem cannot be fixed onsite and have to take the Coffee Maker out from the customer's premises, an alternative Coffee Maker is provided to the customer for temporary use. The faulty Coffee Maker is then repaired at Coffee Maker Manufacturer's repair workshops by its maintenance team. All other planned preventive and predictive maintenance might also done during this time if their schedules are near. During repair and maintenance services, the prime service provider (i.e. Coffee Maker Manufacturer) have to contact its suppliers for components and parts procurement and to receive sub-contracted services. After maintenance and repair, the service provider's call centre staffs contact the customer to make an appointment for returning the serviced Coffee Maker. On the scheduled date and time the Service engineer returns the serviced Coffee Maker to the customer and takes back standby Coffee Maker (provided for temporary use). Databases, IT systems and service records are regularly interacted, updated and maintained throughout the service delivery process.

Data from the aforementioned case study were applied to the Service Information Blueprint model using the FSIB

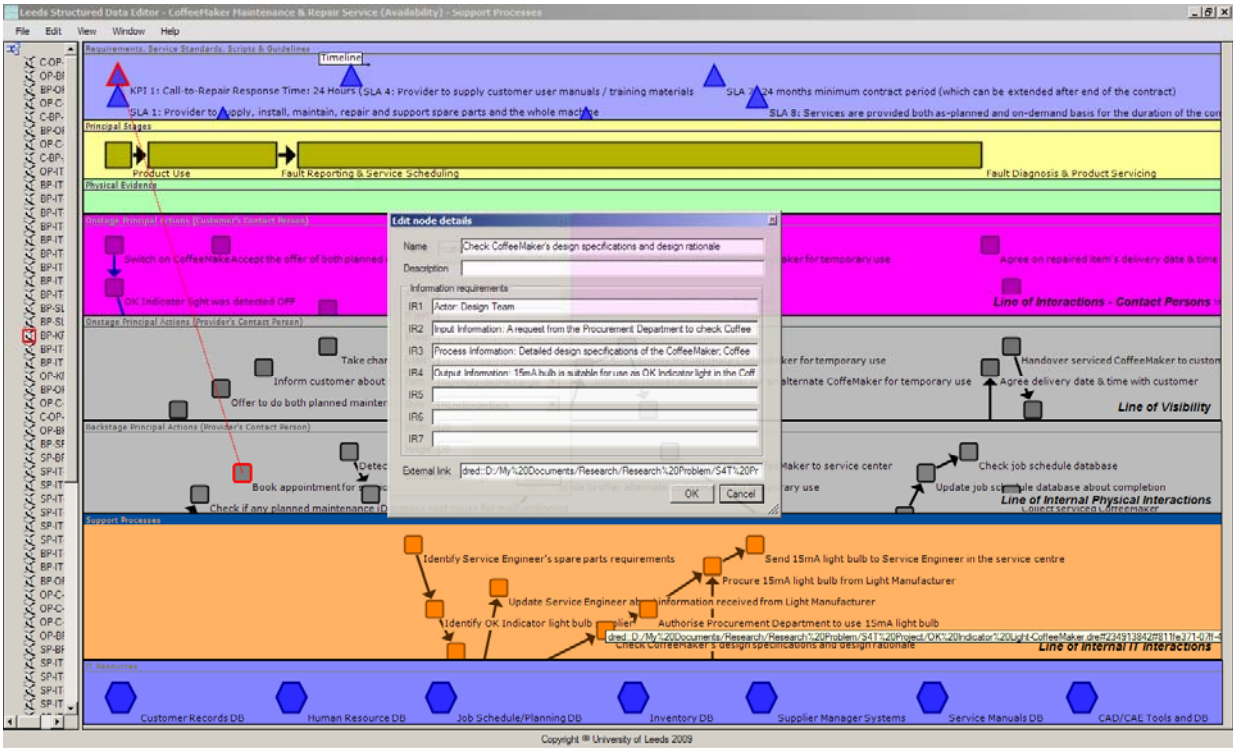

Figure 2: A screen dump of the FSIB software prototype showing results from the application of data for a Coffee Maker

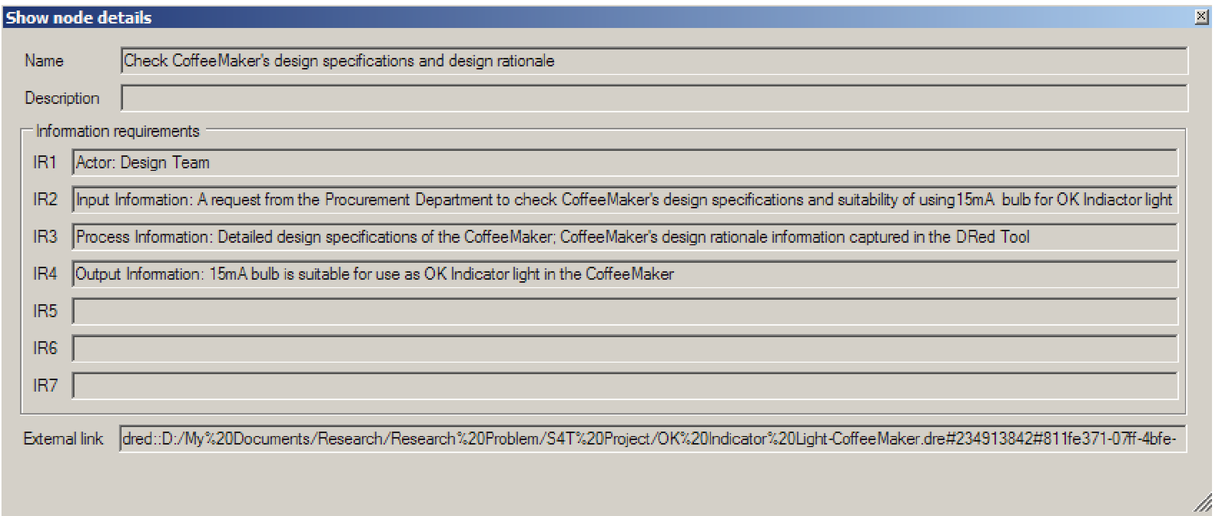

Figure 3: A screen dump showing how service information associated with a service activity is captured.

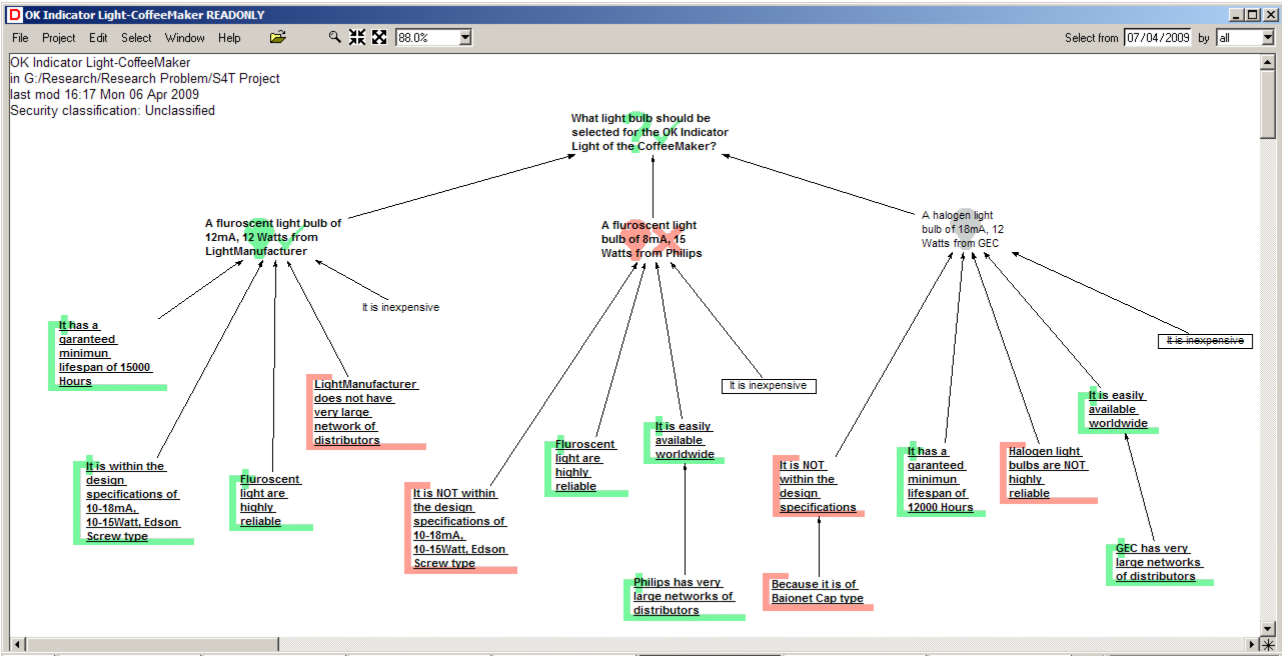

Figure 4: A screen dump showing design rationale information captured in a DRed [21] file.

software prototype. First the service scenario was defined by defining the key elements of each of the swim lanes and mapping relationships among these elements within and across swim lanes. Later, for each service activity, service information required for that activity and information resulted out of that activity were captured.

6 RESULTS

Data from the Coffee Maker machine maintenance and repair service in an availability type contract case study was applied to the FSIB software prototype. The key results are summarised in Figures 2, 3, 4 and 5. Figure 2 presents a snapshot of different swim lanes and their key elements (represented by nodes and relationships arrows/links). Service information required to carry out each service activity (done by either service provider or customer) were also captured in the FSIB software prototype. Figures 2 and 3 present an example of how service information associated with a service activity were captured in the FSIB software prototype. The 'External Link' field (shown in Figures 2 and 3) refers to design rationale information captured in an external DRed (Design Rationale Editor [21]) file. This is depicted in detail in Figure 4. The example in Figure 4 shows rationale behind selection of a 12mA/12W bulb for the Coffee Maker's OK Indictor light. For this case study, service information associated with each of the relationships (both within and across swim lanes) were also captured in the FSIB software prototype.

Figure 5 shows in an example how information associated with a relationship (represented by arrows/links in Figure 2) are captured. The red coloured link shown in Figure 2 is an example of a relationship between elements across swim lanes.

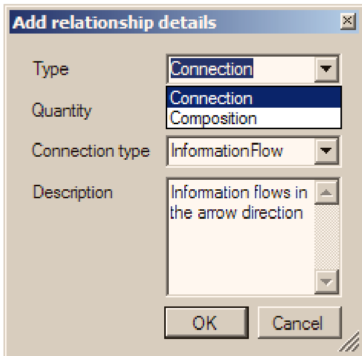

Figure 5: A screen dump showing how information associated with relationships are captured.

7 DISCUSSION

In this section, some key lessons are drawn out from the exploratory research reported in this paper.

Effective delivery of services with improved performance demands access to high quality service information (i.e. complete, correct, minimal and available to the right people at the right time). This is pertinent throughout the lifecycle of the product-service system. To address this there is a need to capture service information requirements while defining services. The Service Information Blueprint allows definition of service information requirements and capture of service information while defining services. It does so by categorising service information according to the swim lanes of the service blueprint. In activity swim lanes, it is important to define information requirements before and during the execution of a service activity. It is also important to capture any information that may result from a service activity as they might be useful in future. The Service Information Blueprint's ability to define accurate service information requirements and to include service information enables product-service system designers to provide improved service definitions.

It is essential to understand how elements within and across swim lanes of a service blueprint are related to each other. The Service Information Blueprint supports this by allowing service designers in defining relationships and capturing information associated with the relationships. One of the major outcomes of this capability of the Service Information Blueprint is the ability to link service activities (done by the service provider and/or customer to deliver the defined service) with the KPIs (Key Performance Indicators), PIs (Performance Indicators) and SLAs (Service Level Agreements) in the 'Requirements, Service Standards, Scripts and Guidelines' swim lane. A large proportion of a service is process/activity and the key feature that differentiates services from processes lies in the need to deliver the requirements of a contract. In the Service Information Blueprint, the relational links between service activities/processes and contractual requirements (such as KPIs, PIs and SLAs) show dependencies among them. For services (especially for contracted services), this means an ability to identify the service activities that need to be controlled in order to reach any particular target performance level (i.e. KPI or PI or SLA) of the contract.

In case the service information already exists in external sources or repositories, the Service Information Blueprint refers to the sources of that information. In the FSIB software prototype this is realised by including hyperlinks in the 'External Link' field. As demonstrated in the coffee making machine case study in Section 6, this external link could be a source capturing design rationale information such as DRed. Design rationale information is key in justifying design decisions or revisiting design decisions made before.

Ideas on service configuration can be drawn from a large body of work in product configuration. Product configuration involves linking physical elements together to form new products; part-whole relationships are used to define product breakdown structures and connection relationships are used to define how parts within a product breakdown structure relate to each other to deliver intended functionality. Different kinds of connection relationship occur in product breakdown structures: for example, mating conditions in assemblies and functional interactions in functional definitions. These ideas have been transferred for service products' definitions in the FSIB software prototype (or the Service Information Blueprint model that underpins the FSIB software prototype) because it is based on an underlying meta-model that treats physical and service products in similar ways.

In the Service Information Blueprint, in the service activity swim lanes, if the external links refer to other instances of service definition (or other instances of service 'Scenario' in the FSIB software prototype) in part-whole type relationships (or composition relationships), the Service Information Blueprint model can be used to define service breakdown structures. In service breakdown structures, such externally linked instances of service definition (or instances of service 'Scenario') are considered as part of the service definition (or the service 'Scenario') from where the links were made (as shown in Figure 6 below).

In the Service Information Blueprint (or in the FSIB software prototype), service elements can be reused within and across swim lanes. However, effective service configuration requires further understanding on how to (i) select service parts and (ii) connect them to each other to create new services that will behave in intended ways. Another key issue for successful service configuration is, given a service catalogue from which service elements can be selected, how will service parts be selected and re-used?

The ability to re-configure services becomes increasingly important when the service contract changes (for example, from availability to spare-only type and vice-versa, or availability to capability type and vice-versa). The Service Information Blueprint (and the FSIB software prototype) was also applied to the Coffee Maker maintenance and repair service in a spare-only type contract (not reported in this paper). It was observed that, with changes in contract type from availability type to spare-only type, some parts of the service definition for the availability type contract had to be changed whilst the other remained the same. With changes in contract type, KPIs (Key Performance Indicators), PIs (Performance Indicators) and SLAs (Service Level Agreements) also change. To reach these new sets of target performance levels, some of the service activities need to be re-defined and/or reconfigured and some new service activities need to be included in the service definition. With changes in service definition, service information requirements also change to meet new sets of target performance levels.

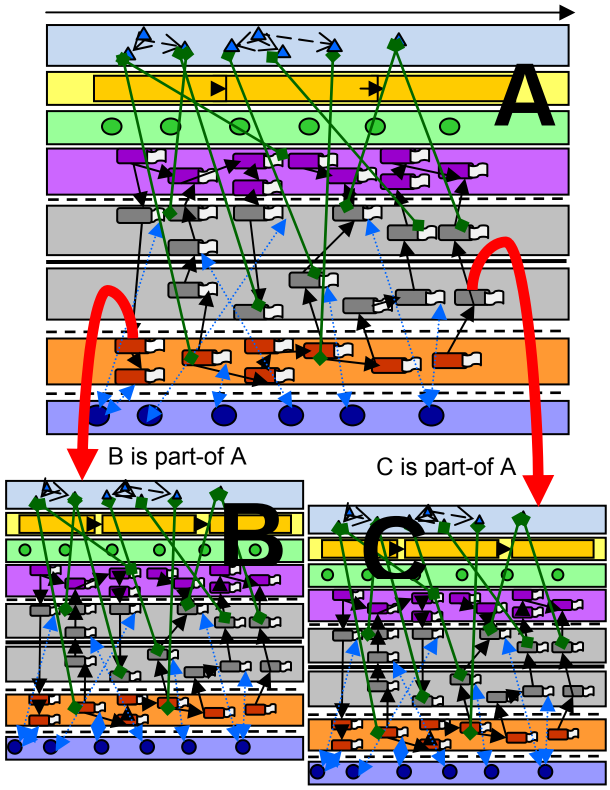

Figure 6: An example service breakdown structure.

8 CONCLUSION

Research reported in this paper provides insights for understanding the importance of service design representations, including service information requirements, in product-service system design. The paper introduced the Service Information Blueprint model and the FSIB software prototype and demonstrated their capability to define service information requirements and capture service information while defining services. The potential of the Service Information Blueprint model to define service breakdown structures was also explored. Early results indicate that the Service Information Blueprint model (and the FSIB software prototype) can support Bill-of-Materials type service breakdown structures. Future research will include development of tools and techniques to support service cataloguing and re-configurability.

9 ACKNOWLEDGMENTS

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10 REFERENCES

[1] McKay, A., Kundu, S., and de Pennington, A., 2009, Supply Networks: An Approach to Designing an Extended Enterprise, Proceedings of the 6th International Conference on Product Lifecycle Management, PLM09, University of Bath, Bath, UK, 6-8 July.

[2] Vermaas, P. E., and Houkes, W., 2006, Technical Functions: A Drawbridge between the Intentional and Structural Natures of Technical Artefacts, Studies in History and Philosophy of Science, 37: 5-18.

[3] Kroes, P., and Meijers, A., 2006, Special Issue of Studies in History and Philosophy of Science on Dual Nature of Technical Artefacts, 37.

[4] McKay, A., Bloor, S., and de Pennington, A., 1996, A Framework for Product Data, IEEE transactions on knowledge and data engineering, 8: 825-838.

[5] Agouridas, V., Winand, H., Mckay, A., and de Pennington, A., 2006, Early Alignment of Design Requirements with Stakeholder Needs. Proceedings of the Institution of Mechanical Engineers: Part B-Journal of Engineering Manufacture, 220(9): 1483-1507.

[6] McKay, A., Hagger, D. N., Dement, C., and de Pennington, A., 2004, Relationships in Product Structures, in 7th Workshop on Product Structuring, Sweden, The Design Society.

[7] Tassi, R., 2009, Service Design Tools: Communication Methods Supporting Design Processes, URL: www.servicedesigntools.org, (accessed November 2009).

[8] Tassi, R., 2008, Design Della Comunicazione e Design Dei Servizi: Progetto Della Comunicazione Per la Fase di Implementazione (Communication Design and Service Design: Implementing Services through Communication Artifacts), Masters Thesis, Politecnico di Milano, Italy.

[9] Engine Group, 2009, Engine Service Design, URL: www.enginegroup.co.uk, (accessed November 2009).

[10] Scarrott, G. G., 1985, Information: The Lifeblood of Organization, The Computer Journal, 28(3): 203-205.

[11] Hollingum, G., and Jowell, R., 1978, Implementing an Information Strategy in Manufacture: A Practical Approach, Springer Verlag and IFS Publications Ltd, UK.

[12] McFarlane, D., and Cuthbert, R., 2008, Meeting Notes from WP2 Case Study Workshop, S4T WP2 Case Study Workshop, Farnborough, UK, 28 May.

[13] Zeithaml, V. A., Parasuraman, A., and Berry, L., 1990, Delivering Quality Service: Balancing Customer Perceptions and Expectations, The Free Press, New York.

[14] Lovelock, C., and Wirtz, J., 2007, Services Marketing: People, Technology, Strategy, 6th ed., Prentice Hall, Upper Saddle River, NJ, USA.

[15] McFarlane, D., 2007, Service Information Systems, DSI Workshop, Pittsburgh, PA, USA, May.

[16] Berkeley, B. J., and Gupta, A., 1995, Identifying the Information Requirements to Deliver Quality Service, International Journal of Service Industry Management, 6(5):16-35.

[17] Tomiyama, T., 2001, Service Engineering to Intensify Service Contents in Product Life Cycles, in Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Tokyo, IEEE Computer Society, 613-618, CD-ROM.

[18] Kundu, S., McKay, A., de Pennington, A., Moss, N., and Chapman, N., 2007, Implications for Engineering Information Systems Design in the Product-service Paradigm, in Proceedings of the 14th CIRP Conference on Life Cycle Engineering: Advances in Life Cycle Engineering for Sustainable Manufacturing Businesses, Waseda University, Tokyo, Japan, Springer, Shozo Takata, Yasushi Umeda (editors), 11-13 June: 165-170.

[19] Eckert, C., Jowers, I., and Clarkson, J. P., 2007, Knowledge Requirements Over Long Product Lifecycles, in Proceedings of the 16th International Conference on Engineering Design (ICED'07), Paris, France, 28-31 August: 913-914.

[20] McKay, A., Kundu, S., Dawson, P. G., and de Pennington, A., 2009, An Integrated Product, Process and Rationale Model for the Provision of Through-life Information in Product-Service Systems, Proceedings of the 17th International Conference on Engineering Design, ICED'09, Stanford University, CA, USA, 24-27 August: 8-263-8-274, CD-ROM.

[21] Bracewell, R. H., Ahmed, S., and Wallace, K. M., 2004, DRED and Design Folders: A Way of Capturing, Storing and Passing on Knowledge Generated during Design Projects, in ASME Design Automation Conference, Salt lake City, Utah, USA, ASME.

Session 2B:
Planning

Hierarchical Planning for Industrial Product Service Systems

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Abstract

Industrial Product Service Systems (IPS²) are an innovative business model for engineering enterprises, integrating products and services. A substantial portion of later operating costs is determined by decisions in the design phase. This leads to a hierarchical problem structure: On the strategic planning level, configuration of IPS² is accomplished regarding customers' requirements and uncertainties. Revenues and (adaptation) costs during the subsequent delivery phase have to be anticipated. The operative planning level is concerned with the use of a given IPS². Later changes of business models are only possible within the scope of the strategic plan. The more uncertainties strategic planning faces, the more flexibility has to be provided in order to assure a successful coordination of both levels.

Keywords

Strategic Planning, Flexibility, Hierarchical Planning, Uncertainty, Cost Model

1 INTRODUCTION

The business situation in the field of mechanical engineering is characterized by increasing international competence. As manufacturing facilities become more and more interchangeable, margins are decreasing. Thus enterprises are forced to shift their activities to new products, new market segments and new business models which allow them to differentiate from competitors and to improve their income situation.

In recent years the additional offer of **industrial services** has been chosen as such a means of differentiation. But they face two main problems: On one hand, offers are often developed rather unsystematically which leads to an uncoordinated set of services whose benefit for the customer is suboptimal. On the other hand, customers tend to accept services as most welcome add-ons but show only a low willingness to pay additional charges.

Industrial product service systems (IPS²) are a new approach to solve this problem. They integrate the customer into the whole process of provision – covering the engineering phase as well as the utilization phase. Therefore they are characterized by a high degree of customization. The planning of activities concerning IPS² is a challenging task that has to meet many demands.

The paper deals with the **hierarchical approach** for planning activities concerning IPS². It is organized as follows: The focus of chapter 2 is to give an overview about the concept of IPS², its origins, its characteristics and the various business models. Chapter 3 presents a general introduction into the theory of hierarchical planning including its basic elements and its fields of application. In chapter 4 the hierarchical planning approach is applied to the problem setting of IPS². Adequate models for the strategic and the operative planning level are formulated and coordinated according to their specific needs. Finally, a survey of future areas of research is given.

2 INDUSTRIAL PRODUCT SERVICE SYSTEMS

2.1 Origins of IPS2

In science and practice the advantages of integrating products and services are discussed from a strategic management perspective. Challenges related to this integration are often neglected. However, the transition from a product manufacturer to a service provider constitutes managerial challenges. [1]

On the one hand, different economic principles respectively characterize the product and service business. Service provision requires organizational principles, structures and processes which are new to many product manufacturers. On the other hand, the management faces new challenges due to the change of the business model. The integration of services into the core products effectuates a **modification of the business relation** from a transaction-based relation to a contractual relation (relation-oriented business model) which takes place over a longer period of time. For this relation new incentive structures are decisive.

Companies pass through various stages on their way from product manufacturers to producing service providers, problems of organization and planning as well pricing and managerial accounting need to be solved for any stage. According to the empiric-based phase schema by Oliva and Kallenberg, [1] one can differentiate between four phases, respectively **four types** of providers of industrial services:

- The first phase is characterized by a **consolidation** of transaction-oriented services. Services are provided by different organizational units, their only aim being the increase of product sales. Services are billed implicitly via the price of the product. An important part of this phase is the introduction of information instruments in order to control the contribution of the services to success and quality. From the managerial accounting point of view, providers profit from a refined cost calculation in the service area.
- The second phase is characterized by a **reorganization** of organizational structures and processes, which is triggered when the industrial services enter the market. Providers of the second phase have an extended range of services with individual prices. Managerial Accounting is particularly interested in aspects of capacity planning. Due to the organizational independence, the service sector gains

responsibility for the results and for its own controlling system.

- In the third phase, the interaction with the customers changes from a transactional exchange to an **interactive, relational process**. Instead of billing each individual service cost-plus, so-called full-service contracts specify a fixed fee for all services within a specific period of time. According to Oliva and Kallenberg, typical services provided in this phase are, apart from maintenance and service contracts in the form of a full service, preventive maintenance, equipment condition monitoring or spare parts management. [1] Usually, full service contracts include an improvement of operational availability and response times in case of failure. The advantage of such contracts is the better use of the capacities created in phase 2. The revenues are not only higher, but also more predictable. Due to shifting the cost risk from the customer to the supplier, the planning of the variable costs and the price setting is crucial to the companies of this type. It is decisive to know the frequency distribution, i.e. the risk of default.
- **Process-oriented services** are added to the offer of industrial services in the fourth phase. This is connected to a change of paradigm, which changes the focus of the value proposition to the end-users. Focus is no longer on product efficacy – whether the product works – rather the effectiveness and efficiency of the product within the end-user's process is now the relevant issue. [1]

  Following such customer-oriented strategies, i.e. centering the offering on the end-user's process, dissolves the boundary of products and services. Most companies' offerings in this phase can at best be characterized as bundles of product and services (IPS^2), that constitute a problem solution to individual customer needs along the life cycle of the installed base.

  Challenges for the management result from the dynamics of IPS^{2}s. It mainly has to adjust problem solutions via the whole life cycle to changing general conditions. Flexibility, as a strategic factor for success, gains importance in this context. It is the task of managerial accounting to support the creation of flexibility potentials in order to reduce costs and to develop corresponding strategies already in the early stages of IPS^2 development. [2]

In the following two subsections, the concept of IPS^2 and the related innovative and flexible business models are introduced.

2.2 Structure of IPS^2

IPS^2 are characterized by an integrated and mutually determining process of planning, development, operation, and use of goods and services. They constitute a problem solution for **business-to-business markets**, tailor-made to individual customers' needs along the IPS^2 life cycle. Customizing an IPS^2 and integrating flexibility is based primarily on the possibility of partially substituting product and service components to meet customer requirements. As illustrated in Figure 1, IPS^2 are composed of pure product modules, pure service modules and hybrid modules that combine specific products and services.

The definition given above allows **different designs** of IPS^2. They are able to cover all market requirements due to the substitution option between the portions and specifications of products and services. These include the sale of a product, where the customer is responsible for all maintenance activities after the purchase, to complex user models, where the supplier is responsible for all production processes. This setting is the background for a first attempt to classify such product/service combinations in literature [3].

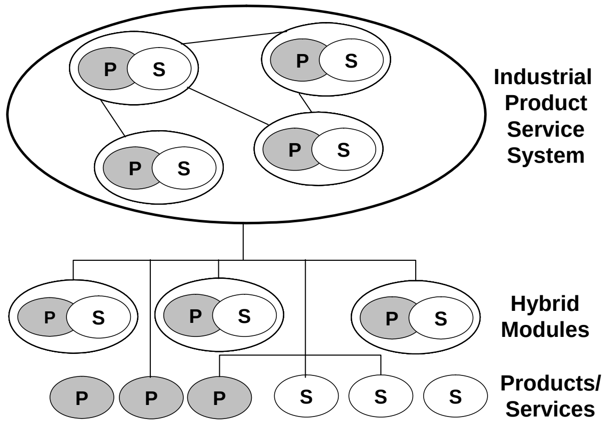

Figure 1: Structure of IPS^2. [5]

A further separation of IPS^2 is to follow. A central criterion for differentiation is the **system complexity** so that IPS^2 can be considered to be little to very complex. Various features influence the complexity of the system:

- Type of customer benefit;
- Range of services offered;
- Amount and heterogeneity of individual part of an IPS^2;
- Degree of technical integration in the value added domain of the customer;
- Degree of individualization;
- Temporal dynamics and changeability of the service provision.

The features "individualization" and "temporal dynamics" are of great importance for the planning problem focused in this contribution because there is a potential trade off. On the one hand, the orientation towards customer benefit with an IPS^2 requires that the individual parts will be developed with regards to specific **customer requirements**. This leads to a technically integrated development of the individual parts of an IPS^2, since the value that can be created exceeds the value generated by purely adding values of individual parts. The higher the degree of integration, the more complex the system becomes. At the same time it is also more difficult to substitute individual parts for the competitors.

On the other hand, within an IPS^2 service provision the interaction with the customer will cover a **longer period of time**. From this it follows that a possible adjustment of the IPS^2 in the use and operating phase becomes necessary, which will lead to an increase of complexity, too. It is a general fact that the complexity of IPS^2 increases the longer the use and operating phase is. The higher the degree of technical integration of an IPS^2 is, the more difficult its adjustment might be.

2.3 Business Models for IPS^2

Innovative and flexible business models which describe the form of relations between the customer and supplier are based on these dynamic IPS^2. A **business model** is a model, which, referred to a business operation, represents the following features: [4]

- The **participants**, their roles and their contribution to the value added (architecture of value added),
- the **benefit** that the customer or other participants can gain from the business operation (value propositions), and

	Function Oriented	Availability Oriented	Result Oriented
Design Object	Potentials	Processes	Products
Basis for Billing	Machine	Hours of Operation	Number of Items
Typical Services	Maintenance Replacement	Monitoring Preventive Maintenance	Solution of Customer Problems
Ownership	Customer	Customer or Supplier	Supplier
Responsibility of Supplier	Machine Quality	Process Quality	Product Quality
Risk of Supplier	low	medium	high

Table 1: Characteristics of IPS².

- the **source of income** resulting from business (revenue model).

The business model is an instrument for strategic planning and communication between all participants – investors, members of staff and customers.

Depending on the value proposition, we differ between three business models for IPS^2 [5]:

- A **function-oriented business model**, for example, includes a maintenance contract in order to guarantee the functionality for a specified period of time.
- An additional availability of the facility is guaranteed in the **availability-oriented business model**, where, for the first time, the supplier is solely responsible for business processes of the customer, thus bearing a share of the production risk. His responsibility covers all processes which guarantee the availability, i.e. maintenance or preventive servicing.
- In a **result-oriented business model**, the supplier is responsible for the production results, as the customers will only pay for faultless parts.

The main characteristics of the three business models for IPS² are summarized in table 1.

The supplier takes over additional tasks, which were originally carried out by the customer, as there is a consequent orientation of the service offer to the individual customer's benefit. The customer-supplier relation changes to an **integrative cooperation**, where the established role perception between supplier and customer, depending on the corresponding business models, dissolves more or less. In general, the business models differ in the ownership structure of the product. While traditional business models are based on the transfer of the ownership rights to the customer, the customer is not the owner of the product he uses in innovative business models. The supplier remains the owner.

Business models are important, as they influence the incentives of all parties involved in the business relation. Basically, innovative business models are better suited than traditional ones in order to harmonize the interests of the cooperation partners and to create incentives [6]. Sometimes the choice of the business model depends on the type of the product, respectively on the complexity of IPS^2 [7].

3 HIERARCHICAL PLANNING

3.1 General structure of hierarchical planning

Hierarchical planning is an approach used in order to reduce complexity of global planning problems. **Complexity** may be caused by various incidents such as a long planning horizon, a wide range of planning objects or distributed decision-making power. Instead of solving a comprehensive problem covering many different aspects by means of a monolithic model, hierarchical planning decomposes the overall problem into at least two less complex sub problems that are coordinated by well-defined interfaces.

The resulting planning levels can be modeled individually by adequate algorithms – either optimizing or heuristic – which are often taken from **operations research**. In the last decades of the 20^{th} century, hierarchical planning methods have been applied especially to production planning problems and are reported to show great success. [8-10]

Typically, upper planning levels cover a longer planning horizon, work with more aggregated data and operate on a higher decision level than lower planning levels. The basic element of a hierarchical planning structure is a **two-level model**. The general workflow of a hierarchical planning approach consisting of two planning levels is given in Figure 2. [11]

The **top level** solves its aggregated planning problem considering the possible performance of the base level by means of an anticipated base model. It generates a solution for the overall system that is partially given as an instruction to the base level.

The **base level** solves its more detailed planning model under the restrictions given by the instructions obtained from the top level. The more slack these restrictions comprise; the bigger is the resulting solution space of the base model. Slack can be given in form of production capacities, scope for decision making or – especially relevant for IPS² – flexibility of the business model.

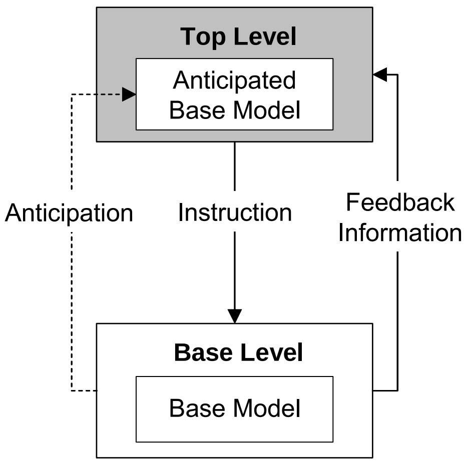

Figure 2: General workflow of hierarchical planning.

The **top level** solves its aggregated planning problem considering the possible performance of the base level by means of an anticipated base model. It generates a solution for the overall system that is partially given as an instruction to the base level.

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After solving the base model, the base level reports its actual decisions and the resulting effects concerning the real-world problem to the top level. As the success and the monetary compensation of the top level depends on the results of the overall system and thus partially on the performance of the base level, the top level evaluates this feedback information in order to generate better instructions during the next run of the planning problem. [12]

A substantial advantage of hierarchical planning is its ability to respect existing **organizational structures**. Thus it obtains much more acceptance within the company than monolithic planning approaches. For these reasons, hierarchical planning shows a wide range of theoretical and practical applications.

3.2 Elements of hierarchical planning

The substantial principle of hierarchical planning is the combination of four **problem simplification strategies** that allow reducing the complexity of the overall planning problem to a manageable size. Theory of hierarchical planning identifies four basic elements that have to be coordinated adequately, see Figure 3: [10, 13]

Decomposition

Decomposition allows solving huge planning problems that are not manageable as a whole. A complex overall planning problem is decomposed into less complex sub problems. These are solved separately by adequate methods. In order to get a solution for the original problem, the results of all sub problems have to be coordinated by well-defined interfaces.

Hierarchy

After decomposition, the sub problems are assigned to hierarchical planning levels that are specialized on the solution of the respective problem. Thus a hierarchy of sub problems is established that coincides with the organizational structure of the enterprise. As a consequence, control mechanisms that are already established in the company may be applied for the coordination of planning levels.

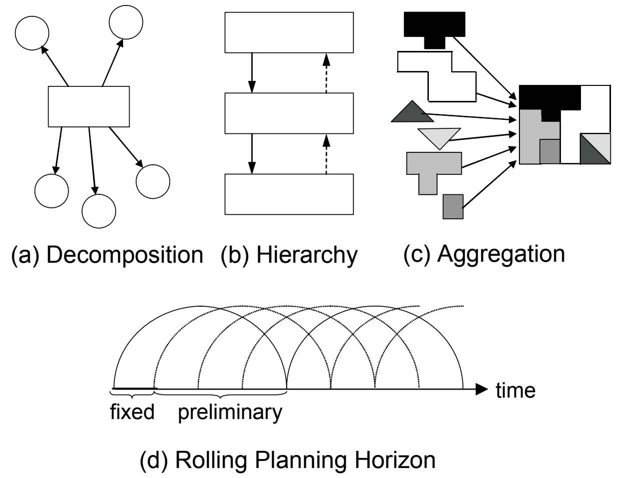

Figure 3: Basic elements of hierarchical planning.

Aggregation

Aggregation of products, production facilities and periods of time is used in order to simplify planning problems especially of upper planning levels. This helps to reduce the amount of data required, model complexity and uncertainties. The reduction of uncertainty results from the reduced variance of aggregated data. Overall, aggregation facilitates the solution of the resulting planning models.

Rolling Planning Horizon

The use of a rolling planning horizon on all planning levels allows deferring decisions for later periods to a point of time when better information is available. If the planning horizon comprises T periods, only the results for the first period are considered as fixed and are implemented. The results for the remaining T-1 periods are preliminary and subject to change if new information is supplied. In the next planning run, the plan for the second period is fixed and the horizon rolls to period T+1. Preliminary planning of later periods is necessary to prevent myopic plans that would be generated if the planning horizon were shortened to the fixed section.

Modeling a hierarchical planning approach, these four elements have to be adapted to the underlying real world problem and coordinated adequately. In combination, their ability to reduce problem complexity is even higher than in an isolated application.

Hierarchical planning has a wide scope of practical applications ranging from production planning and cost accounting to general principal agent relationships. [x5] [14] The following chapter will show how it may be applied to the planning of IPS².

4 HIERARCHICAL PLANNING FOR IPS²

4.1 Planning problems

Planning tasks concerning IPS² take place at different points of time, they cover different scopes, and respective decisions are taken by different agents. As it is neither possible nor sensible to make all decisions simultaneously, a problem-driven **decomposition** becomes necessary. Decisions can be assigned to two subsequent phases that have to be represented as hierarchical planning levels. It is obvious that the development phase has to become the top level whereas the operating phase shows the characteristics of the subordinated base level. This **hierarchy** of planning levels is in accordance with the natural structure of the problem.

Development Phase

In IPS², product and service components are combined in order to create a solution to individual customer problems. The supplier strives to meet his customers' requests for individual business models each of with is a comprehensive and customized problem solution. Only if the customer becomes integrated into development, it is assured that all functionalities he desires are really incorporated so that the IPS² generates value for him.

On the other hand, the **configuration** of an IPS² from product and service modules (see section 2.2) is a decision that also has to generate a profit for the supplier. [15] He has to decide on the type and amount of his investment into the facility that will be delivered to the customer, on the kind of accompanying industrial services, and on the business model he is going to offer. These decisions are taken under uncertainty considering not only customer behavior during the operating phase, but also future technological development as well as various uncertainties of the environment.

In order to handle these uncertainties, the supplier can incorporate a high degree of **flexibility** into the IPS². Flexible resources, flexible products and the flexibility to change the business model during the operating phase if suitable assure a high degree of freedom to the supplier which allows him an appropriate reaction to changing request.

The decisions taken in the development phase are of **strategic relevance** for the economic success of the supplier. They are taken for a medium- or long-term planning horizon of several years. The focus of planning is on the **effectiveness** of the decisions taken. Effectiveness means doing do the right things in order to fulfill customer requirements. This requires double loop learning processes that challenge not only the fulfillment but also the purposes of an action. [16]

The characteristics of the chosen IPS² are passed as **instructions** to the operating phase.

Operating Phase

In the operating phase of an IPS² regular business operations that the supplier offers to the customer are taking place within the framework of the business model chosen in the development phase. The supplier has to take decisions on the quantities of products and services supplied in every single period as well as on the utilization of capacities allocated. As demand may vary, **process flexibility** is necessary on this operative planning level. The planning horizon for the operating phase is typically shorter than one year so that uncertainties are much smaller than in the development phase.

The focus of operative planning is on the **efficiency** of the provision processes for the services associated with the specific business model. Efficiency means to execute a given process with a minimum of inputs thus minimizing operating costs. So single-loop learning which pays attention to a quick and low-cost adjustment to changing demand and other imponderabilities is sufficient on this level.

Even if poor performance or unsatisfactory economic results indicate that the chosen business model should be changed, this decision is not within the range of the operative planning level. Rather a **feedback** to the strategic level is required.

4.2 Strategic Planning Level

The customer-oriented development and design of IPS² is the task that has to be performed on the strategic planning level. The **objective** of strategic planning is the maximization of the value added by the procurement of IPS². As it is necessary to provide specific IPS² for several customers, strategic planning not only has to allocate already existing capacity to competing purposes, but also has to decide about the enlargement or reduction of production and service capacities.

Strategic planning requires various **input data**: Customer requirements respectively anticipated demand for different products and services as well as anticipations for changes of business environment are sources of insecurity and have to be estimated as well as possible. Rather certain data is information about the production program of the company; that means the products and services actually provided. Furthermore, the anticipated performance of the base level is an important input for the top level.

The following **output data** result from strategic planning: Decisions on customer-specific variants of IPS² and the corresponding business models have to be made. These require specific investments into production and service facilities needed to provide the IPS². So the investment level for every period of the planning horizon is another output of the strategic planning model. Furthermore, decisions are necessary on the degree of strategic flexibility which allows changing the business model during operation of an IPS². This requires the assignment of a value to flexibility. Last but not least the operative planning level needs data such as revenue and cost parameters for the IPS² as a whole as well as for every single product or service component which have to be provided by strategic planning.

As it is not necessary to consider every detail of IPS² delivery and operation, strategic planning is performed on the basis of aggregated data. **Aggregation** is applied on production facilities on the input side as well as on business models on the output side.

Due to the high degree of uncertainty and fuzziness of input and output data of strategic planning, the top level has the property of an **ill-structured problem**. So it may not be modeled by an algorithmic method such as linear or convex programming. Instead, contract theory, flexible investment planning, and the real options approach seem suitable for this problem.

The **planning horizon** of strategic planning has to cover the whole IPS² life cycle which normally extends over several years. In order to keep complexity of the planning problem manageable, planning periods should not be shorter than a month. For periods in the far future an additional **aggregation** of time to quarters or even years might be favorable. Solving he problem with a rolling planning horizon helps to cope with the uncertainties addressed before.

4.3 Operative Planning Level

The focus of the operative planning level is on all activities that are necessary to operate an IPS² and adapt it continuously to changing demands and restrictions. Its **objective** may be formulated as maximizing the contribution margins of the IPS² delivered or as minimization of operating costs.

Input data of operative planning originate partially from the environment – such as actual customer demand, actions of competitors and global economic factors – whereas a substantial part is passed as instructions from the strategic planning level. Instructions comprise restrictions like the customer-specific business model for an IPS² or capacities assigned for its delivery and revenue and cost parameters of the product and service modules needed.

The result of the operative planning level are **output data** like the quantity of every product or service module delivered, the actual use of the IPS² specific and general capacities provided and the economic success of these activities.

As uncertainty of data on the operative planning level is much lower than on the strategic planning level, the problem at hand is **well-structured**. It may be modeled as a linear program for production and resource allocation planning. As standard software is available, an optimal solution is possible within reasonable computation time. Remaining uncertainty can be coped with by means of sensitivity analysis.

The **planning horizon** of operative planning is much shorter than for strategic planning. Usually, production and capacity allocation problems are solved for a horizon of one year which allows considering seasonality of demand. Planning periods should reflect operating days or shifts of the workforce. This framework is also suitable for operative planning of IPS². Similar to the strategic level, remote periods that due to the rolling planning horizon will be planned several times might be aggregated to weeks or decades without loss of solution quality.

The results of operative planning are detailed instructions which are given to the workforce for execution. If developments different from planning data arrive, the workforce has to react using **process flexibility** installed in its facilities.

4.4 Coordination of Planning Levels

Coordination of strategic and operative planning is achieved by information flowing from top to base level or vice versa. Three main flows of information can be identified that take place at different points of time (see Figure 4):

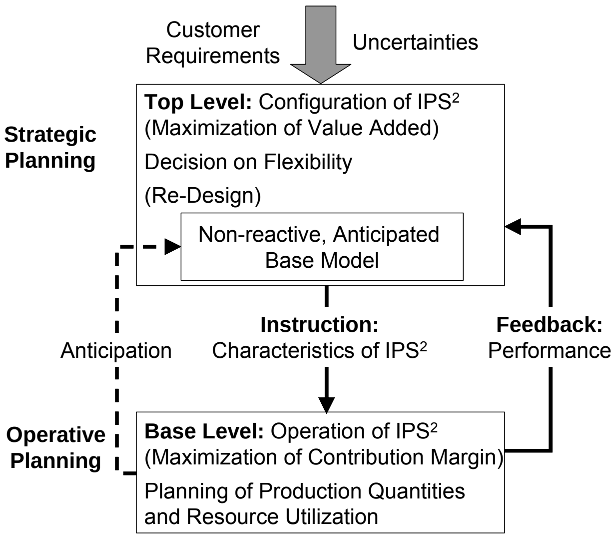

Figure 4: Coordination of strategic and operative planning.

- The first flow of information happens before the plans of both levels are definitely fixed. When the strategic planning level is solving its top model, it has to anticipate what results the operative planning level may achieve within the restrictions that correspond to a certain strategic plan. This **anticipation** is done by means of a non-reactive, anticipated base model which roughly calculates the possible results of the base level if the top level chooses a specific solution. This helps the strategic management choosing a policy that regards the qualified needs of both levels appropriately.
- The main connection between strategic and operative planning is the **instruction** that flows from top level to base level. It takes place when the top level has already made its decisions whereas the base level still has to perform its planning. As both levels from a hierarchical structure, the top level has the right to influence the actions of the base level either by direct commands or by indirect restrictions such as fixed amounts of workforce and machine capacity or fixed budgets. Concerning IPS², the characteristics of the IPS² offered to the various customers, especially the business model to be followed is the most important instruction.
- Last but not least there is a **feedback** flow of information taking place after plans have been implemented. The real performance of the operative planning level is reported to the strategic planning level. If results of the base level are insufficient and its management regards a change of the business model as adequate reaction, this information can also be given to the top level. The decision whether the business model is to be changed is definitely within the scope of the top level.

As both planning levels use a rolling planning horizon, experience and results of the expired planning period can be used for a dynamic learning process: Prognosis of insecure input data can be improved and planning methods can be defined in order to achieve better planning results.

5 SUMMARY AND FURTHER RESEARCH

The paper has proved that hierarchical planning is a suitable approach for the problems of developing and operating an IPS². Starting from general theory on hierarchical planning and using its four elements, a first formulation for the planning problems on the top level and the base level is given. Coordination of planning levels is achieved by instructions, feed-forward and feedback information.

The next step towards a hierarchical planning model for IPS² will comprise a more detailed specification of the planning models for both hierarchical levels. In order to calculate the economic benefit of an IPS², the operative planning on the base level should be related to a cost model. Here the approach of hybrid cost accounting could be used. [17] Furthermore, a practical application in form of a case study is desirable.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Oliva, R., Kallenberg, R., 2003, Managing the Transition from Products to Services, International Journal of Service Industry Management, 14 (2): 160-172.

[2] Richter, A., Sadek, T., Steven, M., Welp, E.G., 2009, Use-oriented Business Models and Flexibility in Industrial Product-Service Systems, in: Roy, R., Shehab, E. (ed.), Proceedings of the 1st CIRP IPS² Conference: 186-192.

[3] Burianek, F., Ihl, C., Bonnemeir, S., Reichwald, R., 2007, Typologisierung hybrider Produkte – Ein Ansatz basierend auf der Komplexität der Leistungserbringung, Arbeitsbericht Nr. 01/2007 des

Lehrstuhls für Betriebswirtschaftslehre – Information, Organisation und Management der TU München.

[4] Rentmeister, J., Klein, S., 2003, Geschäftsmodelle - ein Modebegriff auf der Waagschale, ZfB-Ergänzungsheft, 1: 17-30.

[5] Meier, H., Uhlmann, E., Kortmann, D., 2005, Hybride Leistungsbündel. Nutzenorientiertes Produktverständnis durch interferierende Sach- und Dienstleistungen, wt online, 95: 528-532.

[6] Otte, H.O., Richter, A., Steven, M., 2008, Integrated Design of Industrial Product-Service Systems, in: Kalcsics, J., Nickel, St. (ed.), Operations Research Proceedings 2007, Berlin : 363-368.

[7] Richter, A., Steven, M., 2009, On the Relation between Industrial Product-Service Systems and Business Models, in: Fleischmann, B. et al. (ed.), Operations Research Proceedings 2008, Springer, Berlin: 97-102.

[8] Hax, A.C., Meal, H.C., 1975, Hierarchical Integration of Production Planning and Scheduling, in: Geisler, M.A. (ed.), Logistics, North Holland, Amsterdam 1975: 53-69.

[9] Kistner, K.-P., Schumacher, S., Steven, M., 1992, Hierarchical Production Planning in Group Technologies, in: Fandel, G. et al. (ed.), New Directions for Operations Research in Manufacturing, Springer, Berlin: 60-74.

[10] Steven, M., 2004, Hierarchische Produktionsplanung, Physica, Heidelberg, 2nd Ed.

[11] Schneeweiss, C., 1994, Elemente einer Theorie hierarchischer Planung, OR Spektrum 16:161-168.

[12] Schneeweiss, C., 1999, Hierarchies in Distributed Decision Making, Springer, Berlin.

[13] Steven, M., 2004, Hierarchical Planning Structures in Supply Chain Management, in: Fandel, G. et al. (ed.), Modern Concepts of the Theory of the Firm, Springer, Berlin: 301-312.

[14] Switalski, M., 1990, Fields of Application of Hierarchical Production Planning (HPP), in: Fuchssteiner, B. et al. (ed.), Methods of Operations Research 60, Hain, Frankfurt/M.: 145-151.

[15] Rese, M., 2006, Cost Decisions and Pricing Decisions in Times of Value-Based Management, in: Plötner, O., Spekman, R.E. (ed.), Bringing Technology into Market – Trends, Cases, Solutions, Wiley: 61-76.

[16] Schäfer, U., Weber, J., 2002, Herausforderungen für das Dienstleistungs-Controlling, KRP Sonderheft, 2002 (2): 5-13.

[17] Steven, M., Rese, M., Soth, T., Strotmann, W., Karger, M., 2009, Profitability of Industrial Product Service Systems (IPS²) – Estimating Price Floor and Price Ceiling of Innovative Problem Solutions, in: Proceedings of the 1st CIRP IPS² Conference: 243-248.

An integrated lifecycle model of product-service-systems

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Abstract

Managing today's innovation processes becomes increasingly difficult due to higher dynamics and complexity along the PSS lifecycle. To be able to consider dynamics along the lifecycle early in the innovation process, an integrated understanding of the PSS lifecycle is crucial. Therefore, this paper addresses a PSS lifecycle model considering phases from the planning and development of PSS throughout the phases of use and disposal. The lifecycle of the physical component (product) must thereby not be seen separately from the associated service lifecycle. Based on existing lifecycle models in the areas of service engineering and integrated product development, an aggregated PSS lifecycle model is deduced and discussed.

Keywords

Lifecycle, Innovation Process, Dynamics, Integrated Product Development, Strategic Planning

1 INTRODUCTION – AN INTEGRATED LIFECYCLE MODEL OF PRODUCT-SERVICE-SYSTEMS

1.1 Motivation

Companies in industry face the fundamental challenge to improve their innovation processes in order to cope with the increasing complexity of today's products and corresponding services. Against this background, it is essential for companies to frontload an integrated systems understanding to the early phases of planning future product-service-systems (PSS). In particular changes and corresponding change propagations along the future PSS lifecycle have to be considered early in order to prevent unnecessarily provoked lifecycle costs, which grow exponentially the later unintended changes are made within the lifecycle [1]. In this context, it is essential to anticipate the whole lifecycle of future PSS in order to allow fast responses to influences from the environment and moreover to adapt the portfolio of offered products and services as well as corresponding company processes to the latest conditions with regards to content and time [2, 3]. To be aware of interrelations within the lifecycle and its phases in a first place a sophisticated understanding of the lifecycle phases, a PSS runs through, is needed. In the past the lifecycles of products have been researched a lot, in particular in the areas of engineering design and product lifecycle management. Also service lifecycles have been discussed, especially in the last few years. But in order to plan future PSS in an integrated way, a separate perspective on the product and service lifecycle is not sufficient. Therefore, in the past years, first approaches in respect to an integrated PSS lifecycle understanding have been established. E.g. the research project TR29 [4] presents a framework of dealing with information along the PSS lifecycle. Nevertheless, there is still a need for a PSS lifecycle model which is suitable for describing interrelations along the lifecycle at a reasonable level of granularity in the early phases of planning future PSS.

1.2 Background of research

Research presented in this paper is carried out against the background of the collaborative research centre "SFB 768 Managing cycles in innovation processes". Within the SFB 768, participants of social, economic and engineering sciences follow the goal of supporting engineers and other stakeholders along the innovation process in dealing with the heterogeneous temporal behaviour of artefacts (cycles) within the innovation process. For example, cycles can be detected in respect to usable technologies, as company-relevant technologies in the competitive environment (suddenly) emerge, evolve, get obsolete, get replaced by another emerging technology which evolves, and so on. In order to be able to manage these cycles throughout the innovation process, it is important to already consider these cycles when planning future PSS. In this context, it is essential to anticipate changes in respect to the potentials and constraints along the lifecycle in order to launch product-service-systems which fulfil customer needs but at the same time fit into the processes and possibilities of the PSS-providing company. Furthermore, changes within the singular phases of the PSS lifecycle may impact changes in other lifecycles phases, which are not obvious at a first sight. In order to describe possible change propagations along the lifecycle, a detailed understanding of lifecycle phases and their interrelations is needed. Thereby, the question arises, which lifecycle phases are run through by a PSS. Where in the PSS lifecycle are tasks concerning the product being carried out separately from the service and where is an integrated perspective obligatory?

Thus, this paper presents an integrated model of the lifecycle of product-service-systems throughout the phases of planning, designing, delivering/using and decomposing PSS – deduced from various lifecycle literature in the disciplines of engineering design, service and PSS engineering. In section one, different lifecycle models in product, service and PSS engineering are discussed and compared. Based on this literature review, the process of aggregating an integrated PSS lifecycle is described and the integrated PSS lifecycle model is presented. Thereby, not only the singular phases the PSS runs through are shown, but also specifics in dealing with the lifecycle model are explained. Finally, conclusions are drawn and an outlook on future research based on the reference model of the PSS lifecycle is given.

2 EXISTING SERVICE, PRODUCT AND PSS LIFECYCLE MODELS

In this section, an overview about existing lifecycle models in service, product and PSS engineering is given. The models, identified and explained in the following, describe the basis for the aggregated PSS lifecycle model in section 3.

2.1 Service lifecycle models

A first existing approach, presented in the context of modelling the service lifecycle has been researched by Schwarzer [5]. This model consists of the phases 'Idea generation and evaluation', 'Requirements', 'Design', 'Implementation', 'Service delivery' and 'Replacement'. Another model – deriving from service engineering science – which is comparable to the model of Schwarzer is discussed by Meiren und Barth [6]. It also consists of five superordinate phases. Each of the phases is split down to several submodels, which have to be considered within each phase (see Figure 1). Bullinger et al. [7] consider similar phases in their model, but further add the phase of 'Post-launch review' in their waterfall model.

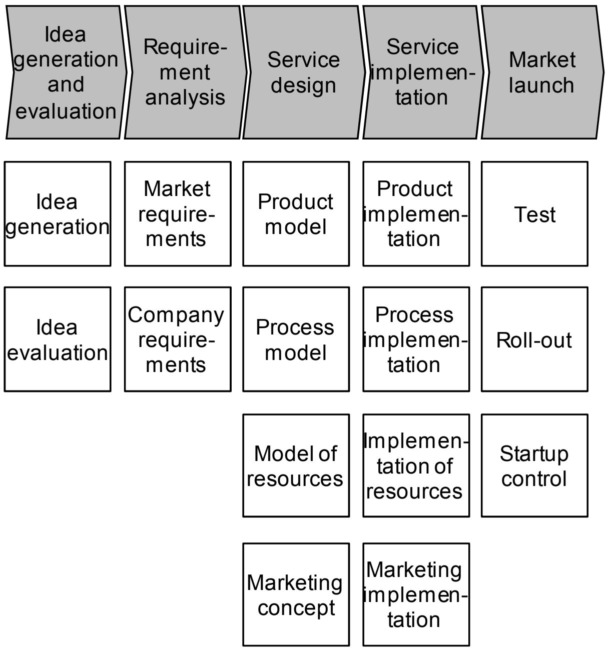

Figure 1: Service lifecycle model according to Meiren and Barth [5]

Another model describing the service lifecycle is presented by Ramaswamy [8]. In this model, a feedback loop specifically emphasises the importance of improving the service after measuring the performance and customer satisfaction. When improving the service, the lifecycle is run through again and thus the lifecycle is shown as a loop. A very similar model to Ramaswamy's one is presented by Cernavin et al. [9].

Besides the above mentioned aspects within the service lifecycle, Krallmann and Hoffrichter [10] also consider a phase of looking at already implemented services in order to evaluate new service ideas.

A very detailed lifecycle model of services has been researched by Schneider and Scheer [11]. Their 'Customer related Service Life Cycle (CurLy)' is divided into the superordinate phases:

- Start-Up-phase
- Concept-phase
- Implementation-phase
- Monitoring-phase

Each of these superordinate phases is detailed by many subphases. E.g. within the phase of 'Monitoring', the 'Customer Relationship Management' is explained in order to tie the customer to the company.

Although there are far more models concerning the service lifecycle, these are not further explained due to their similarity with the already explained models. Thus, following discussions in section 3 in respect to an aggregated PSS lifecycle model are based on the presented literature.

2.2 Product lifecycle models

Within the research project SFB 768, a reference model of the product lifecycle with respect to further use in the context of supporting strategic planning has already been established and published by Hepperle et al. [12] (see Figure 2). Thereby, the model has been deduced on the basis of various existing lifecycle models in product lifecycle management [e.g. 13-16] and engineering design [e.g. 17-20]. As this lifecycle model provides an ideal basis and will therefore be used for discussing an integrated PSS lifecycle model in section 3, the major aspects of the model and according literature are shortly presented in this section.

The lifecycle model consists of the superordinate phases of 'Product planning', 'Product development and design', 'Production process preparation', 'Production', 'Distribution', 'Utilisation', 'Maintenance', 'Modernisation lifecycle' and 'Product disposal'. Thereby, the phase of product planning has been detailed based on VDI 2221 [17], VDI 2220 [21] and Braun [22]. In this phase, product ideas are generated and prioritised based on the market needs and the company potential before a product recommendation is handed over to the next lifecycle phase. The 'Product development and design' is particularly based on the 'Munich Model of Product Concretisation' by Ponn and Lindemann [23], VDI 2221 [17] and Hundal [24]. Thereby, requirements are continuously updated, while the product gets more detailed by defining the product functions, the working elements, the components and their structure before building and testing the prototype. The phase of 'Production process preparation' is mainly described based on literature by Arnold et al. [13], Gausemeier et al. [25] and VDI 4499 [26]. As there is a high number of different manufacturing and assembly techniques, the phase of production is reduced to the three steps of manufacturing, assembly and test of the product. These phases are mainly described based on Ehrlenspiel [19], Gausemeier et al. [25] and Conrad [27].

The next phase 'Distribution' consists of the steps packaging and warehousing the product, delivery and possible intermediate warehousing of the product. These steps are deduced from Kleinaltenkamp and Plinke 1995 [28]. Within the following phase 'Utilisation', it is emphasised according to literature by Ullman [20] to consider multiple periods of utilisation. In this context, the modernisation / upgrade of products is based on the discussion of Mörtl [29], also baring the phase of recycling in mind according to VDI 2243 'Recycling-Oriented Product Development' [30].

In parallel to the phase of utilisation, major tasks concerning the maintenance of products are shown according to DIN 31051 [31]. After the phase of utilisation, the product lifecycle ends with the 'Product disposal and recycling'. After shutting down and disassembling the product, components are disposed or recycled according to VDI 2243 [30] and Stengel et al. [32].

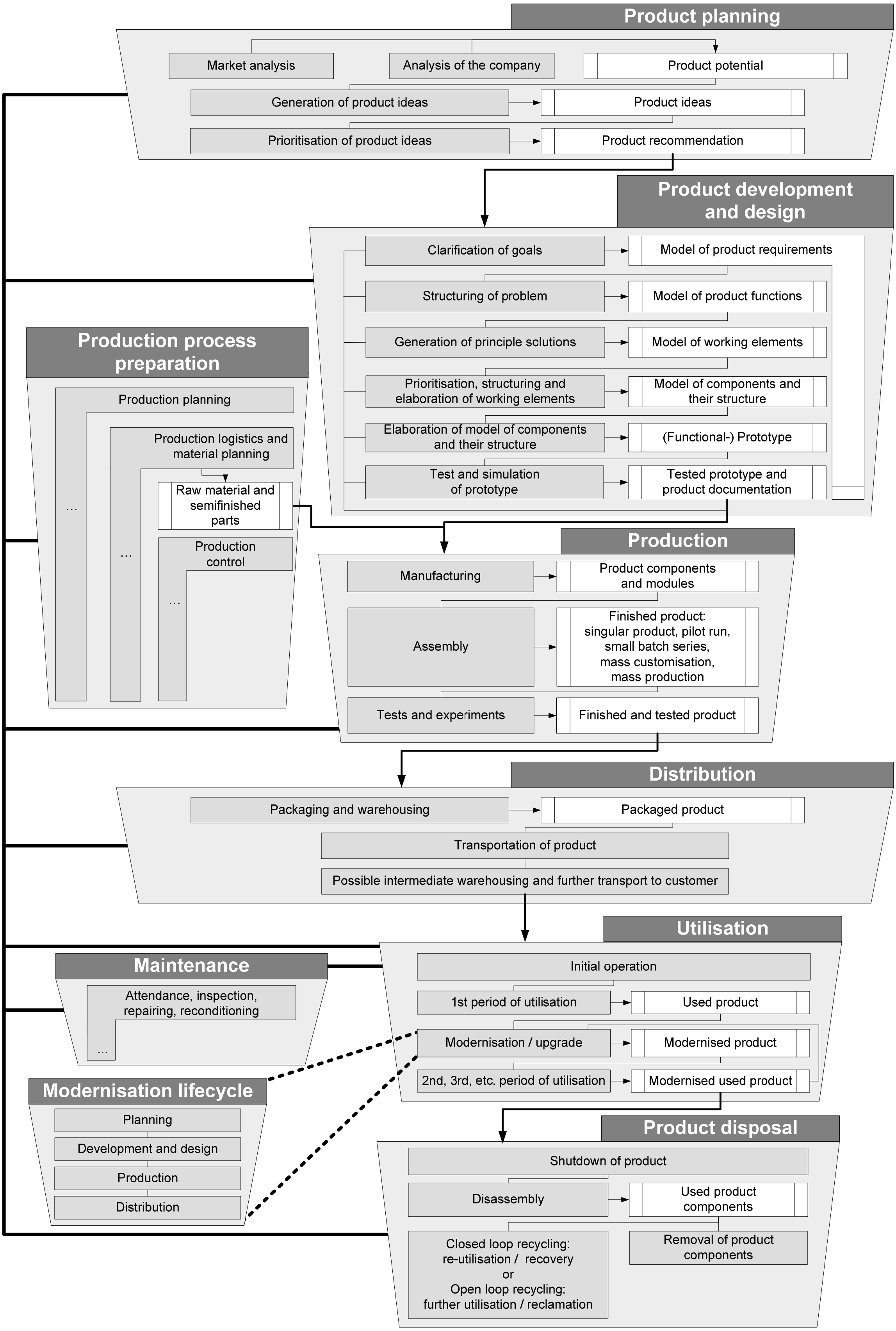

Figure 2: Product lifecycle reference model according to Hepperle et al. [12]

2.3 Preliminary work concerning lifecycle models of product-service-systems

Besides the isolated perspective on products and services, also first approaches in dealing with the lifecycle of product-service-systems have been researched. For example, Becker et al. [33] discuss a framework of hybrid value creation. The lifecycle of PSS is thereby split up into the superordinate phases of design, delivery and replacement. Around these core processes, they describe supporting, coordinating, supply and sales processes.

In the lifecycle model of Hartel [34] only five product related lifecycle phases 'Research', 'Development', Production', 'Utilisation' and 'Disposal' are shown. In this model the PSS-perspective comes in, as various services are assigned to the product phases. Thereby, Hartel distinguishes between 'Pre-sales', 'Sales' and 'After-sales' services. This differentiation can also be detected in the work of Knackstedt et al. [35], who research product accompanying services.

As already mentioned in the introduction, the collaborative research centre TR 29 also discusses product-service-systems. Within that research, e.g. Abramovici and Schulte look at the PSS lifecycle both from the company's and the customer's perspective [36]. Thereby, the model is not too detailed, as in the first place it tries to give an initial picture how the lifecycle management, i.e. the information flow throughout the lifecycle can be arranged.

Another reference to mention in the context is delivered by Aurich et al. [37]. Thereby, besides introducing phases of the technical service design process, they provide a 'concept of process modularization'. This concept focuses on linking product and service design processes but also bearing the flexibility in mind which is necessary to consider individual demands in the extended value creation network.

The presented references rather help to understand the integrative perspective on PSS or focus how to deal with the different data throughout the lifecycle. As the provided information is not sufficient for getting a more detailed overview of aspects to be considered in the early planning of PSS, an aggregated PSS lifecycle model with an appropriate detail level is deduced in the next section.

3 AN INTEGRATED PSS LIFECYCLE MODEL

3.1 Procedure of aggregating the PSS lifecycle

Mainly based on the mentioned references, an aggregated PSS lifecycle model is deduced in this section. Thereby, the PSS lifecycle model consists of phases which should necessarily be run through interactively, while other phases are run through separately in the product and service discipline, still baring the continuous communication between the disciplines in mind.

In the area of more product related aspects of the PSS lifecycle, the product reference model according to Hepperle et al. [12] (see Figure 2) was used for the aggregation. This model is deduced from various existing literature in order to allow a detailed view on aspects relevant for early planning of products and therefore describes an appropriate basis for the product elements within the PSS lifecycle.

For considering service aspects within the integrated PSS lifecycle none of the existing models distinguishes itself to being directly taken over. Therefore, in section 3.2 a reference model of the service lifecycle is presented before the aggregated PSS lifecycle is explained in section 3.3.

Besides the considered product and service lifecycle, further issues have to be taken into account in order to emphasise the integration of the two disciplines. Therefore, the lifecycle model consists of elements, which are necessary to describe the interaction between product and service aspects within the lifecycle. These elements are described in section 3.3.

Finally, there are some issues to be considered when dealing with the presented PSS lifecycle model. These aspects are disclosed in section 3.4. In particular, the linkage to further considered aspects within the collaborative research centre SFB 768 'Managing cycles in innovation processes' are pointed out in order to classify the results concerning the integrated PSS lifecycle.

3.2 Aggregation of the service lifecycle

Before aggregating the model of the PSS lifecycle in section 3.3, a service lifecycle model for the further use is presented in this section. The model (see Figure 3) is particularly derived from the references by Meiren and Barth [6], Ramaswamy [7], Cernavin et al. [8], Krallmann and Hoffrichter [10] as well as Schneider and Scheer [11].

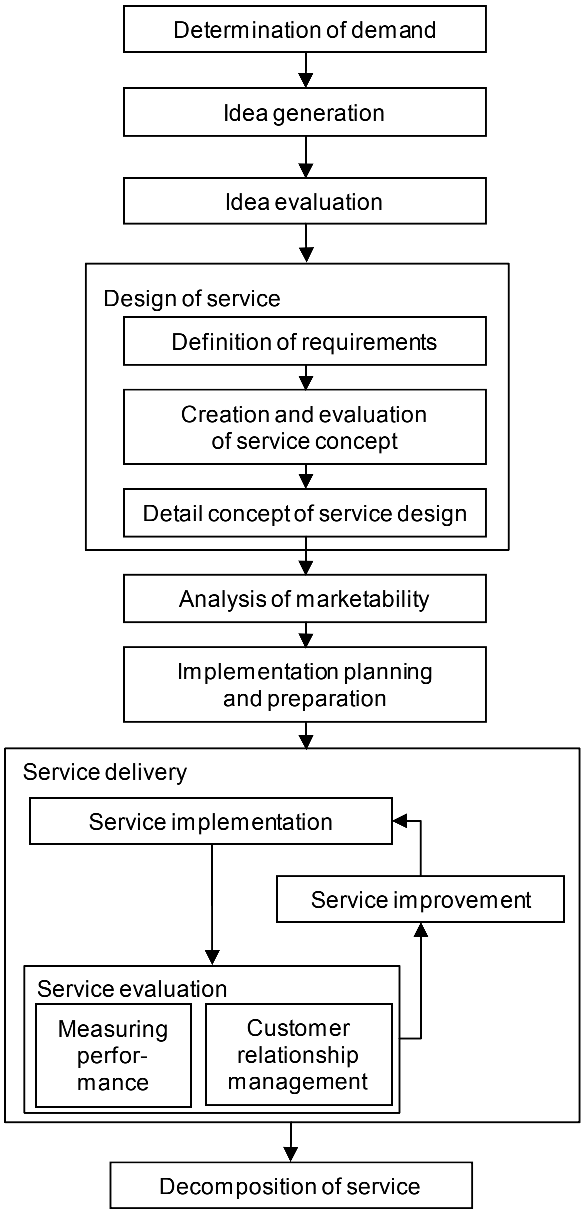

Figure 3: Reference model of service lifecycle

3.3 Aggregation of the PSS lifecycle

As already mentioned, the integrated lifecycle model of PSS (see Figure 5) is predominantly deduced based on the product lifecycle reference model by Hepperle et al. [12] (see Figure 2) as well as the service lifecycle reference model presented in this paper (Figure 3). The aggregated PSS model consists of the three major parts:

- PSS planning
- PSS development
- PSS production, delivery and decomposition

Thereby, the model consists of PSS states and PSS working phases. From the PSS planning to the PSS development, an integrated PSS-development suggestion is handed over. Similarly, from the PSS development to the PSS production, delivery and decomposition, the designed PSS is transferred.

Within each of the superordinate phases, tasks can be performed integrated (e.g. PSS planning) or being solved partly separately, bearing a continuous communication between the disciplines in mind (e.g. PSS development).

In a first step, PSS potentials are deduced from environment and company potentials and PSS ideas are generated and evaluated according to these potentials. Based on the PSS development suggestion, it is necessary to decide whether and to which extent the offered solution is being carried out by a service or by a product element. In the next step, requirements both for the product and for the service are gathered. The requirements are regularly updated during the design process and thus, a continuous communication between the product development and the service design department is essential for the later success of the PSS. After both product and service elements of the PSS are finally designed, a test of marketability shows, whether the PSS is ready for being launched and delivered to the market.

While the product is produced in the next steps, it is important that the service implementation is prepared. Thereby, supporting tools have to be finalised. Already around the phases of distribution, singular product accompanying services can be delivered (Pre-product-use-services). This can for example be a service concerning the transport of the product. During the phase of using the product, further services may be demanded within the customer's solution (Services during product use). Such services may be attributed to a modernisation or maintenance contract. Particularly for the case that a product upgrade is performed, the service has to be adapted. Therefore, a communication between the adaptation / improvement of the service and the modernisation lifecycle of the product is necessary. Also services, concerning the phases of 'After-product-use' are considered within the integrated PSS lifecycle model. These kinds of services may e.g. concern the shut-down of the product as well as the redemption of product components. For all kinds of services, the same 'Service delivery' is run through.

As it is not shown in Figure 5, one should bear in mind that some services – in particular those corresponding to the after-product-use phase – cannot finally be designed before the PSS is launched. E.g. for products which stay at the customer for more than 30 years, it may not be possible to already consider how the respective product can be disposed. Thus, the detail service design has to be finalised while the product is already on the market. Nevertheless, a first concept should already be taken into account in the early stage of the PSS lifecycle in order to have an integrated concept and in order to provide potentially necessary interfaces at the product.

Furthermore, not all tasks have to be performed by one company. E.g. the company offering the PSS may outsource the production of the product. In addition, not all of the phases have to be run through compulsory.

3.4 Additional considerations

The integrated PSS lifecycle model gives an overview about the different phases and can therefore be seen as a checklist, which aspects may already be considered in a lifecycle oriented planning of PSS. When planning future PSS, it is of interest, how the PSS of the future has to change compared to the currently offered PSS. Thereby, changes within the lifecycle from PSS to PSS may derive from manifold sources and according context factors. Changes can originate both from the environmental, market and company background.

Different factors, which can be assigned to manifold areas both concerning the side of 'purchases' as well as the 'sales' side, can be detected based on the research by Langer and Lindemann [38] (see Figure 4).

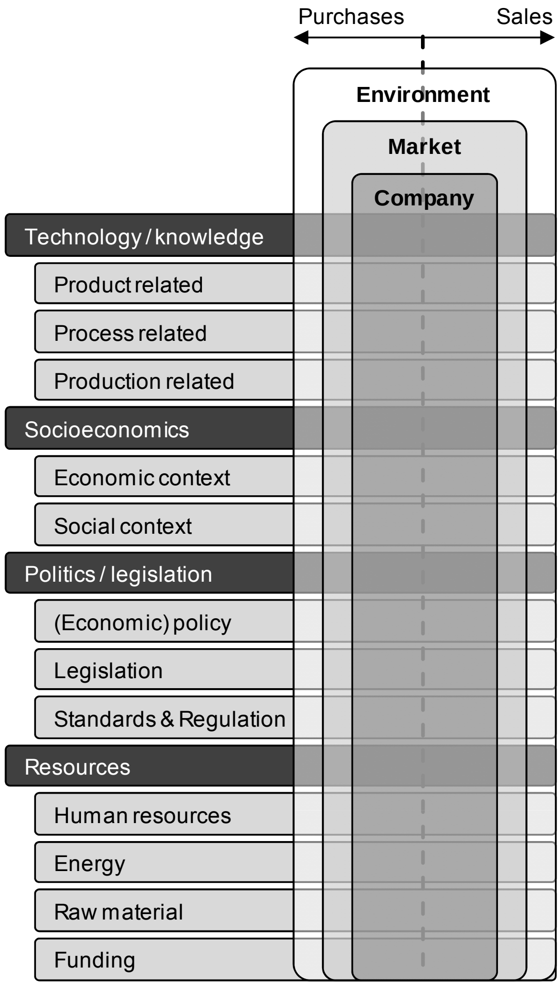

Figure 4: Context factors of product development according to Langer and Lindemann [38]

As these context factors are often characterised by dynamic behaviour, the influenced PSS lifecycle also shows dynamic behaviour. Thus, it is of interest, which factors within the different categories influence the different lifecycle phases and how the impact on the lifecycle phases looks like. Furthermore, by identifying interrelations between the lifecycle phases, it will be possible to setup chains of cause and effect by increasing the transparency of change propagations within the lifecycle.

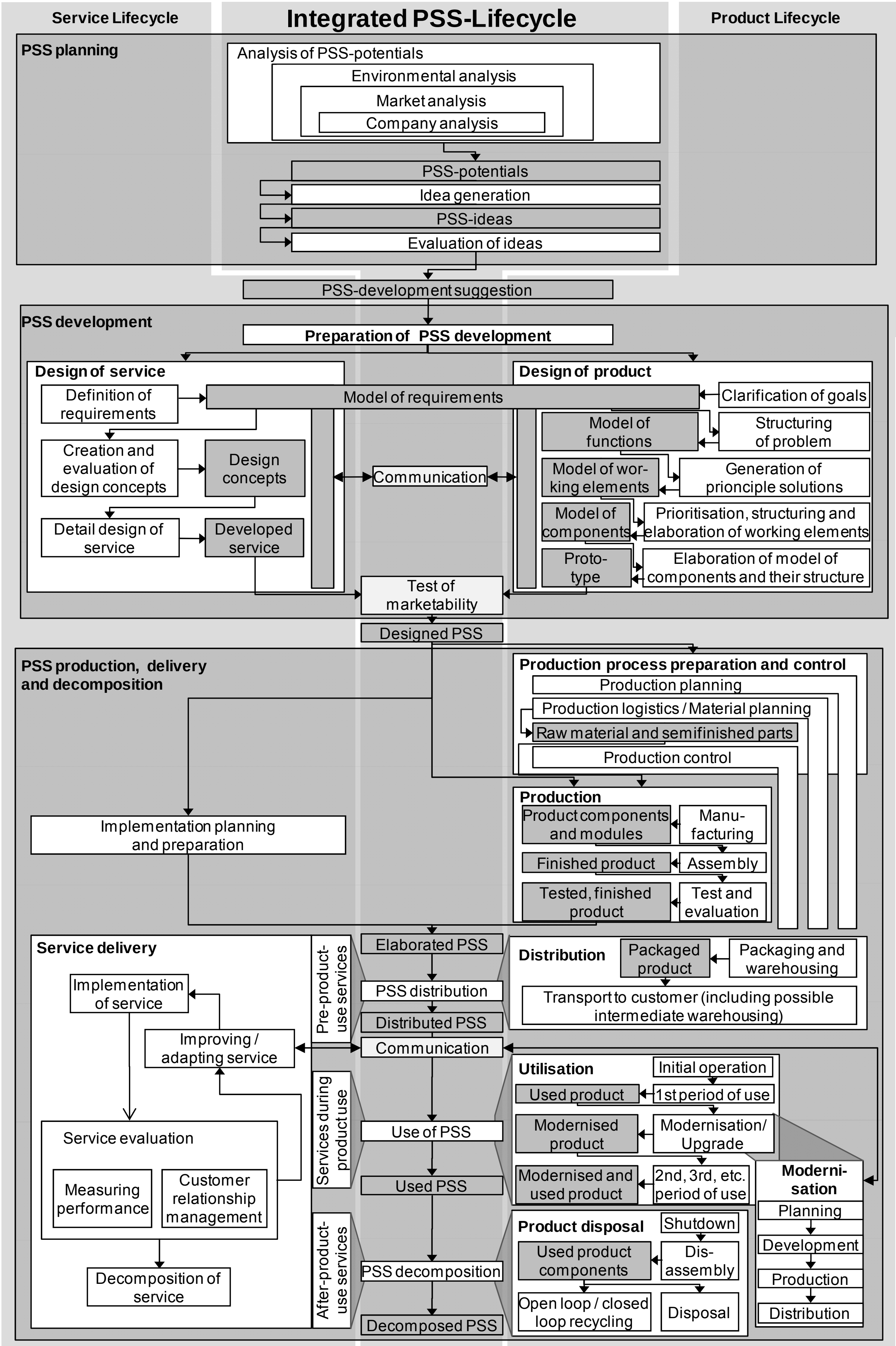

Figure 5: Reference Model of integrated PSS lifecycle

4 SUMMARY

4.1 Conclusions

Based on various existing literature, a reference model of the PSS lifecycle has been presented in this paper. Thereby, the model was aggregated with the goal of getting an appropriate basis for further analyses concerning a lifecycle oriented planning of PSS.

In comparison to other existing PSS lifecycle models, which are still very rare in literature, the presented model followed the purpose to be detailed enough but still manageable to overview the singular phases a PSS runs through.

Against that background, a major focus of the research was to share an integrated perspective on the PSS lifecycle. On the one hand, that means that all lifecycle phases from the early planning of PSS until the later phases of utilisation and decomposition of products and corresponding services have been taken into account. On the other hand, it means that throughout the lifecycle, the strong interaction and integration in dealing with the PSS have been emphasised.

Despite the limitations of a generic approach to describe the PSS lifecycle, it still allows an overview about singular tasks and PSS states along the lifecycle. Further, the model itself provides a valuable input for further work, which is presented in the final section.

4.2 Outlook

Until now, the aggregated PSS lifecycle model is particularly based on literature, but also on industrial experience. Thereby, on the one hand discussions with different industrial partners from automotive industry as well as from a company developing and producing 'white goods' and household equipment have been reflected. On the other hand the authors' experience from working in different industrial projects has been considered in deducing the PSS lifecycle model.

Furthermore, the model has been validated successfully based on simple examples. Nevertheless, in order to validate the results in depth, one of the next steps will be to evaluate the model based on a case study. For this evaluation, interviews which are currently conducted will also be taken into consideration.

As section 3.4 has shown, one important step in researching the dynamic behaviour of subsequently following lifecycles will be to assign the factors, influencing the PSS lifecycle, and the corresponding identified cycles to the singular phases of the lifecycle. This will support the transparency in respect to lifecycle oriented planning of PSS.

Another focus of further work is directed on interrelations between the singular phases of the PSS lifecycle. A more sophisticated understanding of those interrelations will help to support the understanding of general and company specific change propagations within the lifecycle of product-service-systems.

For the identification of interrelations, an extended analysis of 'Design for X' [39] guidelines will be performed. This approach to identify interrelations within the product lifecycle has already been successfully tested in a first step. Thus, this analysis will be extended, now also taking guidelines like 'Design for service' into account [40]. In parallel, a framework of how these interrelations can be classified and further analysed is built up based on previous work from Maurer et al. [41].

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] Ehrlenspiel, K., Kiewert, A., Lindemann, U., Hundal, M.S., 2007, Cost-Efficient Design, Berlin: Springer.

[2] Gausemeier, J., Lindemann, U., Schuh, G., 2004, Planung der Produkte und Fertigungs-systeme für die Märkte von morgen, Frankfurt: VDMA.

[3] Georgantzas, N.C., Acar, W., 1995, Scenario-Driven Planning – Learning To Manage Strategic Uncertainty, Westport: Quorum Books.

[4] Meier, H., Kortmann, D., Völker O., 2007, Gestaltung und Erbringung hybrider Leistungsbündel, wt Werkstattstechnik online Jahrgang Vol 97, Iss. 7/8.

[5] Schwarzer, B., 2005, Der Einsatz von Electronic Meeting Systems im Service Engineering am Beispiel von GroupVision.Web. In: Herrmann, T., Kleinbeck, U., Krcmar, H. (Eds.), Konzepte für das Service Engineering, Heidelberg: Physika-Verlag.

[6] Meiren, T., Barth, T., 2002, Service Engineering in Unternehmen umsetzen. Stuttgart: Fraunhofer IRB.

[7] Bullinger, H.-J., Fähnrich, K.-P., Meiren, T., 2003, Service Engineering – Methodical Development of New Service Products, International Journal of Production Economics 85.

[8] Ramaswamy, R., 1996, Design and Management of Service Processes: Keeping Customers for Life, Reading: Addison-Wesley Publishing Company, Inc.

[9] Cernavin, O., Ebert, B., Keller, S., 2007, Service Engineering und Prävention, Wiesbaden: BC GmbH Forschungs- und Beratungsgesellschaft 2007.

[10] Krallmann, H., Hoffrichter, M., 1998, Service Engineering – Wie entsteht eine neue Dienstleistung. In: Bullinger, H.-J.; Zahn, E. (Eds.): Dienstleistungsoffensive – Wachstumschancen intelligent nutzen, Stuttgart: Schäffer-Poeschel.

[11] Schneider, K., Scheer, A.-W., 2003, Konzept zur systematischen und kundenorientierten Entwicklung von Dienstleistungen. Institute for Information Systems, Research Report 175.

[12] Hepperle, C., Thanner, S., Mörtl, M., Lindemann, U., 2009, An integrated product lifecycle model and interrelations in-between the lifecycle phases, 6th International Conference on Product Lifecycle Management, Bath (UK).

[13] Arnold, V., Dettmering, H., Engel, T., Karcher, A., 2005, Product Lifecycle Management beherrschen – Ein Anwenderbuch für den Mittelstand, Berlin: Springer.

[14] Stark, J., 2005, Product Lifecycle Management – 21st Century Paradigm for Product Realisation, London: Springer.

[15] Grieves, M., 2006 Product Lifecycle Management – Driving the Next Generation of Lean Thinking, New York: McGraw-Hill.

[16] Saaksvuori, A. and Immonen, A., 2005, Product Lifecycle Management, 2nd ed. Berlin: Springer.

[17] VDI 2221, 1993, Systematic Approach to the Development and Design of Technical Systems and Products, Düsseldorf: VDI-Verlag.

[18] Pahl, G., Beitz, W., Feldhusen, J., Grote K.-H.; Eds.: Wallace, K., Blessing, L., 2007, Engineering Design: A Systematic Approach, 3rd ed. Berlin: Springer.

[19] Ehrlenspiel, K., 2006, Integrierte Produktentwicklung, 3rd ed. Munich: Hanser.

[20] Ullman, D.G., 1997, The Mechanical Design Process, 2nd ed. Boston: McGraw-Hill.

[21] VDI 2220, 1980, Product Planning; Flow, Terms and Organization, Düsseldorf: VDI-Verlag.

[22] Braun, T., Gausemeier, J., Lindemann, U., Orlik, L. and Vienenkötter, A., 2004, Design Support by Improving Method Transfer – A Procedural Model and Guidelines for Strategic Product Planning in Small and Medium-sized Enterprises, International Design Conference – Design 2004, Dubrovnik, Zagreb: Sveucilisna tiskara.

[23] Ponn, J., Lindemann, U., 2008, Konzeptentwicklung und Gestaltung technischer Produkte, Berlin: Springer.

[24] Hundal, M.S., 2002, Mechanical Life Cycle Handbook, New York: Marcel Dekker.

[25] Gausemeier, J., Hahn, A., Kespohl, H.D., Seifert, L., 2006, Vernetzte Produktentwicklung: Der erfolgreiche Weg zum Global Engineering Networking, Munich: Hanser.

[26] VDI 4499, 2008, Digital Factory – Fundamentals, Düsseldorf: VDI-Verlag.

[27] Conrad, K.-J., 1998, Grundlagen der Konstruktionslehre, Munich: Hanser.

[28] Kleinaltenkamp, M.; Plinke, W. (Eds.) (1995) Technischer Vertrieb – Grundlagen, Berlin: Springer 1995.

[29] Mörtl, M., 2003, Design for Upgrading' of Machines and Production Processes: A Guideline Based on Actual Demands of Industry and Sustainable Design, 14th International Conference on Engineering Design, ICED' 03, Stockholm.

[30] VDI 2243, 2002, Recycling-Oriented Product Development, Düsseldorf: VDI-Verlag.

[31] DIN 31051, 2003, Fundamentals of Maintenance, Berlin: Beuth.

[32] Stengel, T., Schießl, P., Heinz, D., 2006 Nachhaltige Kreislaufführung mineralischer Baustoffe, Munich: TUM, Research report F2032.

[33] Becker, J., Krcmar, H., 2008, Integration von Produkten und Dienstleistungen – Hybride Wertschöpfung, Wirtschaftsinformatik Vol. 3.

[34] Hartel, I., 2004, Virtuelle Servicekooperationen, Zürich: vdf Hochschulverlag.

[35] Knackstedt, R., Poppelbuss, J., Winkelmann, A., 2008, Integration von Sach- und Dienstleistungen – Ausgewählte Internetquellen zur hybriden Wertschöpfung, Wirtschaftsinformatik Vol. 3.

[36] Abramovici, M., Schulte, S., 2006, Life Cycle Management für hybride Leistungsbündel, wt Werkstatttechnik online Vol. 96, Iss. 7/8.

[37] Aurich, J.C., Fuchs, C., 2006, Wagenknecht C., Life cycle oriented design of technical Product-Service Systems, Journal of Cleaner Production 14.

[38] Langer, S., Lindemann, U., 2009, Managing Cycles in Development Processes – Analysis and Classification of External Context Factors, 17th International Conference on Engineering Design, ICED09, Stanford.

[39] Meerkamm, A., 1994, Design for X – a core Area of Design Methodology, Journal of Engineering Design, Vol. 5, No. 2.

[40] McAloone T.C., Andreasen M.M., 2004, 'Design for Utility, Sustainability and Societal Virtues, Developing Product Service Systems', International Design Conference – Design 2004, Dubrovnik, Zagreb: Sveucilisna tiskara.

[41] Lindemann, U, Maurer, M, Braun, T., 2009, Structural Complexity Management - An Approach for the Field of Product Design. Springer: Berlin.

TPI-based Idea Generation Method for Eco-business Planning

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Abstract

Environmental consciousness has gained increasing interest in recent years, and product life cycle design that aims to maximize total value while minimizing environmental load and costs should be implemented. To achieve that, the processes of idea generation and decision-making for eco-business strategies, as well as the design of a target product and its life cycle options, should be systematically supported. This paper proposes a strategic decision-making method for eco-business planning so that a designer can easily find a set of eco-business ideas that effectively improve environmental and economic performance simultaneously. A decision-making procedure based on this method is also illustrated with a simplified example of a laptop computer business.

Keywords

product service system (PSS), eco-business, total performance indicator (TPI), idea-generation method, eco-business rule, eco-business case base.

1 INTRODUCTION

Environmental consciousness has been growing in recent years, and product life cycle design that aims to maximize utility value while minimizing environmental load and cost should be implemented in addition to environmentally conscious design of the product itself. In this context, many life cycle design tools and concepts have been proposed in recent years [for example, 1,2,3,4,5,6]. Among them, Product Service System (PSS) [5,6], which is often defined as "a marketable set of products and services capable of jointly fulfilling a user's needs" [5], is seen as an excellent means for significant reduction of environmental load as well as enhancing competitiveness of the businesses.

However, it is not easy for a designer to derive a practical design solution for the product life cycle (e.g., product specifications and life cycle options for components, etc.) by using them. To solve these problems, we have proposed the Total Performance Design (TPD) method, focusing on the balance of the customer's utility value of a product and its resulting environmental load and cost throughout the entire life cycle [7]. In this method, the Total Performance Indicator (TPI), which represents the environmental and economic performance of the product life cycle, is used as an objective function and a design solution is derived as a set of life cycle options (e.g., reuse, recycling, upgrading, extension of physical lifetime, and upgrading) for each component, specifications for each functional requirement, and product lifetime that maximizes TPI under a given business environment.

Although this tool was shown to be useful through a case study, it is also important to consider eco-business strategies (e.g., three types of PSS: product-oriented services, use-oriented services, result-oriented services) to improve TPI. For example, adequate control and management of operating conditions are effective for products which consume large quantities of energy and materials during their usage stage (classified as a kind of result-oriented services of PSS). In this case, providing products with energy-saving service (e.g., ESCO business [8] and eco-drive training for drivers) is a promising approach. In addition to operating conditions, product lifetime and its physical wear and deterioration are also insufficiently controlled by product design alone. Therefore, the idea generation and decision-making processes for eco-business strategies, as well as the design of the target product and its life cycle options, should be examined.

The objective of this study is to propose a decision-making method for eco-business planning so that a designer can easily find a set of practical business ideas that effectively improve TPI in a systematic manner. Specifically, we take an approach that provides a business designer with general rules extracted from existing eco-businesses in relation with 17 business parameters that describe the applicability of each rule in a given business environment. In other words, we seek to develop a pattern language in the domain of eco-business planning.

2 APPROACH

2.1 Definition of eco-business and objective function

We here define eco-businesses as businesses that provide greater user value at lower environmental load and cost than existing ones. By using the Total Performance Indicator (TPI) [7], which simultaneously represents the efficiency of utility value production from environmental and economic viewpoints, eco-businesses are considered to be those that achieve higher TPI than existing ones. TPI, which is used as an objective function in this study, is defined as the balance of customer utility value (UV) and its resulting environmental load and cost as follows:

$$TPI = \frac{UV}{\sqrt{LCE \times LCC}} \qquad (1)$$

where LCE and LCC denote environmental load and cost throughout the entire life cycle, respectively. We selected equation 1, above, because (i) the evaluation of environmental and economic performance is viewed as having the same level of importance and (ii) arithmetic average of LCE and LCC is not suitable due to difficulties in converting LCE and LCC into the same unit.

2.2 Strategic decision-making method for eco-business planning

In order to help a designer to find eco-business ideas that effectively improve TPI, we provide a business designer with a set of eco-business rules and conditions for applying them.

First, we identify 17 business parameters, from which UV, LCE and LCC are constructed. A set of key (influential) parameters in a given business environment is identified by sensitivity analysis of TPI and it gives a pattern of a given business environment.

Second, for each eco-business rule, we analyze its effect on these 17 parameters in 70 eco-business examples in Japan. Summarizing a general tendency of each rule, the applicability of each rule is given by a rules-parameters matrix. By using this matrix and consulting business case base, a business designer can easily find a set of business rules that effectively improve TPI in a given business environment.

The procedure of the method is summarized as follows.

Step 1: Identification of business environment

First, the business designer identifies customers' functional requirements and calculates the values for 17 parameters in a given business environment.

Step 2: Sensitivity analysis of TPI

The business designer executes sensitivity analysis of TPI to find a set of influential parameters.

Step 3: Idea generation for eco-business

Using predefined eco-business rules that were derived by analyzing existing eco-businesses, the business designer selects a set of rules that improves the key parameters derived in Step 2, and generates eco-business ideas by consulting the eco-business case base, which describes how each rule improves these parameters in each existing eco-business case.

Step 4: Evaluation of the eco-business ideas by TPI

Based on the eco-business ideas generated in Step 3, TPI of a product (service) is recalculated. If the business designer is not satisfied with the improvement in TPI, then the designer returns to Step 2.

The remainder of this paper is organized as follows. Section 3 presents the 17 business parameters that construct the objective function TPI. Section 4 describes the rules we used in this study. Section 5 illustrates a procedure of this method through a case study of a laptop computer business. Section 6 concludes the paper.

3 FORMULATION OF UV, LCE AND LCC

3.1 Formulation of UV

UV as time integral of product value.

The UV of a product rises as the product's functional performance increases and the longer it is used. Thus, UV is defined as the time integral of product value, assuming that the product value is strongly correlated with its functional performance.

$$UV = \int_0^{lt} V(t)dt \quad (2)$$

where *lt* and *V(t)* denote the lifetime and product value at time *t*, respectively.

Estimation of UV by multi-attribute utility theory

From the viewpoint of the multi-attribute utility theory [9], product value at time *t* can be allocated to its dominant functional requirements (FR) given as follows:

$$V(t) = \sum_i V_i(t) \quad (3)$$

$$V_i(t) = w_i(t)FR_i(t) \quad (4)$$

where i, $V_i(t)$, $w_i(t)$ and $FR_i(t)$ denote the index of FRs, product value allocated to FR_i, weighted factor for FR_i, and functional performance of FR_i at time t, respectively. The weighted factor for each FR represents its consumer importance. Those with high importance have great potential for improving product value. In this study, we assume that product value is measured by market price. Therefore, the importance of each FR can be estimated by conjoint analysis of various products with different specifications.

Time variation of UV.

Since UV is defined as the time integral of product value, the time variation of product value should be estimated. Product value deteriorates for the following reasons: *(i) physical causes* and *(ii) value causes* [10]. Physical causes include product failure and degradation due to aging and wear. Value causes include obsolescence of product FRs (including aesthetic quality). The value of products such as computers or mobile phones deteriorates too fast due to very rapid technological innovations, and so both types of causes should be estimated at the same time. Since the value of a product is given as the weighed sum of its functional performance, value deterioration over time is given by decreases in functional performance and importance.

(i) Deterioration due to physical causes

Here, deterioration due to physical causes is represented as a decrease in functional performance $FR_i(t)$. $FR_i(t)$ is estimated using empirical data on the deterioration of similar products at their usage stage by applying reliability theory. For the sake of simplicity, deterioration of $FR_i(t)$ is expressed by the following linear equation:

$$FR_i(t) = c_i t + d_i \quad (5)$$

where c_i and d_i denote deterioration rate and initial performance of FR_i, respectively.

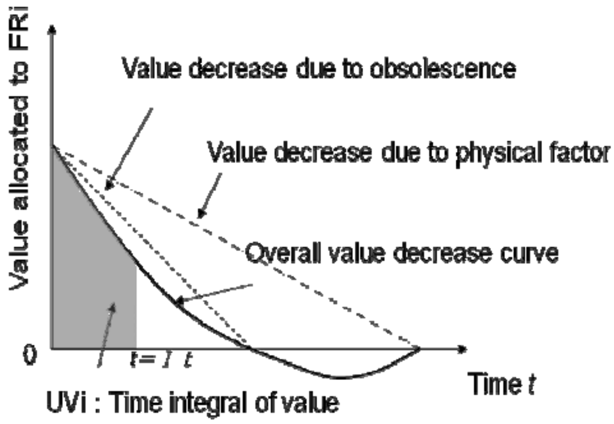

Figure 1: Time variation of value and UV

(ii) Deterioration due to value causes

Another cause of product value deterioration is obsolescence of FRs. Assuming that a set of dominant product FRs does not change, the obsolescence of each FR is expressed by the decrease in importance of each FR given as follows:

$$w_i(t) = a_i t + b_i \quad (6)$$

where a_i and b_i denote the obsolescence rate and initial importance of FR_i, respectively. These values can be estimated by regression analysis on $w_i(t)$ at various times t.

Figure 1 depicts the time variation of value allocated to each FR. The horizontal axis and vertical axis denote product use time, and value allocated to FR_i, respectively.

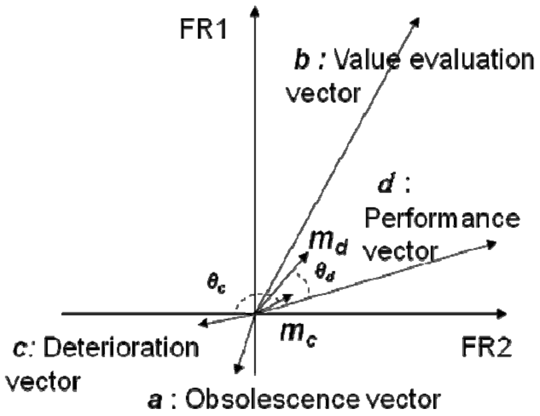

Figure 2: Relationship among obsolescence, value evaluation, deterioration and performance vectors

Vector representation of UV.

Let assume that a target product contains n FRs. The UV of a product is formulated as follows:

$$UV = lt^2(\frac{1}{3}lt\vec{a} + \frac{1}{2}\vec{b}) \cdot \vec{c} + lt(\frac{1}{2}lt\vec{a} + \vec{b}) \cdot \vec{d} \tag{7}$$

where ***a***, ***b***, ***c***, and ***d*** denote obsolescence vector, value evaluation vector, deterioration vector, and performance vector, respectively.

In general, ***a*** and ***b***, which represent user preference for a product and its time variation respectively, are given by the market environment and cannot be controlled by a business designer, whereas ***c*** and ***d***, which represent product performance and its time variation respectively, can be controlled by a business designer. Thus, a designer should select adequate values for ***c*** and ***d*** for given ***a*** and ***b***.

Introducing $\boldsymbol{m_c}$ and $\boldsymbol{m_d}$, which are resultant vectors of ***a*** and ***b***, equation 7 can be transformed as follows by using scholar values: norms of $\boldsymbol{m_c}$, $\boldsymbol{m_d}$, ***c*** and ***d*** and the angles between them.

$$UV = lt^2\|\vec{m}_c\|\|\vec{c}\|\cos(\theta_c) + lt\|\vec{m}_d\|\|\vec{d}\|\cos(\theta_d) \tag{8}$$

$$\vec{m}_c = \frac{1}{3}lt\vec{a} + \frac{1}{2}\vec{b} \tag{9}$$

$$\vec{m}_d = \frac{1}{2}lt\vec{a} + \vec{b} \tag{10}$$

where ||c||, and ||d|| represent physical deterioration speed, and overall performance of a target product, respectively.

θ_c and θ_d ,which are called *deterioration fitness* and *performance fitness* in this study, denote angles between ***c*** and $\boldsymbol{m_c}$ and ***d*** and $\boldsymbol{m_d}$, respectively. The former and the latter represent adequateness of product deterioration and initial performance in a given market environment ($\boldsymbol{m_c}$ and $\boldsymbol{m_d}$), respectively. Relationships among these vectors for n = 2 are depicted in Figure 2. Note that ***c*** and $\boldsymbol{m_c}$ belong to different quadrants while ***d*** and $\boldsymbol{m_d}$ belong to the same quadrant. Thus, the first term of the left side of equation 8 is a negative quantity and the second term is positive quantity.

Interpretation of UV parameters.

Equation 8 shows that enhancement of overall performance (||d||) is quite effective when *lt* is small and on the contrary, improvement of deterioration speed (||c||) is quite effective when *lt* is large.

In addition to norms of ***c*** and ***d***, the angles between ***c*** and $\boldsymbol{m_c}$ (θ_c) and ***d*** and $\boldsymbol{m_d}$ (θ_d) also affect UV. As shown in equation 8 and Figure 2, UV becomes large as θ_d approaches 0 degree and θ_c approaches 90 degree. This means that preferential improvements of c_i and d_i, which effectively improve θ_c and θ_d are also quite promising.

3.2 Formulation of LCE and LCC

Focusing on energy-using products, the longer a product is used, the higher its LCE and LCC become. Thus, the simplest representation of LCE and LCC of a product is given as follows:

$$LCE = e_{use}\ lt + e_{prod} + e_{dist} + e_{col} + e_{eol} \tag{11}$$

$$LCC = f_{use}\ lt + f_{prod} + f_{dist} + f_{col} + f_{eol} \tag{12}$$

where e_{use} and f_{use} denote environmental load and cost during the product usage stage per unit time, respectively. e_{prod}, e_{dist}, e_{col}, and e_{eol} denote environmental load at the production, distribution, collection and end of life (EOL) treatment stages, respectively. f_{prod}, f_{dist}, f_{col}, and f_{eol} denote the cost at production, distribution, collection and EOL treatment stages, respectively.

LCE and LCC of a product can be calculated by conventional life cycle assessment (LCA) and life cycle costing (LCC) tools, respectively.

3.3 Sensitivity analysis

As given in equations 8, 11 and 12, TPI is constructed from 17 parameters, namely, $\|\boldsymbol{m_c}\|$, $\|\boldsymbol{m_d}\|$, $\|\boldsymbol{c}\|$, $\|\boldsymbol{d}\|$, θ_c, θ_d, e_{use}, e_{prod}, e_{dist}, e_{col}, e_{eol}, f_{use}, f_{prod}, f_{dist}, f_{col}, f_{eol} and *lt*. Note that due to interdependency among these parameters, each parameter cannot be controlled independently from the others. Therefore, preferential improvement of the parameters with the greatest influence is an effective approach. In order to find influential parameters among them, sensitivity analysis of TPI should be executed. However, interdependency among the parameters which construct UV and those which construct LCE and LCC is generally unknown in mathematical forms. Thus, we separately conducted sensitivity analysis on the numerator and the denominator of TPI. A set of key parameters is selected by calculating sensitivity vector s as follows:

$$s = (\|c\|\frac{\partial UV}{\partial\|c\|}, \|d\|\frac{\partial UV}{\partial\|d\|}, \theta_c\frac{\partial UV}{\partial\theta_c}, \theta_d\frac{\partial UV}{\partial\theta_d}, e_{use}\frac{\partial TL}{\partial e_{use}}, e_{prod}\frac{\partial TL}{\partial e_{prod}}, e_{dist}\frac{\partial TL}{\partial e_{dist}}, e_{col}\frac{\partial TL}{\partial e_{col}}, e_{eol}\frac{\partial TL}{\partial e_{eol}}, f_{use}\frac{\partial TL}{\partial f_{use}}, f_{prod}\frac{\partial TL}{\partial f_{prod}}, f_{dist}\frac{\partial TL}{\partial f_{dist}}, f_{col}\frac{\partial TL}{\partial f_{col}}, f_{eol}\frac{\partial TL}{\partial f_{eol}}, lt\frac{\partial TPI}{\partial lt}) \tag{13}$$

where *TL* denotes the geometrical average of LCE and LCC.

$$TL = \sqrt{LCE \cdot LCC} \tag{14}$$

4 RULES FOR ECO-BUSINESS PLANNING

Now we can choose a couple of influential parameters. The next issue is how to improve these key parameters without considerable impact on other factors. To do that, we provide a business designer with a set of eco-business rules and conditions for applying them in relation to the 17 business parameters.

In this study, we use 12 eco-business rules that are extracted and modified from our previous work [11]. In our previous work, we identified four kinds of customer benefits (cost reduction, avoidance of risks, improvement

Rules/parameters	UV				LCE					LCC					
	Deterioration speed $\|\|c\|\|$	Deterioration fitness θ_c	Overall performance $\|\|d\|\|$	Performance fitness θ_d	Use e_{use}	Production e_{prod}	Distribution e_{dist}	Collection e_{col}	EOL e_{eol}	Use f_{use}	Production f_{prod}	Distribution f_{dist}	Collection f_{col}	EOL f_{eol}	lifetime
(A) Management of life cycles	*		*		*	*	*	*	*	*	*	*	*	*	*
(B) Expansion of the business scale				○		○	○	○	○		○	○	○	○	
(C) Reutilization of wastes /Use one more time						○	○	○	○			○	○	○	
(D) Utilization of knowledge and information	○	○		○	○					○					○
(E) Linkage and cooperation among various industries			○	○				○	○		○	○	○	○	
(F) Combining various business values	○	○	○	○	○					○					○
(G) Technological innovation	○	○	○	○	○	○	○		○	○	○	○		○	
(H) Outsourcing / Contracting for environmental loads						○			○		○			○	
(I) Servicizing					○	○	○	○	○	○	○	○	○	○	
(J) Timesharing	×		○		×					×					×
(K) Management of hidden bottlenecks	○	○			○					○					○
(L) Application of cleaner methods to satisfy customer needs					○	○			○	○	○			○	

Table 1: Rules-parameters matrix

of service quality, and improvement of customer's image from a societal viewpoint) and derived 8 rules for improving these benefits and 8 rules for decreasing operation cost through an analysis of 130 eco-business cases in Japan, considering the material and monetary flows among all the stakeholders involved. As the description of each rule only contains its meaning and typical examples in our previous work, we formulated their applicable conditions by analyzing the effect of each rule on the 17 business parameters in 70 typical eco-business cases in Japan. Although the effect of each rule on each business parameter differs from case to case, the general tendency of its effect is summarized as follows:

(A) Management of life cycles

Proper management and control of product life cycle (especially, after they are sold) can reduce both environmental loads and costs. Closed-loop manufacturing of a one-time-use camera is an example of this rule. This rule is interpreted as changing a set of control parameters by taking responsibility for the life cycle stages other than the production stage.

(B) Expansion of the business scale

As in traditional businesses, expansion of business scale reduces LCE and LCC at the production, distribution, collection, and EOL treatment stages (e_{prod}, e_{dist}, e_{col}, e_{eol}, f_{prod}, f_{dist}, f_{col} and f_{eol}). Examples include sharing of the logistic system (including reverse logistic system) among multiple firms. In addition, this rule sometimes helps improve performance fitness θ_d because the larger the scale of business, the easier it becomes to collect a wide variety of users.

(C) Reutilization of wastes / Use one more time

Reusable or recyclable goods and energy are sometimes thrown away because, for instance, the amount is too small for them to be reused or recycled. If they are used one more time, LCE and LCC at both the EOL treatment and the production stages (e_{prod}, e_{eol}, f_{prod}, and f_{eol}) are reduced. Utilization of waste plastics as reductant in blast furnaces is an example of this rule.

(D) Utilization of knowledge and information

Utilization of knowledge and information about usage conditions can effectively reduce LCE and LCC at the product usage stage (e_{use} and f_{use}) by increasing the efficiency of energy and material usage. In addition, this rule also improves product lifetime (*lt*) and durability ($||\boldsymbol{c}||$ an θ_c) by providing adequate maintenance or consultancy services on product use. Eco-drive training service for a driver provided by auto manufacturer is an example of this rule.

(E) Linkage and cooperation among various industries

Related to the rule *Expansion of the business scale*, cooperation among various industrial sectors sometimes contributes to reduction in LCE and LCC at the production, distribution, collection, and EOL treatment stages (e_{prod}, e_{dist}, e_{col}, e_{eol}, f_{prod}, f_{dist}, f_{col} and f_{eol}). The zero emission concept, which aims at reutilizing wastes from a factory as resources for another factory by organizing industrial clusters, is an example of this rule. In addition, this rule sometimes improves utility value ($||\boldsymbol{d}||$ and θ_d) by creating a new combination of services (related to the rule *Combining various business values*).

(F) Combining various business values

Providing multiple products/services bundled into a package sometimes improves the customer benefit ($||\boldsymbol{c}||$, $||\boldsymbol{d}||$, θ_c, and θ_d). In addition, product lifetime and LCE and LCC at the usage stage (*lt*, e_{use} and f_{use}) can be improved by providing products with maintenance and consultancy services.

(G) Technological innovation

Technological innovation is sometimes indispensable for implementing a business idea described as a combination of other business rules. The overall performance and durability of a product, and LCE and LCC at the production, distribution, product-use, and EOL treatment stages (||***d***||, ||***c***||, θ_c, θ_d, e_{prod}, e_{dist}, e_{eol}, $f_{pro}d$, *fdist*, and *feol*) were improved by various technological innovations in many cases.

(H) Outsourcing/Contracting for environmental load

As eco-businesses often cover multiple life cycle stages (from cradle to grave), firms cannot execute the entire tasks by themselves. Therefore, making the right outsourcing decision is important for reducing LCE and LCC. Furthermore, undertakers of the outsourcing can reduce their costs by applying the rule *Expansion of the business scale*.

(I) Servicizing

Servicizing [2] refers to selling a service or functionality rather than a product. While the product is still owned by an eco-business provider, customers pay for use or maintenance. E-learning and videoconference substituting for transportation are examples of servicizing. This rule sometimes significantly reduces LCE and LCC (e_{use}, e_{prod}, e_{dist}, e_{col}, e_{eol}, f_{use}, f_{prod}, f_{dist}, f_{col} and f_{eol}).

(J) Timesharing

The capacity of products such as personal automobiles and industrial equipment is sometimes under-utilized. By encouraging users to abandon individual ownership, more intensive utilization of products can be realized (i.e., a kind of use-oriented services of PSS). This can reduce users' procurement costs and risks for disposal of products. Leasing and rental schemes are examples of this rule. Assuming that *m* users with the same preference for a product (***a*** and ***b***) use the same product in a lease and rental scheme under the same operating conditions, ||***d***||, ||***c***||, e_{use}, and f_{use} become $m \times \|d\|$, $m \times \|c\|$, $m \times e_{use}$, and $m \times f_{use}$, respectively.

(K) Management of hidden bottlenecks

Identification and proper management of hidden environmental bottlenecks of a user's activities often reduce the user's costs and environmental risks. An example of application of this rule is the ESCO business [6], where ESCO comprehensively manages the use of electricity by its user to save electricity. This rule can improve the overall deterioration speed, deterioration fitness, LCE and LCC at the product-use and EOL treatment stages (||***c***||, θ_c, e_{use}, e_{eol}, f_{use}, and f_{eol}).

(L) Application of cleaner methods to satisfy customer needs

Applying cleaner products or services to satisfy customer needs can improve the environmental performance of products/services directly. Examples of this rule include introduction of green electricity such as photovoltaic power generation. This rule improves LCE and LCC at the use and production stages (e_{use}, e_{prod}, f_{use}, and f_{prod}).

Table 1 summarizes the result of analyzing 70 eco-business examples in Japan. The effect of each rule on each parameter is represented by the symbols ○, × and * in each cell of the table. Improved and deteriorated parameters after applying each rule are represented by ○ and ×, respectively. * denotes the possible control parameters when a business designer applies the rule *(A) Management of life cycles*.

5 EXAMPLE

In order to illustrate the procedure of idea generation and decision-making for PSS business strategies, a case study of a laptop computer is described in this section.

5.1 Identification of business environment

The first step is to identify dominant functional requirements to be provided and calculate the obsolescence, value evaluation, deterioration, and performance vectors of a target product (or service), as well as its resulting LCE and LCC in a given business environment. In this example, first we assume that the business sells its laptop computers to the customers.

Table 2: FRs of a laptop computer

FRs		a_i	b_i	c_i	d_i
FR1	Computing speed	−0.78	100.06	−0.004	1
FR2	Compute large-capacity data	−0.48	29.19	−0.004	1
FR3	Storage capacity	−2.00	107.64	−0.010	1
FR4	Portability	−0.10	27.70	−0.004	1
FR5	Easily viewable	−0.41	114.68	−0.001	1
FR6	Handle multiple recording media	−1.21	88.05	−0.010	1

Table 2 summarizes the dominant FRs of a laptop computer. In the table, all the elements of ***d*** are normalized to 1. ***a*** and ***b***, which consist of obsolescence rate a_i and initial importance b_i for each FR, respectively, are calculated by conjoint analysis for two different years (2002 and 2006). For example, we calculated that the weighted factor for FR1: Computing speed was 58.65 [kJPY/GHz] in 2002 (i.e., the performance of FR1: computing speed (1 GHz) was worth 58,650 yen) and it decreased to 36.95 [kJPY/GHz] in 2006 due to technological innovation. Thus, the obsolescence rate of FR1 (a_1) is calculated as -0.45638 by substituting these two values into Equation 6. For the initial importance (weighted factor) of each FR (b_i), the importance value in 2002 is used. ***c***, which consists of deterioration rate for six FRs, was assumed by referring to the physical lifetime of the constituent components of similar products in the market.

LCE and LCC are also calculated by using the conventional LCA and LCC methods. Product lifetime *lt* is assumed to be 48 months in this example. TPI was calculated as 85.4.

5.2 Sensitivity analysis of TPI

As a result of sensitivity analysis, ||***d***||, e_{prod}, and f_{prod} were selected as key parameters in this example.

5.3 Idea generation for eco-business

Referring to Table 1, the designer selected those rules that improve the key parameters determined in section 5.2. ||***d***|| can be improved by *(J) Timesharing*, *(E) Linkage and cooperation among various industrial sectors*, *(F) Combining various business values*, and *(G) Technological innovation*; e_{prod} can be improved by *(B) Expansion of business scale*, *(C) Reutilization of waste / Use one more time*, *(G) Technological innovation*, *(H) Outsourcing*, *(I) Servicizing*, *(K) Management of hidden bottlenecks*, and *(L) Application of cleaner methods to satisfy customer needs*; and f_{prod} can be improved by *(B) Expansion of business scale*, *(E) Linkage and cooperation among various industrial sectors*, *(G) Technological innovation*, *(H) Outsourcing*, *(I) Servicizing*, and *(L) Application of cleaner methods to satisfy customer needs*. Referring to the eco-business case base associated with these rules, the designer generated a business idea as follows:

The business provides a user with a laptop computer in a lease/rental scheme (improve ||***d***|| by *Timesharing*). At the same time, the business also gets revenue from advertising on the rental laptop computer for another user (improve $||\boldsymbol{d}||$ by *Combining various business values*). In addition, laptop computers are recycled or reused at the end of their lives to reduce LCE and LCC at the EOL treatment and production stages (improve e_{prod} and f_{prod} by *Reutilization of waste/ Use one more time*).

5.4 Evaluation of the eco-business ideas by TPI

Assuming that key parameters change as shown in Table 3, TPI was improved to 274. Thus, an approximately three-fold improvement was achieved in this example.

Table 3: Estimation of improvement

Influential parameters	Applied rules	Estimation of improvement
Overall performance $//d//$	(J) Timesharing	$//d//$, $//c//$, e_{use}, f_{use} will double by intensive use of a laptop computer.
	(F) Combining various business values	$//d//$ will increase by 48 [thousand Yen × months].
Environmental load at EOL treatment stage e_{prod}	(C) Reutilization of wastes /Use one more time	e_{prod} will reduce to 54%.
Cost at production stage f_{prod}	(C) Reutilization of wastes /Use one more time	f_{prod} will reduce to 62%.

6 CONCLUSION

This paper proposed a strategic decision-making method for eco-business planning so that a designer can easily find a set of eco-business ideas that effectively improve TPI in a systematic manner. To this end, we identified 17 business parameters, from which TPI is constructed, and formulated 12 eco-business rules in relation with these parameters. Through a case study of a laptop computer business, an idea generation procedure was illustrated, and the validity and effectiveness of the method were demonstrated.

Future work includes the following topics:

Modification of eco-business rules and collection of eco-business cases:

Collection and formulation of existing eco-business cases in relation with 12 rules can help a designer to generate new eco-business ideas. In addition to the 12 rules used in this study, other rules and guidelines for eco-businesses [for example, 4] and PSS reasoning methods can also be used by formulating their applicable conditions in relation with the 17 parameters.

Consideration of interdependency among UV, LCE, and LCC:

In general, there exist interdependencies among the parameters that form UV and those that form LCE and LCC. Therefore, such interdependencies should be considered in a future work.

7 REFERENCES

[1] Hauschild MZ, Wenzel H, Alting L (1999) Life Cycle Design. A Route to the Sustainable Industrial Culture? Annals of the CIRP 48(1):93.96.

[2] White, Allen L., Stoughton, M. and Feng, L., 1999, Servicizing: The quiet Transition to Extended Product Responsibility, Tellus Institute.

[3] Lindahl, M. and Olundh, G., The Meaning of Functional Sales, 2001, Proc. of the 8th CIRP Int. Seminar on Life Cycle Engineering, 211-220.

[4] UNEP, 1997, ECODESIGN: a promising approach to sustainable product and consumption, UNITED NATIONS PUBLICATION

[5] Goedkoop, M. J., van Halen, Cees J.G., te Riele, Harry R.M., and Rommens, Peter J.M., 1999, Product service systems, ecological and economic basis, PricewaterCoopers.

[6] Morelli, N., 2006, "Developing new product service systems (PSS): methodologies and operational tools", Journal of Cleaner Production, Vol. 14, pp.1495-1501.

[7] Kondoh, S. et al., 2008, "Robust design method for product life cycle considering the future uncertainties", Proceedings of DESIGN 2008, pp. 439-448, 2008.

[8] Association for ESCO Business Introduction in Japan, 1998, Committee report for ESCO business introduction in Japan, Energy Conservation Centre Japan.

[9] Winterfeld, D. V and Edwards, W., 1986, Decision Analysis and Behavioral Research, Cambridge University Press, Cambridge, England.

[10] Daimon, T. et al., 2004, "Proposal of Decision Support Method for Life Cycle Strategy by Estimating Value and Physical Lifetimes", Proc. of the 11th International CIRP Life Cycle Engineering Seminar.

[11] Kondoh, S. et al., 2006, "Analysis of Key Success Factors for Eco-Business through Case Studies in Japan", Proceedings of 13th CIRP International conference on Life Cycle Engineering, pp. 275-280, 2006

Concern of Uncertainty and Willingness to Pay for Adopting PSS: Example of Solar Power System Leasing

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Abstract

Conjoint analysis has been widely used to find consumers' preference and direction of improvement in new product development. It can also be used in product service system development and marketing as long as attributes and attribute levels are carefully selected. This study focuses on consumers' preference and willingness to pay (WTP) of product service system taking photovoltaic system as an example. Leasing is considered as a type of product service that consumers could choose. In addition, consumers' concerns on several uncertainties are measured in order to find the effect of uncertainty on preference of different lease times. The results show that the concern of uncertainties on government subsidy, electricity price, reliability, and rise of new generation solar power system would significantly affect the additional willingness-to-pay for shorter lease time. The relation between gap of WTP between lease times and uncertainty scores that measure consumers' concern are presented. Cluster analysis is used to find two groups with high and low concern of uncertainty. People with higher concern on uncertainty tend to pay more for adopting PSS with shorter lease time.

Keywords

Conjoint analysis, Lease time, Photovoltaic System, Uncertainty

1 INTRODUCTION

Conjoint analysis has been used to find consumers' preference for new product development and marketing. It can also be used in product service system (PSS) development and marketing as long as attributes and attribute levels are carefully selected. Since PSS is a combination of product and service, attribute selection needs to consider both ends to reflect characteristics of PSS and get adequate responses from customers. Defining attributes in conjoint analysis is essential and should be carefully conducted in a case by case basis. This study works on PSS of photovoltaic system with leasing service and finds consumers' preference and willingness to pay (WTP) for various service types, i.e. lease time. Preference of purchase and leasing are presented and compared while gaps of WTP between service types are estimated.

Since photovoltaic electricity system is considered clean and sustainable transforming solar energy directly to electricity, many countries have announced that photovoltaic energy is going to play essential role in electricity generation in near future. EPIA [1] estimated that overall annual installation of photovoltaic systems will increase more than three times by 2013. In fact, overall installation has grown 15 times from 1998 to 2008. For example, Taiwan's installed capacity has increased from 3KW to 2060KW from 2000 to 2007. Recently, local government also announced that electricity from renewable energy will be more than 11% of the total electricity generation by 2015. Among the capacity, solar power capacity would stand 6.25%.

As an emerging energy supplier, there are several competing solar energy technologies such as c-Si technology, thin film technology and new concepts technology. According to technology forecast [2], the cost and efficiency of solar energy technology will greatly improve in next 20 years. Among the technologies, thin film technology could have more improvement (up to 30% cost reduction) than silicon based technology. Efficiency improvement of both technologies is also expected to be 15% to 40%. Hoffmann et al [3] estimated that market share of thin film technology will increase from 5% (2005) to 35% (2030) while new concept technology such as chemical compound technology might also increase from 0%(2005) to 35% (2030). These technology forecast pointed out tremendous growth potential of solar power system, but also revealed that there would be dramatic change and competition among various solar power technologies.

In light of the technology uncertainty as well as policy uncertainty, this study considers effect of uncertainty in solar power system diffusion. Since photovoltaic technology is still an emerging technology, consumers are often concerned about uncertainty factors like inconsistent government incentive policy, changing price of electricity, reliability and maintainability, product lifetime, energy efficiency, and phase-out speed. It is essential to deal with these uncertainty concerns in order to expedite the growing speed and volume of solar power system market.

In summary, this study shows the use of conjoint analysis for finding consumers' preference and willingness to pay for new product service system, taking photovoltaic system leasing as an example. On the other hand, concern of uncertainty, including policy and technology uncertainty, is investigated to see its effect on adoption of photovoltaic systems with different types of PSS.

2 CONSUMERS' PREFERENCE AND ESTIMATION OF WILLINGNESS-TO-PAY VIA CONJOINT ANALYSIS

Conjoint model has been widely used in new product development (Krieger et al [4]; Green and Srinivasan [5]) to estimate consumers' utility function and find the preference structure. The part worth utility estimation of multiple attributes could be helpful in detecting consumers' responses to the new product and provide feed-back to product development process for further improvement. Recently, conjoint analysis is also used in new service design evaluation. Good examples include Danielis et al [6], Lockshin et al [7], and Enneking et al [8].

In general, conjoint analysis consist of five steps, including determining attributes and levels, constructing model, building profiles, conducting survey and data collection, and conducting statistical analysis. For PSS application, attribute selection is the most essential part since it should cover both product and service concerns from customer's point of view. A good combination of attributes and attribute levels could reflect faithfully the preference structure of customers and hence obtain better estimate of WTP. In this study, conjoint analysis is conducted as follows:

- **Select important attributes and attribute levels of PSS**

Since number of attributes in conjoint analysis is recommended less than eight, attributes representing characteristics of PSS must be carefully selected. The attributes should cover aspects that targeted customers would consider in adopting a PSS to faithfully reflect the utility structure. Attributes should be representing characteristics for both product and service so that difference between product and PSS can be detected. It is better if attribute levels could stand for different types of PSS. A good selection of attributes would make conjoint analysis to have better explaining ability and useful results.

- **Construct preference model**

Several types of conjoint models have been proposed since the method was first proposed in 1970s. The mathematical form of multiple attribute utility function could be additive, multiplicative, and nonlinear. Evaluation collected from respondents could be ranking, rating, and comparison. This study presents a conventional conjoint model, where addition of main effects is adopted and rating scores on PSS profiles are collected in a survey. For the ensuing discussion, some notations are introduced herein.

m denotes the index for attribute. Assume there are M attributes, i.e., m = 1, 2, …, M.

l is the level for an attribute, for example, l = 1, 2, …, L_m denoting the levels of m^{th} attribute.

s_r^i is the evaluation rating obtained for the rth full profile received by respondent i.

r is the index for full profile, where r = 1,…, R, R is the total number of PSS profiles.

The preference model is in regression model form:

$$s_r^i = a + \sum_{m=1}^{M}\sum_{l=1}^{Lm} B_{ml}\, I_{rml}^i + e_r^i \qquad (1)$$

where I_{rml}^i equals to 1 when the rth full profile matches the level l at the m^{th} attribute; otherwise, I_{rml}^i equals to 0. In regressing the data, s_r^i and I_{rml}^i are adopted from the ratings from the respondents. It should be noted that **a** and B_{ml} are regression parameters in expression (1) while e_r^i is an error term. The parameter B_{ml} eventually is the part worth value at the level l of the mth attribute.

- **Build PSS profiles with factorial design**

In conjoint analysis, combinations of PSS profiles are presented to potential customers and ask for their rating and willingness to adopt the products that match the profile. Profiles of PSS are made according to combinations of all attributes levels. When the number of profiles is too large, fractional factorial design is used to reduce number of profiles in questionnaire design. Respondent would give rating of willingness to adopt for each product profile and the ratings from respondents are used in regression analysis in order to estimate part worth utility of attributes. The hypothetical product profile was presented verbally, as a list of attributes and levels.

- **Questionnaire survey and data collection**

PSS profiles are presented in a questionnaire to collect respondents' rating on willingness to adopt. A combination of attribute levels is showed as a profile to respondents. Number of profiles should be reduced to an acceptable level to avoid lengthy questionnaire and ineffective responses. In addition, personal data of respondents is collected to conduct marketing research such as finding market segment using cluster analysis. In this study, respondents' concern on uncertainty is measured using Likert scale. Six questions regarding six major uncertainties are included in the questionnaire.

- **Conduct statistical analysis and result analysis**

Conjoint analysis provides estimates of the part worth utilities of all attributes. As indicated in expression (1), part worth utilities are estimated using coefficients of the regression model. Commercial software like SPSS can well be used to conduct the regression analysis and present the part worth utilities. Since utility corresponding to each attribute level can be estimated, the shape of utility function for each attribute (i.e. part worth utility, PWU) can be obtained. Furthermore, Green and Wind [9] suggested that the range of part worth utility of an attribute represent the relative importance of this attribute.

Conjoint analysis can also be used to estimate willingness-to-pay (WTP) on certain attributes provided that price is selected as one of the attributes. Many recent literatures have used the method such as Hurlimann et al [10], Espino et al [11] and Longo [12]. The willingness to pay can be calculated using equation (2) where difference of part worth utility (PWU) between any pair of selected attribute levels is used to multiply the price coefficient. The price coefficient can be obtained using the price difference and the PWU difference of price attribute.

$$\beta_p = \frac{\beta_{highp} - \beta_{lowp}}{HighPrice - LowPrice} \qquad (2)$$

$$WTP_{pair} = -\frac{\Delta\beta_{selected}}{\beta_p}$$

β_p: price coefficient

β_{highp}: PWU of the higher level of price attribute

β_{lowp}: PWU of the lower level of price attribute

HighPrice: higher level of price

LowPrice: lower level of price

WTP_{pair}: gap of WTP between the selected pair of attribute levels.

$\Delta\beta_{selcted}$: PWU difference between levels of selected attribute

3 UNCERTAINTY FACTORS IN ADOPTING PHOTOVOLTAIC ELECTRICITY SYSTEM

Not only solar power systems, uncertainty factors could cause resistance in adopting many innovative products. Ram and Sheth [13] stated that there are three major barriers in adopting innovation including value barrier, usage barrier and risk barrier. Value barrier means innovation's inability to produce economic-or performance-based benefits while use barrier means innovation may not be compatible with existing workflows, practices and habits. The third barrier for consumers adopting innovative products is risk barrier which includes physical risk, functional risk, economic risk and social risk. Customers, aware of the risks, could postpone adopting the innovation until they could learn more about it or avoid the risks. Cox et al [14] mentioned that consumers are cautious about accepting novel technologies because of perceived risk and lack of benefits. They used conjoint model to study consumers' perceived risk, benefits, need, unnaturalness and safety of the technologies. Participants were segmented by the sum of their beliefs on the novel technologies.

Since photovoltaic technologies are still in a fast changing stage, consumers are also very cautious in adopting the technology. Uncertainty of payment for innovative products could increase the value barrier. They include government policy on subsidy, selling price and the price of electricity which heavily depends on changing fossil fuel prices. On the other hand, the risk barrier could be caused by several uncertainty factors such as product lifetime, reliability and maintainability, replacement by new generation technology. This study focuses on value and risk barriers in adopting solar power systems.

Before actually designing the questionnaire, field interview was conducted to verify the uncertainty factors that are concerned by customers. Questions about whether respondents are concerned about the uncertainty factors while considering adopting solar energy system are included in the questionnaire. Five point Likert scale was used to collect degree of concern on the particular uncertainty. Each respondent was asked to choose between "very agree" and "very disagree" on the statement concerning each of the six uncertainty factors. These responses reflecting respondents' concern would be used to find their relationship to the adoption and willingness to pay later.

4 CONJOINT ANALYSYS FOR SOLAR POWER SYSTEM ADOPTION CONSIDERING LEASING

Leasing is considered an option of PSS in promoting photovoltaic systems. Instead of purchase, leasing may reduce consumers' worry on these uncertainty factors, especially for an expensive new product. By leasing a solar system, consumers can get electricity without actually owning it. The risk due to uncertainty factors of new products is taken by the service providers. Currently, there are some leasing service providers in the US. Consumers can choose lease term for one, five, ten or fifteen years. Service providers would take care of installation, maintenance, and repair of the system. The rent may be fixed or adjustable following local electricity price at the time. Service providers generally do not charge rent if the system is broken or under maintenance. When the lease term is up and extension is of interest, the companies can upgrade the system for free.

In light of the existing lease service of photovoltaic power system, this study works on consumers' preference and willingness-to-pay for the leasing service using conjoint analysis. Multiple attribute utilities of consumers' preference are estimated. Gaps of willingness-to-pay from one attribute level to another level are estimated. Time period for leasing is intentionally set as one of the attributes to investigate the willingness to pay between various leasing time. On the other hand, consumers' concerns on several uncertainty factors are measured. The main research question is how much consumers are willing to pay (WTP) to reduce the aforementioned uncertainty by adopting leasing instead of purchase.

When consumers consider a solar energy system, many attributes could be considered. Besides price, capacity, reliability, maintenance, and efficiency are some examples. They could reflect economical as well as functional aspect on the consumer side. In this study, lease time is included to find out the utility of leasing duration. The levels of leasing time are selected as 5, 15, and 20 years while 20 years is looked as purchase. Payment per month for leasing is selected as one attribute so that gap of WTP could be calculated for comparison. Other attributes selected include monthly payment, capacity, and frequency of break down. Table 1 shows the attribute and attributes levels. The attribute levels of capacity and monthly payment are defined based on the ranges of actual electricity usage. As to reliability concern, Goett et al [15] suggested that when a solar energy system breaks down more than three times, the reliability would be considered a serious problem.

attribute	levels
Capacity	（1） 300 KW hr
	（2） 700 KW hr
	（3） 1100 KW hr
Payment per month	（1）2500 NT dollars per month*
	（2）6000 NT dollars per month
	（3）9500 NT dollars per month
Lease time	（1）5 year
	（2）10 years
	（3）20 years (equivalent to purchase)
Frequency of break down	（1）high
	（2）low

*Note: 1 US dollar is approximately 32 NT dollars

Table 1: Attributes and attribute levels.

Questionnaire survey is conducted via internet, while popular web sites and BBS are selected to spread the message. A web site was set for questionnaire and collecting responses. 317 responses were collected within a month. The respondents aged less than 21 were erased to represent the population who may purchase solar power systems. The effective sample size is then reduced to 217 (70%). Table 2 shows the statistics of the sample.

variables	number	Percentage (%)
Male	82	37.8
Female	135	62.2
21-25	89	41.0
26-30	94	43.3
31-35	24	11.1
36-40	5	2.3
41 and above	5	2.3
High school	7	3.2
College	150	69.1
Graduate school	60	27.6
30K and below	120	55.3
30-50K	77	35.5
50K and above	20	9.2

Table 2: Sample statistics.

5 RESULTS OF PART WORTH UTILITY AND CONCERN ON UNCERTAINTY FACTORS

Part worth utilities (PWU) of the four attributes are obtained using conjoint analysis. Table 3 shows the PWU and the relative importance based of the ranges of PWU. Payment per month is the most important attribute (51.7%) while electricity capacity is the least important attribute (8.8%). Leasing time ranks the third (10.8%).

attributes	level	PWU	Range of PWU	Relative importance
capacity	300 kW hr/month	0.1490	0.2980	8.8%
	700 kW hr/month	0.2980		
	1100 kW hr/month	0.4470		
Payment per month	2500 dollars	-0.8771	1.7542	51.7%
	6000 dollars	-1.7542		
	9500 dollars	-2.6313		
Lease time	5 years	0.1546	0.3656	10.8%
	10 years	0.0563		
	20 years	-0.2110		
Frequency of break down	Low	0.4869	0.9738	28.7%
	High	-0.4869		

Table 3: PWUs of four attributes and relative importance.

In the questionnaire, Likert scale of five was used to measure the concern severity of uncertainty factors. Table 4 shows the statistics on the concern on uncertainty factors including government subsidy, price, lifetime, reliability, replaced by new model and electricity price. For overall sample, replaced by new model, lifetime and price are of more concern with average score greater than 4 (5 for very concern). Concern on reliability is also high. Cluster analysis is used to see if there is significant difference between concerns on uncertainty. The bottom half of Table 4 shows two clusters with significant different opinions on uncertainty factors using analysis of variance (ANNOVA). Group 1 with higher concern scores is named "high concern group", while group 2 is called "low concern group".

Table 5 shows the relative importance of four attributes from the responses of the two groups. Group of higher concern ranks lease time the third while group of lower concern ranks it the fourth. The percentage of female of group 2 is higher than of group 1. The average age of the first group is slightly younger than the second group. On the other hand, Group 1 has higher income than that of group 2.

group	Sample size	subsidy	price	replacement of new model	reliability	lifetime	Electricity price
All	217	3.89 (0.76)	4.08 (0.76)	4.16 (0.74)	3.97 (0.71)	4.13 (0.66)	3.77 (0.90)
Group 1	140	4.02	4.34	4.44	4.26	4.34	4.08
Group 2	77	3.66	3.61	3.65	3.44	3.77	3.61
ANNOVA results	F	11.65	58.56	76.36	93.81	44.98	14.53
	p value	0.001	0.000	0.000	0.000	0.000	0.000

Table 4: Results of uncertainty scores of all sample and two groups.(standard deviation is inside parenthesis).

attributes	level	Group 1 importance	Group 2 importance
Capacity kW hr/month	300	8.79%	4.78%
	700		
	1100		
Monthly payment	2500	51.72%	56.12%
	6000		
	9500		
Lease time	5 years	10.78%	4.08%
	10 years		
	20 years		
Frequency of break down	Low	28.71%	35.02%
	high		
variables		Percentage (%)	Percentage (%)
Gender	Male	42.9	28.6
	Female	57.1	71.4
Age	21-30	85.0	83.2
	31-40	12.8	14.3
	41 above	2.1	2.6
Monthly income (NT dollars)	30K and below	50.7	63.6
	30-50 K	39.3	28.6
	50K and above	10.0	7.8

Table 5: PWU and relative importance of attributes in two groups.

6 GAP OF WILLINGNESS TO PAY BETWEEN LEASING AND PURCHASE

After obtaining part worth utilities of all attributes, willingness to pay for each pair of attribute levels can be calculated using equation (2). For example, Table 6 shows the utilities between different lease times as well as the gaps of willingness to pay between pairs of lease times. Consumers are willing to pay extra NT 1459 dollars on the average for choosing 5 year lease time than 20 year lease time. Please note that leasing 20 years means a long term commitment and could be interpreted the same as purchase herein. Comparing to the monthly worth of purchase, 3200 dollars, extra payment of 1459 dollars is about 45% of the purchase price. The gap of WTP implies that consumers are willing to pay 45% more to take an option of leasing the system for five years instead of purchasing it. This can also be seen as a payment to avoid the risk of holding a solar system for more than 20 years. The difference of WTP between leasing 5 years and 10 years is 392 NTD, while the difference of WTP between leasing 10 years and 20 years is 1067 NTD.

Difference of utility	10 years	20 years
5 years	0.098	0.366
10 years	-	0.267

Difference of willingness to pay (NTD)	10 years	20 years
5 years	$392	$1459
10 years	-	$1067

Table 6： Differences of utilities and willingness to pay between lease times.

Another interesting question is whether concern of the uncertainty factors is related to the WTP between short term lease and purchase. People with higher concern on uncertainty and resistance to new products are supposed to choose shorter term lease. Table 7 shows the correlation between gap of WTP and concern scores of uncertainty factors using Pearson correlation. Gap of WTP between lease times is highly correlated with most uncertainty factors like government subsidy, product lifetime, reliability, rise of new model and electricity price. The only uncertainty measure that is not significantly related to gap of WTP is product price. Among the uncertainty scores, score on reliability concern is highly correlated with gap of WTP. Concern on product lifetime has the least correlation with gap of WTP.

Gap of WTP (5 years-20 years)	Government subsidy	Product price	Product lifetime
Pearson correlation	0.168	0.077	0.143
p value	0.013**	0.257	0.035**

Gap of WTP (5 years-20 years)	reliability	Rise of new model	Electricity price
Pearson correlation	0.298	0.161	0.158
p value	0.000***	0.017**	0.020**

Table 7： Correlation between WTP gap and uncertainty score.

To compare the willingness to pay between groups of higher concern and lower concern on uncertainty factors, differences of utility and WTP between different lease times are shown in Figure 1. Group 1 has larger gap of WTP between lease times, meaning people with higher uncertainty concern prefer shorter lease time to avoid the risk. Take the comparison between 5 and 20 year lease times as an example, group 1 is willing to pay extra 1969 NT dollars for 5 year lease time than 20 year lease time. The extra payment per month is larger than that offered by group 2, 508 NT dollars. Comparing the lease times of 5 and 10 years, group 1 are willing to pay extra 537 NT dollars, which is larger than that (64 NT dollars) willingness to pay offered by Group 2. This result meets our hypothesis that short term leasing would be adopted by people who have higher concern of uncertainty factors. Higher amount of WTP for shorter leasing time by group 1 verifies the hypothesis.

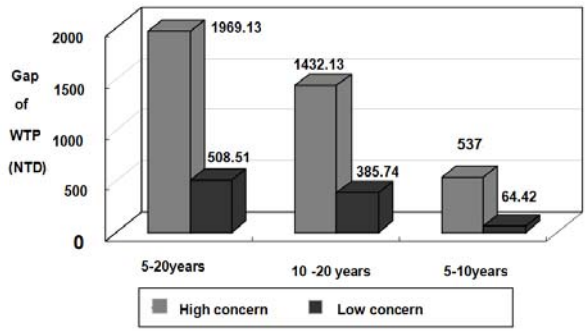

Figure 1 ：Gap of WTP between different lease times for two groups.

7 SUMMARY

This study presents application of conjoint analysis on PSS marketing and development, taking solar power system as an example. Solar power system is looked as one of the most promising renewable energy sources and novel green products adopted by consumers in the near future. But, since there are many uncertainties for the emerging technology, PSS such as leasing might be an option to help consumers reduce their risk and worry. This study finds consumers' preference of solar power systems and focuses on the willingness to pay for leasing the system comparing to purchasing. Questionnaire survey on consumers' concern on certain uncertainty factors that may affect the adoption of solar power system is conducted. Conjoint analysis is used to estimate PWU of the attributes of solar power system and the willingness to pay regarding various attributes. By including lease time as an attribute in conjoint model, the gap of WTP between various lease times can be estimated. Gaps of willingness to pay between shorter and longer leasing times could be estimated. Since leasing time equal to 20 years is interpreted as purchase, the gap of willingness to pay between shorter leasing time and purchase can be estimated.

In addition, the relation between gap of WTP between lease times and uncertainty scores that measure consumers' concern are presented. Cluster analysis is used to find two groups with high and low concern of uncertainty. Gaps of WTP for different lease time for the two groups are compared. People with higher concern on uncertainty tend to pay more for adopting shorter lease time. Characteristics of the two groups are also presented.

8 ACKNOWLEDGEMENT

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9 REFERENCES

[1] European Photovoltaic Industry Association, 2009, “Global market outlook for photovoltaics until 2013, EPIA report.

[2] Bagnall, D.M. and Boreland, M., 2008, ”Photovoltaic technologies,” *Energy Policy* 36, 4390-4396.

[3] Hoffmann, W., S. M. Pietruszko, M. Viaud, 2004, ”Towards an Effective European Industrial Policy for PV Solar Electricity”, 19th PVSEC Paris, June.

[4] Krieger, A. M.; P. E. Green; Y. J. Wind, 2004, Adventures in Conjoint Analysis: A Practitioner’s Guide to Trade-Off Modeling and Applications, Monograph, University of Pennsylvania.

[5] Green, P. E. and V. Srinivasan, 1990, Conjoint Analysis in Marketing: New Developments with Implications for Research and Practice, Journal of Marketing, 54, 4, 3-19.

[6] Danielis, R., E. Marcucci and L. Rotaris, 2005, Logistics Managers Stated Preferences for Freight Service Attributes, Transportation Research Part, E41, 201-215.

[7] Lockshin, L., W. Jarvis, F. Hauteville, and J. Perrouty, 2006, Using Simulations from Discrete Choice Experiments to Measure Consumer Sensitivity to Brand, Region, Price, and Awards in Wine Choice, Journal of Food Quality and Preference, 17,166-178.

[8] Enneking, U., C. Neumann, and S. Henneberg, 2007, “How Important Intrinsic and Extrinsic Product Attributes Affect Purchase Decision,” Journal of Food Quality and Preference, 18,133-138.

[9] Green, P.E. and Y. Wind, 1975, “New Ways to Measure Consumer Judgments,” Harvard Business Reviews, 53,107-117.

[10] Hurlimann, A. and McKay J., 2007, “Urban Australians Using Recycled Water for Domestic Non-Potable Use-An Evaluation of the Attributes Price, Saltiness, Color and Odor Using Conjoint Analysis, “*Environmental Management*, 85, 1, 93-104

[11] Espino, R., Martin, J. C. and Roman, C., 2008, “Analyzing the Effect of Preference Heterogeneity on Willingness to Pay for Improving Service Quality in an Airline Choice Context,” *Transportation Research part E*, 44, 4, 593-606.

[12] Longo, A., Markandya A. and Petrucci M., 2008, “The Internalization of Externalities in the Production of Electricity: Willingness to Pay for the Attributes of a Policy for Renewable Energy,” *Ecological Economics*, 67, 1, 140-152.

[13] Ram, S. and Sheth, J., 1989, “Consumer Resistance to Innovations: The Marketing Problem and Its Solutions,” *Journal of Consumer Marketing*, 6, 2, 313-326.

[14] Cox, D. N., Evans, G. and Lease, H. J., 2007, “The Influence of Information and Beliefs about Technology on the Acceptance of Novel Food Technologies: A Conjoint Study of Farmed Prawn Concepts,” *Food Quality and Preference*, 18, 5,813–823.

[15] Goett, A., Hudson, K. and Train, K., 2000, “Customers’ Choice among Retail Energy Suppliers: The Willingness-to-Pay for Service Attribute,” AAG Associates, and Department of Economics University of California, Berkeley.

Session 3A:
Design Issues

Development accompanying calculation - How to calculate IPS² costs during the early development phase?

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Abstract

Recently, many companies of the capital goods industry are moving away from simply offering individual products to providing innovative customized solutions, so called Industrial Product-Service Systems (IPS²). This article introduces a system which enables the calculation of an IPS² in the early phase of development. This system is based on specific IPS² characteristics and information which is provided in the different phases of development. We therefore deduce the requirements for the development accompanying calculation which are caused by the transformation from a product supplier to a supplier of IPS². Subsequently, we make use of a systematic illustration of these requirements to examine to what extent traditional instruments of construction accompanying calculation are able to meet these requirements and to reveal weaknesses of these instruments. We then provide solution alternatives, which lead to the design of a calculation system for IPS².

Keywords

IPS², Development accompanying calculation, Time-Driven Activity-Based Costing, Target Costing

1 INTRODUCTION

Recently, many companies of the capital goods industry are moving away from simply offering individual products to providing innovative customized solutions. While a few years ago the core competences of such enterprises were centered on the development and production of machines and plants, today's highly dynamic markets ask for a radical change of mind. Due to the globally accelerated spread of information an approximation of competitors' core performances has taken place. In this regard, it becomes very difficult for a company to differentiate itself from others which leads to a severe price erosion with decreasing profit margins. On this background enterprises try to successfully rival on the global market by designing highly complex products. This on the other hand is accompanied by a shortfall of customers' knowledge regarding the use, maintenance and disposal of such commodities. Thereby, the primary technological advantage which is, compared with standardized products, used to justify the accordant additional charges, is being ruined. [1]

Based on the previously described problems companies are forced to expand their product-centric business models by offering after sales services. In this regard, short-term strategies which are mostly used in the context of such after sales businesses turn out to be unrulable cost drivers. Furthermore, these widespread unplanned offerings mostly emerge as a so called "service jungle" which is in the end neither transparent for the provider nor for the customer. [2] In this regard, they also often fail to meet their customers' requirements. To that effect, in the long term enterprises have to emerge as providers of so called **Industrial Product-Service Systems (IPS²)**. Such innovative customized integrated solutions similarly consist of products and services which have been simultaneously developed and are being offered on business-to-business markets. [1]

It is the aim of this contribution to point out the development accompanying calculation of industrial product service systems as the crucial part of a proactive cost management. Deduced from the requirements which go alongside with the transformation towards an IPS² supplier this contribution highlights solutions of a development accompanying calculation which are then integrated into the system of a **proactive cost management** of IPS².

2 BASIC PRINCIPLES OF A DEVELOPMENT ACCOMPANYING CALCULATION

The possibility of influencing costs is highest in the early stage of development. At this stage 70% to 80% of the overall company costs are being determined. The fact that constructing engineers make their decisions during the development stage without taking into consideration economic aspects therefore has to be seen as critical. This can be exemplified by focusing on the decision regarding the system architecture of a product, which is to be made during the development process. The core product's technical alternatives which are needed to warrant the functions dictated by customer needs are mostly being selected based on experience or gut feeling of the constructing engineer. [3] Selection of technical alternatives based on such an approach are being made without including economic considerations and cannot be used as a basis for further decisions. The purely technologically oriented development approach needs to be extended by an economic perspective.

The **Development accompanying calculation** aims at solving this problem. The constructing engineer is being provided with information which allows the estimation of cost consequences of the actions taken during every phase of the development process. However, the different directions of calculation and development are problematic in this regard. Calculation follows a bottom-up approach in which overall product costs are being determined starting with single components and assemblies. Development follows a top-down approach as illustrated in Figure 1.

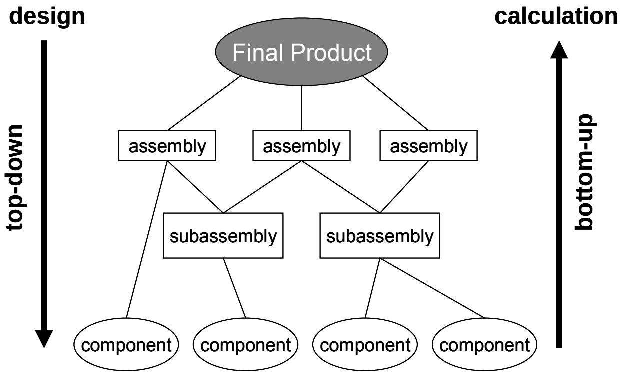

Figure 1: Direction of calculation and design. [4]

Following this approach calculation can only start after the development is completed. At this point of time, however, factors which trigger company costs have already been determined. Therefore only a reactive cost management can be used. As this contradicts the demand for a proactive cost management, the development accompanying calculation provides methods which are adjusted to the information level of the different development phases.

The following phases can be distinguished:

- the planning phase
- the conception phase
- the draft phase
- the project engineering phase.

In the planning phase only the requirements which have to be met by the IPS² are being described. The conception phase focuses on the functions which need to be fulfilled by the IPS². Solution concepts, but no product drafts are being created. Products drafts are being developed in the draft phase. The project engineering phase is characterized by the highest level of detail, the final form and dimension as well as the construction data are being determined. [4]

2.1 Planning Phase of an IPS²

In the context of IPS² the development accompanying calculation adopts a special role. Customized problem solutions require quick and precise cost estimation already in the planning phase. The precision of the calculation in this phase is decisive for the economic success of an IPS² and therewith for the economic success of an IPS² provider. Missing knowledge about or missing precision regarding costs which will incur in the future can lead to the following effects: On the one hand prices set by the IPS² supplier might be too high, leading to failing business negotiations on the other hand suppliers might not be able to cover future costs incurring during the processing of orders. To solve this problems the instrument target costing, as part of the proactive cost management of IPS², needs to be applied parallel to the development accompanying calculation.

Target costing serves to circumvent prices rejected by the customer, by not developing the IPS² with the maximum technological capacity, but instead developing a configuration which focuses on the parameters costs, characteristics and quality and is accepted by the customer. [5] Target costing provides an answer to the question “at which level can the IPS² price be set”. The development accompanying calculation answers the question “at which level will the IPS² price be set”.

Target Costing consists of four steps: [6]

1. Determination of overall target costs
2. Target cost splitting
3. Target cost attainment
4. Target cost controlling

Only the first step occurs in the IPS² planning phase. To carry out the subsequent steps information is necessary, which cannot be provided at this early stage of development. The determination of overall target costs (Step 1) depends on the object focused upon.

Beside the market into company approach, the approaches out of company, into and out of company, out of competitor and out of standard costs can be applied. However, only the market into company approach determines overall target costs out of the relevant market respectively out of the specific customers in the case of IPS². The other approaches mentioned derive target costs either completely or in parts from the technologies and experiences of the supplier company and the competitors. To reduce the threat of a target price which is not accepted by the customer these approaches should therefore not be used for IPS².

The result of the first step of target costing is the target price of an IPS². Subtracting a target profit for the supplier from this price leads to the overall IPS² costs which are accepted by the customer, so-called allowable costs. [7] The cost ceiling of an IPS² is therewith already calculated during development. Crossing this cost ceiling results in failing economic viability.

The calculation of the IPS² costs during the planning phase is problematic due to the low degree of detail of the IPS² which is to be configured. A bottom-up approach cannot be chosen as neither solution concepts nor parts and components to be used have yet been determined. Calculation therefore needs to be focused on the level of the end product. The costs of the IPS² which is to be developed are hereby derived from the costs of similar IPS² of the supplier. The costs of similar systems can be extracted from a cost data base, in which the system architecture as well as the requirements are displayed and in which cost data are available broken down to the level of components. [4] The assessment of economic success of IPS² to be developed depends on the precision of this data. Therefore the choice of the cost accounting methods which are to be used by a company is very important.

Another factor with great importance for assessing the economic feasibility is the IPS² business model chosen by the customer. Three different types of business models can be distinguished, **function oriented**, **availability oriented and result oriented business models**. [8]

- The objective of a function oriented business model is to secure the functioning of a good over an agreed upon period of time. Hence, the core business is gradually extended by product accompanying services to the degree that a cooperation between supplier and customer is requested.
- When the supplier takes over availability guarantees (e.g. maintenance and optimization services) it is the first time that he has a personal responsibility concerning the technical production risks of the customers and is thus directly integrated in the business processes (availability-oriented business model).
- If the supplier is completely responsible for the production result, we talk of a result-oriented business model.

Depending on the chosen business model a gradual shift of cost risks from customer to supplier takes place. While in the function oriented business model customers initiate the conduction of services, this is the direct responsibility of the supplier in the result oriented business model. Costs incurring in this phase of an IPS², including all services conducted, need to be covered by the customer in the function oriented business model and by the supplier in the result oriented business model. This has consequences for the system architecture and the methods of cost estimation which are used in the planning phase.

Consequences for the system architecture:

While minimizing life cycle costs should be the aim of constructing engineers, the purchase price is still the most important aspect in the machine and construction site sector, although this approach is myopic and often not economically feasible. [9] In this context the trade-off between initial costs and follow-up costs is crucial. Minimizing life cycle costs is mostly accompanied by an increase in initial costs (development costs, costs of production, etc.) which are being compensated by a disproportionate decrease of follow-up costs (costs of operation, maintenance costs, energy costs, costs of disposal, etc.).

Consequences result especially for the function oriented business model, because customers are at first primarily interested in buying the physical component of an IPS².

An IPS², based on minimal life-cycle costs, leads to a price increase due to high start-up costs in this first, short-term relation between customer and supplier. It is a result of the fact that, in this business relation, only the customers profit from the cost savings in the operation and disposal phase. Empirical surveys proved, however, that only a minor part of potential customers uses the Total Cost of Ownership method, which helps to unveil the advantage of increasing acquisition costs. [10] [11] [12] [13] Therefore, IPS² suppliers should thoroughly consider the strategies which are to be followed within the function-oriented business models. On the one hand, it is possible to present calculations concerning increasing life cycle expenses to the customer in order to reveal the advantages of the higher purchase price; on the other hand, the target of the development can be a minimal purchase price. The last-mentioned strategy cannot be recommended to IPS² suppliers, as the current price war in the capital goods industry is one of the major reasons to become a supplier of Industrial Product Service Systems.

Effects on quotation costing:

Apart from the described effects on the system architecture of an IPS², the selection of the business model will also effect quotation costing. In case of the **function-oriented business model**, the calculation of the primary costs of the IPS² is sufficient, as the material components of the IPS² and the services required by the customers in the operational phase are priced individually. It is necessary to include further types of costs, when taking over a part of the cost risks (**availability-oriented business model**) respectively the full cost risks (**result-oriented business model**) by the IPS² supplier in the pre-development phases. In case of the availability-oriented business model, it needs to be clarified, from the supplier's point of view, which services need to be available at which point and to what extent, in order to fulfill the availability agreed. Finally, in a result-oriented business model, the complete life cycle costs of an IPS² need to be determined as the supplier is responsible for the operation of the machines. This relation between selected business model and extension of the business relation between customer and supplier needs to be considered explicitly when using the methods of target costing and the development accompanying calculation.

Finally the result of the planning phase is a target price which is derived from the customer's willingness to pay for an IPS² which serves as a cost ceiling during development. By using development accompanying calculation a matching of target costs and costs emerging on the level of the whole product is possible already in the planning phase of an IPS².

2.2 Conception and draft Phase of an IPS²

In the conception phase, the IPS² is described with the help of functions, in order to prevent a fixation on components (products) and processes (service). Functions fulfill requirements, which are performed and considered as important by the customers. [14] Within the context of a proactive cost management it is not sufficient to contrast the overall target costs, determined in the planning phase of an IPS², with the incidental costs. A specific cost influence requires a higher level of detail. Target costs need to be specified in the level of the products component, respectively processes. The distribution of the overall target costs on functions and corresponding components, respectively processes is made in the second step of Target Costing, target cost distribution (see Figure 2). Different approaches of target cost distribution have been dispread in literature. [7] The Functional Area Method is used for complex innovative products, it is based on the assumption that an IPS² can be represented by a combination of functions, which are fulfilled by technical components or processes. [15] Basis for the Functional Area Method is the conjoint-analysis, whose goal is to specify the functions which need to be

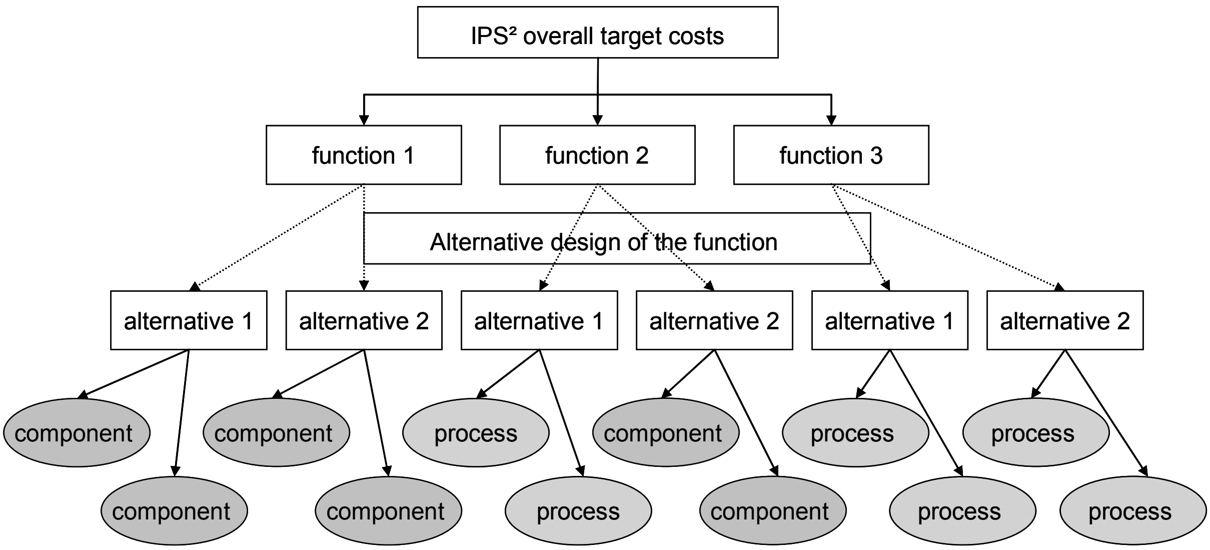

Figure 2: IPS² system architecture

fulfilled by an IPS² (from a customer's point of view) and, at the same time, to show the valuation the customer gives to these functions. Based on the latter, the share of benefits of the components, respectively processes, which are required to fulfill the functions, in the overall benefit will be specified. This share of benefits can be interpreted at the same time as an upper cost limit of the function. [16]

The second step of target costing cannot be applied during the conception phase. The necessary details will only be supplied in the following draft phase. In this phase, a so-called rough draft of the IPS² will be developed; the result being a list of all technically possible alternatives of functional compliance. In the case of IPS²s, this rough draft will also show the substitution of products and services. There is the option that either components (products) or processes (services) can be used to fulfill several of the functions (compare Figure 2).

Result of the target cost distribution is, apart from the listing of required components, respectively processes to fulfill the function, an upper cost limit of individual functions. In the third step of target costing, target cost attainment, so-called drifting costs need to be specified and contrasted with the target costs. Drifting costs are predicted costs for the IPS² creation based on the existing technology and process standards of the company.

A rough draft of an IPS² is used to specify the incidental costs of a company up to process, respectively component level. The systems used for cost calculation will be explained in chapter 3 in more detail.

The alternatives to fulfill the functions have been determined from a mere technical point of view and are now subject to an economic evaluation. The proceedings, which have been criticized in chapter 2, namely the selection of alternatives for function fulfillment, which are based on the experience of the developer, have thus been extended by an economic point of view.

Cost information has been provided, which is, apart from strategic aspects, particularly relevant in, e.g. make-or-buy decisions. Based on this cost information, a statement can be made if certain components or processes are to be produced, respectively provided or if they are to be sourced out. [16] [4]

The costs of the function are specified by adding up the components, respectively processes which are part of an alternative of function fulfillment. In the following confrontation of these drifting costs and target costs, there are three cases which require different types of action:

- **Target costs = drifting costs**: In this case the customer's requirements are fulfilled in an optimal way. The costs caused by the components, respectively processes correspond exactly to the weight of this component, respectively process for the fulfillment of the IPS² function
- **Target costs > drifting costs:** The customer assigns a higher value to the function, than the costs it causes. In this case it needs to be examined if the processes, respectively components used fulfill the customer's actual requirements**.**
- **Target costs < drifting costs:** The costs exceed the value attributed by the customer. Costs need to be reduced.

At the end of the design phase all information is available in order to choose a variety of the components and processes used in the function realization, both from a technical and economic point of view. This information can be used to support the decision when selecting the system architecture of an IPS².

It needs to be pointed out that a mere cost observation as a decision criterion for the alternative selection and thus the decision about the system architecture of an IPS² is not sufficient. With the transition to a long-term business relation, as in the availability- and result-oriented business model, a certain degree of flexibility will be required in order to be able to react to future environmental influences in an appropriate way. This flexibility needs to be designed already in the development of an IPS², by adjusting the system accordingly. In this context, cost information can only be used to support the decision.

Based on the results of the draft phase, the final design and dimension of the IPS² can be made in the project engineering phase. In this phase, every component and its alternatives will be formulated technically and evaluated economically so that the best alternative can be selected [4].

The combined use of target costing and the development accompanying calculation enable, in the early phases of the IPS² development already, the support of engineering methods and complements the merely technically point of view by an economic perspective. The strict pursuit of a customer orientation over the complete design process and the constant comparison with the future costs of an IPS² enable an early evaluation of profitability. At the same time, approaches for cost influences will be shown at an early stage already, thus supporting a proactive cost management as illustrated in Figure 3.

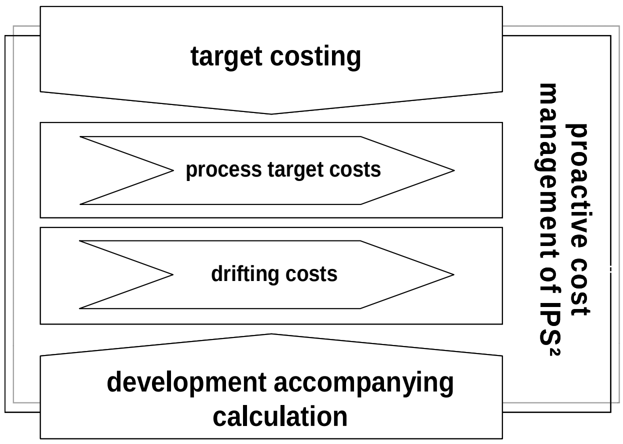

Figure 2: IPS² Cost Management. [17]

3 COST ACCOUNTING FOR IPS²

As mentioned in the previous chapters, cost calculation of IPS²s is very important within the development accompanying calculation. Without a **cost accounting system**,

which provides detailed information concerning the costs of the companies, an economic foundation for the transfer to an innovative business model it is not possible.

It is particularly the fact that IPS² suppliers do not only offer products, but services too, which is a challenge to the **traditional cost accounting systems** which are used in mechanical engineering. Due to a lack of organizational units for the service provision, the costs are usually allocated indifferently to cost centers. [18] In the case that services are recorded separately, there is also a problem with traditional cost accounting systems. Service costs can usually not be added to individual performance and are therefore overhead costs, and are allocated via surcharges to calculation objects. The problems arising from this fact will be described in detail later in this article.

The use of traditional cost accounting systems can also be criticized within the frame of a development accompanying calculation. A special emphasis needs to be placed on the decision in the design phase of the IPS² concerning the alternative selection for the function fulfillment (compare chapter 2). When the focus is on the direct material costs, as common in traditional systems, a wrong signal is sent to the developer. It is a result of the allocation of overhead costs via a direct-material burden rate. Developers are going to choose alternatives with particularly low material costs, in order to reduce the overheads costs allocated to the components. Therefore, traditional cost calculation systems favor alternatives with a large number of reasonably-priced components. Here, complexity costs in form of overhead costs will not be allocated to the components individually, but to the individual material costs via overhead rates. [19] A way out is Activity-Based-Costing (ABC). In this system overhead costs are not allocated via overhead rates but are allocated process-oriented. The following section is supposed to represent the ABC system by means of the service processes occurring in an IPS² and show the amount of extensions which need to be added.

3.1 Costing of IPS² service processes

Service characteristics pose a major challenge, when it comes to calculating the costs of an IPS². In this regard, the integration of a customer or rather his external factors as well as the intangibility or rather the fact that services cannot be produced in advance, can be considered to be most fundamental. [20] In order to be able to perform such processes, service providers have to 'establish' capacities (e.g. personnel) which cannot be reduced at short notice. Hence, due to the fact that in most cases such capacities cannot be assigned to one single process, but rather to a multitude of different service offerings, overheads emerge. Traditional cost accounting systems allocate such indirect costs generally via a direct material burden rate. In case of services, where such indirect costs are dominant, these rates lose their validity. That is attended by the fact, that in the past, mainly products rather than services have been used as calculation object. Thus, against this background, a direct costing of service processes is not possible.

3.2 Time-Driven Activity-Based Costing (TDABC)

In view of the previously described problem, *Cooper* and *Kaplan* developed a method called **'Activity Based Costing' (ABC)**. [21] In opposition to traditional cost accounting instruments, due to its complex exposure to overhead costs, such a costing technique can be particularly valuable, when it comes to calculating an IPS²'s service processes.

However, by virtue of the increased share of fixed indirect costs in the context of services, the ABC approach cannot be adapted without specific modifications. In order to determine the emerging costs of an activity or rather process, the respective resource costs are being calculated. After that, they are being divided by the estimated or actual sum of cost drivers. In this regard, the notion 'cost driver' describes a reference parameter which particularly influences the amount of costs. However, in case of fixed overheads it is to criticize that the respective cost rates vary, depending on the amount of cost drivers.

The following example shall help to explain the previous argument. Resources, worth of $112.500, have been assigned to a specific process (e.g. maintenance) during a period t_1. Furthermore, cost drivers (e.g. number of performed maintenances) emerged in the amount of 800. This in turn leads to a process cost rate of $140,63.

In opposition to period t_1, in period t_2, cost drivers occurred in the amount of 700. Such a reduction is caused e.g. by the loss of customers. Against this background, due to the fact that the respective resources (e.g. personnel) cannot be rapidly reduced, the process cost rate varies. Hence, although the same amount of resources has been used as in period t_1, during period t_2 the process cost rate rises to $160,71 (cf. Table 1). In this context, the difference of $20,08 cannot be traced back to a loss of efficiency, e.g. regarding the personnel's performance etc. In fact, this rather indicates the costs which are caused by unused capacities. [22]

Period	Activity	Assigned costs	Activity Quantity	Cost Driver Rate
t1	maintenance	$112.500	800	$140,63
t2	maintenance	$112.500	700	$160,71

Table 1: Exemplary calculation of a maintenance costs by using the ABC approach

As a result, a company's degree of capacity utilization decides about the amount of the respective process cost rate. In order to avoid such unsteadiness, **Time-Driven Activity-Based Costing (TDABC)** has to be used. In general, this approach can be understood as an advancement of Activity-Based Costing. In case of the TDABC, the time needed to perform a certain process one-time, is being multiplied by the respective costs per time unit. Hence, this approach only needs the following two parameters in order to calculate the emerging costs:

1. costs per time unit in order to provide the respective resource capacities, and
2. time necessary to render a specific process one-time. [23]

Such a calculation can be subdivided into the following steps.

(1) First of all, in order to calculate the costs per time unit, one has to identify the amount of resources (e.g. personnel, tools etc.), necessary to perform a certain process. In a second step, one has to determine the respective resource's maximum capacity. In case of personal, it is assumed that 80% of the theoretic maximum capacity can be used. If it is about a machine, one calculates with 85 % of the theoretic maximum capacity. With regard to human resources, this is based, e.g. on work breaks, schooling or illness. In case of technical resources (machine), interruptions, just like repair or maintenance, lead to such a reduction of the theoretic maximum capacity. In a last step, the respective process's resource costs have to be divided by the calculated maximum capacity. As a result, one achieves the respective costs per time unit. In the following, these explanations will be clarified with the help of the previously described example. It is assumed that a company employs 15 people that are all equally qualified to render a specific service, e.g. maintenance. Each employee theoretically works 40 hours per week. This results in a maximum capacity of 32 hours per week or rather 128 hours per month (period). So to speak, in case of 15 people, this leads to a maximum capacity of 1.920 hours or rather 115.200 minutes per period. Hence, if it is additionally assumed that resources in the amount of $112.500 have been assigned to that particular process, costs to the tune of $0,98 per minute occur for the capacity's provision.

(2) Besides identifying the costs per time unit, the time necessary to render the process once also has to be determined. In most cases, this is based on direct observations. With regard to our example, we assume that a process time of 120 minutes has been assigned to each maintenance provision. Thus, by multiplying the costs per time unit by the respective one-off execution time, this results in a cost rate of $117,60 for performing the respective process once. As a result, such a cost rate has been calculated independently of the cost drivers' amount. Hence, the variability which has been criticized in the context of the ABC approach can be avoided. Therefore, in view of our example, the process cost rate of $117,60 per period t_1 and period t_2 correctly reflects the real amount of resources needed to perform the respective maintenance one-time. Table 2 illustrates these coherences.

Period	Activity	Activity Quantity	Unit Time	Total Time used	Total Time Supplied
			In minutes		
t1	main-tenance	800	120	96.000	115.200
t2	main-tenance	700	120	84.000	115.200

Period	Assigned Costs	Cost-Driver Rate	Cost of unused Capacity
t1	$112.500	$117,19	$18.750
t2	$112.500	$117,19	$30.469

Table 2: Exemplary calculation of a maintenance's costs by using the TDABC approach

In this regard, the costs of an action in the amount of $140,63 (period t_1) and $160,72 (period t_2) which had been calculated with aid of the ABC approach include idle time costs.

However, in the context of the traditional Activity-Based Costing such costs cannot be identified separately. Only by using the proposed TDABC approach, such idle time costs become obvious.

With the help of the TDABC approach, the cost information provision of the decision which needs to be made in the design respectively offer phase of the IPS², concerning the choice of the various ways to fulfill the functions can be guaranteed. With the identification of a resource use caused by a particular process, there is an additional guarantee that the cost approaches will not be distorted by the company's periodic capacity utilization.

4 CONCLUSION

70% to 80% of the overall company costs are being determined during the development of a product. Therefore, it has to be seen as critical that constructing engineers often make decisions without any economic information. In this paper we showed that the development accompanying calculation and target costing as parts of a proactive cost management for IPS² are able to complement the merely technically point of view by an economic perspective.

Based on the level of information of the different development phases of an IPS² we examined the applicability of development accompanying calculation and target costing. Furthermore, we identified IPS² specific requirements. As a result we can state that a matching of IPS² costs and the costs which customers are willing to cover can be done on various levels of detail in the different development phases. In an early phase of development a cost calculation of the IPS² which is to be developed has to be based on similar, already existing, IPS² which the supplier offers. In this phase costs can only be estimated for the overall IPS². In subsequent phases costs can be estimated for components and processes, due to further detailing of the IPS² system architecture. In this regard, the kind of cost accounting system used plays a major role. Traditional cost accounting systems are not suitable for the development accompanying calculation of IPS². In this systems product costs were systematically distorted through the focusing on direct material costs and allocating overheads via a direct-material burden rate. Therefore we presented the activity-based-costing as system to eliminate this problem. However, services, which form an additional part of IPS², demand an enhancement of ABC. TDABC has been introduced as such an enhancement; its advantages have been emphasized by means of a example.

Target costing and development accompanying calculation have been pointed out as methods of a proactive cost management which allows a systematic match of incurring and allowable costs already during the development phase.

5 ACKNOWLEDGEMENTS

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6 REFERENCES

[1] Meier, H., Uhlmann, E., Kortmann, D., 2005, Hybride Leistungsbündel. Nutzenorientiertes Produktverständnis durch interferierende Sach- und Dienst-leistungen, wt online, 95: 528-532.

[2] Spath, D., Demuß, L., 2006, Entwicklung hybrider Produkte – Gestaltung materieller und immaterieller Leistungsbündel, in: Bullinger, H-J., Scheer, A-W., (ed.): Service Engineering- Entwicklung und Gestaltung innovativer Dienstleistungen, Springer, Berlin, 2nd Ed: 463-502.

[3] Horváth, P., Gleich, R., Scholl, K., 1996, Vergleichende Betrachtung der bekanntesten Kalkulationsmethoden für das kostengünstige Konstruieren, KRP Sonderheft, 1/1996: 53-62.

[4] Burger, A., 1999, Kostenmanagement, Oldenburg, München 3rd Ed.

[5] Stirzel, M., Zeibig, S., 2009, Target Costing, Controlling 6/2009: 322-325.

[6] Horváth, P., 2009, Controlling, Vahlen, München 11th Ed.

[7] Seidenschwarz, W., 2009, Target Costing - Marktorientiertes Zielkostenmanagement, Vahlen, München 2nd Ed.

[8] Meier, H., Kortmann, D., Krug, C., 2006, Von der Technologie zur Nutzenführerschaft – Die Zukunft der Werkszeugmaschine als hybrides Leistungsbündel, ZWF, 7-8/2006: 431-434.

[9] Ehlenspiel, K., Kiewert, A., Lindemann, U., 2000, Kostengünstig entwickeln und konstruieren, Springer, Berlin 3rd Ed.

[10] Denkena, B., Rudzio, H., Eikötter, M., Blümel, P., 2009, Total Cost and Benefit of Ownership, Industrie Management, 5/2009: 35-38.

[11] Lorenzen, L.-E., Rudzio, H., Blümel, P., 2009, Die totale Kostenkontrolle: Ergebnisse einer Umfrage zu dem Thema Total Cost of Ownership, wt online, 96: 489-494.

[12] Wynstra, F., Hurkens, K., 2005, Total Cost and Total Value of Ownership, in: Essig, M. (ed.): Perspektiven des Supply Management: Konzepte und Anwendungen, Springer, Berlin, Heidelberg, New York: 463-482.

[13] Tönshoff, H.K., Reinsch, S., Eger, M., 2005, Lebenszykluskosten von Werkzeugen und Formen, wt online, 96: 872-876.

[14] Coenenberg, A. G., Fischer, T., Schmitz, J., 1994, Target Costing und Product Life Cycle Costing als Instrumente des Kostenmanagements, ZP, 1994: 1-38.

[15] Buggert, Wielpütz, 1995, Target Costing – Grundlagen und Umsetzung des Zielkostenmanagements, Hanser, München, Wien.

[16] Schwengels, C., 2004, Ein Verfahren zur kostenorientierten Entwicklung von Dienstleistungen im Rahmen hybrider Produkte, Jost-Jetter, Heimsheim.

[17] Steven, M., Wasmuth, K., Soth, T., 2008, Cost Management for PPS, in: Transregio 29 (ed.) , Transregio 29. Product-Service Systems. Dynamic Interdependency of Products and Service in the Production Area - International Seminar on PPS 21-22 January 2008, Shaker, Aachen: 53-58.

[18] Reckenfelderbäumer, M., 2004, Die Wirtschaftlichkeitsanalyse von dienstleistungsorientierten Geschäftsmodellen als Herausforderung für das Controlling, in: Meier, H. (ed.), Dienstleistungsorientierte Geschäftsmodelle im Maschinen- und Anlagenbau – Vom Basisangebot bis zum Betreibermodell, Springer, Berlin, Heidelberg: 209-242.

[19] Labro, E., 2004, The Cost Effects of Component Commonality: A Literature Review Through a Management-Accounting Lens, Manufacturing & Service Operations Management, 6: 358-367.

[20} Engelhardt, W. H., Kleinaltenkamp, M., Reckenfelderbäumer, M., 1993, Leistungsbündel als Absatzobjekt – Ein Ansatz zur Überwindung der Dichotomie von Sach- und Dienstleistungen, ZfBf, 45/5: 395-426.

[21] Cooper, R., Kaplan, R.S., 1991, Activity-Based Costing: Ressourcenmanagement at its best, Harvard Manager, 13/4: 87-94.

[22] Kaplan, R.S., Cooper, R. 1998, Cost & Effect – Using Integrated Cost Systems to Drive Profitability and Performance.

[23] Kaplan, R.S., Anderson, S.R. 2004, Time-Driven Activity-Based Costing, HBR 85/11:131-138.

Analyzing structures of PSS types for modular design

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Abstract

Most market entities around us are shifting to complex combination of products and services, particularly in advanced countries. In PSS (Product/Service-System) research, modular representation has not been studied in detail, although we could understand the basic concept of a PSS because of extensive literature. In this paper, we model and analyze eight well-known types of PSSs from three viewpoints: the state of receivers, functions, and attributes of entities. As a result, the following are described along with the corresponding models: characteristics of each type, transitions from typical product sales, and differences among types. This result will contribute to configuring modules of product-service combination toward a design of new PSS.

Keywords

Classification of PSS, Service Engineering, Function and attribute, computer-aided design

1 INTRODUCTION

As our economy matures, good combinations of tangible products and intangible services are necessary to achieve a balance between economic growth and environmental concerns. In this context, the engineering target that needs to be analyzed and designed is shifting from simple products to service offering. In order to serve this need, new concepts such as Product/Service-Systems (PSSs) [1-3], Functional Sales [4], and Functional Products [5] have thus far been developed. A PSS can be defined as consisting of “tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs” [6]. The basic concept of a PSS is to sell functions of products, and not to sell the products themselves. From a manufacture’s point of view, a major objective of a PSS is to generate better overall revenue over the life cycle of a product. The business concept of Functional Sales can be defined as “…to offer a functional solution that fulfills a defined customer need. The focus is, with reference to the customer value, to optimize the functional solution from a life-cycle perspective. The functional solution can consist of combinations of systems, physical products and services” (modified from [4]). Functional Products, also known as “total care products” are products that comprise combinations of “hard” and “soft” elements [5]. In spite of these many studies, effective design methodologies have not still been developed sufficiently [7].

To establish design methodologies of PSS, theories of modular representation and modular design are crucially important. Modular design is an approach that subdivides a system into small parts (modules) that can be independently created and then used in different systems to drive multiple functionalities. This requires a well-structured representation of PSS to be analyzed.

The present authors have been researching Service/Product Engineering (SPE) [8-10] since 2002 so as to model and evaluate a PSS. Our approach on SPE is characterized as a top-down approach to providing a service definition and modeling method. It has a great advantage in computer-aided design systems as a theory on service must be implemented in a computer so as to prove its effectiveness.

This paper attempts to analyze structures of PSS types by using our developed modeling method and computerized tool so as to obtain modules of product-service combination toward a design of new PSS. The rest of the paper is organized as follows: Section 2 explains a classification of PSSs to be analyzed. Section 3 illustrates a representation method of a service that the authors have proposed and analyzes PSS types by using the method. Section 4 discusses this study and concludes the paper.

2 CLASSIFICATION OF PSS

In PSS research, Tukker’s classification shown in Figure 1, which classifies PSSs into eight types according to the ratio of product/service contents, is well known. Shown on the left in Figure 1 is the class “pure product,” which has value mainly in product content, while shown on the right in Figure 1 is the class “pure service,” which has value mainly in service contents. According to the spectrum from the pure product to the pure service, Tukker insists that services in a PSS are divided into three main types: a product-oriented service, use-oriented service, and result-oriented service. Explanation of each type is as follows, as given in Table 1: a product-oriented service is a business

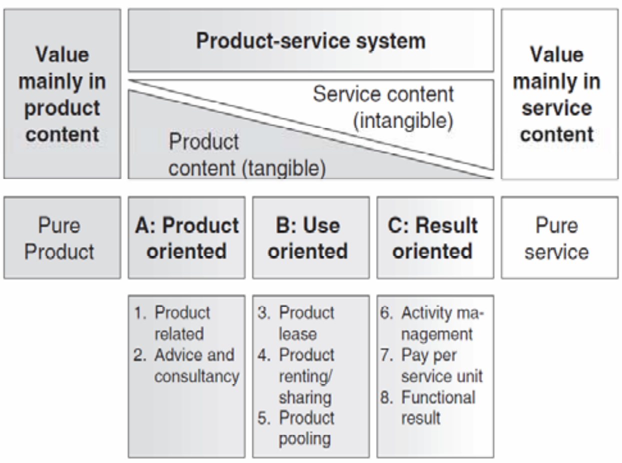

Figure 1: Eight types of PSSs [1]

Table 1: Descriptions of eight types of PSS (modified from [2]

Type of PSS	Description
Product-oriented service	
Product-related service (e.g., car repair, warranty, discard)	Provider sells product as well as services needed during use phase.
Advice and consultancy (e.g., information of traffic jam)	Provider gives advice on most efficient use of product.
Use-oriented service	
Product lease (e.g., car lease)	Provider retains ownership of product and is often responsible for maintenance/repair. User pays regular fee, normally for unlimited individual access.
Product renting/sharing (e.g., car renting/sharing)	Provider retains ownership of product and is often responsible for maintenance/repair. User pays regular fee but does not have unlimited and individual access. Same product is used sequentially by users.
Product pooling (e.g., car pooling)	Provider retains ownership of product and is often responsible for maintenance/repair. User pays regular fee but does not have unlimited and individual access. Same product is used simultaneously by users.
Result-oriented service	
Activity management (e.g., driving agent, car paint, and car wash)	A part of an activity of a customer is outsourced to a third party. Most of the outsourcing contracts include performance indicators to control the quality of the outsourced service.
Pay per service unit (e.g., car renting with pay per mile)	Product still forms the basis of PSS. User buys output of product according to level of use.
Functional result (e.g., taxi)	Provider and user agree on an end result without specifying how the result is delivered.

model that is still largely associated with sales of products to consumers, with some additional services; use-oriented service is a business model where products remain central, but are owned by service providers and made available to users in different forms; and result-oriented service is a business model where customers and service providers agree on a desired outcome without specifying the product involved. Each type can be also divided into two or three subtypes according to the style of a business model. The classification conveys us a fundamental understanding about the relationship between a product and a service. The objective of this research is to analyze structures of these PSS types by decomposing them into elements of the state of a service receiver, function, and attribute for addressing modular representation of PSS.

3 ANALISYS OF STRUCTURES OF PSS TYPES

3.1 Modular representation based on receiver's state

The motivations for the SPE research that the authors we have been conducting include the importance of service activities that have been becoming increasingly critical in manufacturing industries. Our research group captures services in such a slightly different way from others that receivers' transition of status, not the providers' activities, is the core of a service. Our approach does not regard physical products as a prerequisite in provided offers, while most of the other existing research does.

Figure 2 shows a schematic illustration of a modular representation of a PSS that is used in the later analysis from the viewpoints of receiver's state, function, and attribute. In the figure, the circle node in the "function of service contents" represents a receive state parameter (RSP) [8-10] that is an index of customer satisfaction in receiving a service. In general, a service may target several RSPs during its delivery process. The rectangle nodes in the figure represent the functions of a service in a tree structure, while rounded rectangle nodes represent the entities that contribute to a change in an RSP. Yoshikawa's general design theory (GDT) [11] provides a basis for our approach. The theory is discussed in terms of two topologies defined by the functions and attributes of artifacts. The projection from functions to attributes can be universally recognized as design of products. By assuming that services can also be designed by the same projection, RSPs may consist of parameters in both functions and attributes.

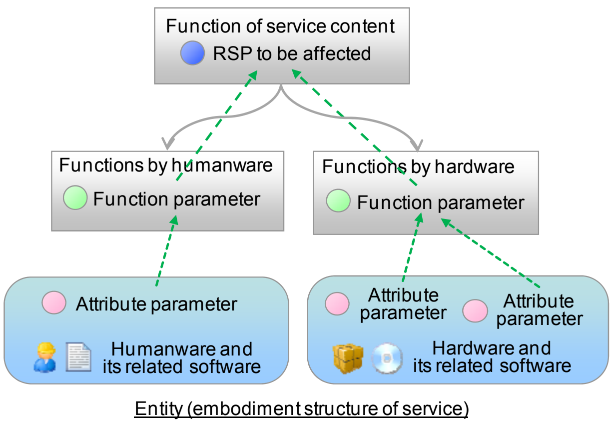

Figure 2: Proposed modular representation of PSS

Function representation

In this paper, a function is defined as "a description of behavior abstracted by humans through recognition of the behavior in order to utilize the behavior" [21]. Here, the term behavior implies both physical phenomena and human activity. According to this definition, a function can be represented in two ways: (1) as symbols represented in the form of "to do something" and (2) as a set of behaviors. In order to emphasize the flexibility of the description, let us consider the first representation wherein the functions in a module can be represented as lexical symbols with parameters (i.e., (1)). Although the symbols are meaningful only to designers, this information, which is associated with the RSP, is essential for clarifying the roles of the design objects. On the other hand, the behavioral aspects of functions (i.e., (2)) are incorporated in the linkage with the service delivery process, as discussed in literature [10].

Attribute representation

The function of service contents is divided into subfunctions implemented by an entity in the real world, such as humanware (e.g., staff and customers), hardware (in the form of machines and facilities), and software. Here, software is any component such as the computational codes, policies, norms, rules, procedures, practices, and any other formal or informal rules that define the manner in which the system components interact [12]. In this paper, software is grouped with hardware or humanware: software is either related to hardware or humanware. Further, an entity has one or more attribute parameters.

The presented representation has an advantage of enabling static evaluation of customer satisfaction. Functional qualities for RSPs can be specified by specifying embodiment structures of the service: entities with their attributes. Paper [13] demonstrates evaluation of customer satisfaction by introducing nonlinear satisfaction mapping of function quality on the parameters in the model. In that evaluation, the Kano model [14] and prospect theory [15] are applied as basis of constructing such nonlinear mappings. The Kano model insists that the satisfaction that a quality level delivers has different inclinations due to different types of quality element. The prospect theory in behavioral economics also insists that a cognitive benefit in human decision-making is inconsistent with an actual benefit. By measuring the customer satisfaction for each RSP based on the satisfaction mappings of function quality, a designer can review to what extent a service provides customer satisfaction.

3.2 Results of analysis

Table 2 presents the results of analyzing the structures of PSS types. Tukker's classifications of PSSs explained in Section 2 are listed in the first column. The elements of the model explained in Section 3 are listed in the first row: RSPs, functions, and attributes. The key differences between simple product sales and each PSS typology are filled out in the table. In this paper, four basic RSPs are analyzed for simplification: the benefit of product use, risk reduction, availability of product, and monetary cost to be paid by a customer (i.e., service receiver). Each PSS type may enhance, deteriorate, or newly target these RSPs in comparison with typical product sales. The rest of this section elaborates the results with corresponding graphical representations on our service CAD system [8-10].

Product-related service

Among the services offered by a provider during the use phase in this PSS type, the service activities of the staff, such as repair, maintenance, and upgrade enhance the RSP "benefit of product use," as shown in Figure 3. Product functions themselves usually do not change, but the structure of a product may be changed so as to facilitate new service activities. Thus, the attributes to be evaluated involve both the attributes of the maintenance staff (and its system) and the product.

Table 2: Result of analysis of structures of PSS types

No.	PSS Types (strategies for PSS)	Influences on RSPs	Influences on service functions		Influences on attributes	
			Functions activated by humanware	Functions activated by hardware	Humanware and its related software (i..e., staff and organization)	Hardware and its related software (i.e., product)
1	Product-related service	Enhancing the RSP "benefit of product use"	Maintaining products	-	Ability to maintain Frequency of maintenance	Ease of maintenance
2	Advice and consultancy	Enhancing the RSP "benefit of product use"	Improving the efficiency of product use	-	Ability of advice and consult	-
3	Product lease	Enhancing the RSP "benefit of product use"	Maintaining products	-	Ability to maintain Frequency of maintenance	-
		Taking risks for the RSP "risk reduction"	Long-term leasing of product	-	Maintenance cost in purchasing Depreciable rate on product Up-to-date product lease	Initial cost in purchasing Discard cost in purchasing
4 5	Product renting/sharing Product pooling	Enhancing the RSP "benefit of product use"	Maintaining products	-	Ability to maintain Frequency of maintenance	Ease of maintenance
		Taking risks for the RSP "risk reduction"	Short-term leasing of product	-	Maintenance cost in purchasing Depreciable rate on product Up-to-date product lease	Initial cost in purchasing Discard cost in purchasing
		Limiting the RSP "availability of product"	Arranging sequential/simultaneous utilization among customers	-	Capacity of users Algorithm of assignment Number of users	-
6	Pay per service unit	Enhancing the RSP "monetary cost"	Charging based on amount used (charged cost)	Recording and reporting amount used	Fee per service unit	Capability of reporting amount used Capability of recording amount used
7	Activity management	[Change] RSP "benefit of product use" changes to "contarcted performance"	[Replace] Providing products while customer's activities	[Change] Optimized for achieving contracted performance	Efficiency of business process Degree of familiarity with the product	Basic functionality
		Taking risks for the RSP "risk reduction"	Using and managing products	-	Maintenance cost in purchasing Depreciable rate on product Up-to-date product lease	Initial cost in purchasing Discard cost in purchasing
		Enhancing the RSP "monetary cost"	Reducing operational cost	[Change] Additional functions are removed due to effective use of product by provider	Operational cost	Cost needed for basic functions [Remove] Cost needed for additional functions of product
8	Functional result	[Change] RSP "benefit of product use" changes to "end result tp be obtained"	Achieving contracted performance	[Change] Optimized for achieving contracted performance	Efficiency of business process Degree of familiarity with the product	Basic functionality

Advice and consultancy

Giving advice and consultancy on a proper method for using a product improves the efficiency of product use by a user. Consequently, it may enhance the RSP “benefit of product use,” as shown in Figure 4. The function parameters and attribute parameters to be evaluated are “degree of improving the efficiency of product use” and “ability of giving advice and consultancy,” respectively. Unlike the PSS type “product-related service,” any changes are normally made in the existing product structures and the behaviors.

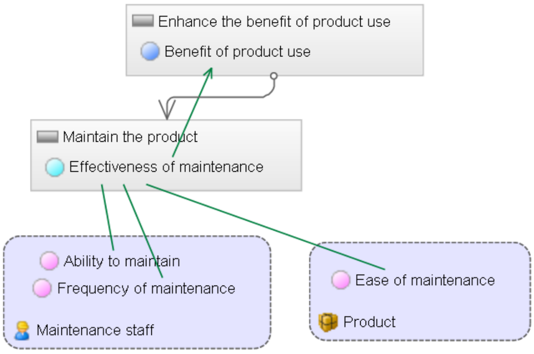

Figure 3: Product-related service for the RSP “benefit of product use.”

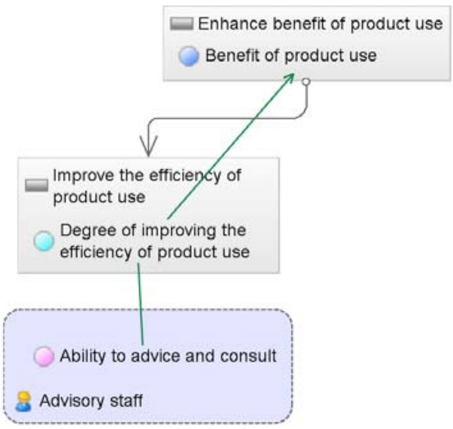

Figure 4: Advice and consultancy service for the RSP ”benefit of product use.”

Product lease

In this PSS type, a provider retains the ownership of a product and is often responsible for its maintenance/repair. A user pays regular fees, normally for unlimited individual access. A new function of a long-term lease of a product enables risk reduction that the business of product sales does not deal with. The attribute parameters to be evaluated involve the following: various types of costs considered in purchasing a product; lease options such as an up-to-date lease, as shown in Figure 5. Other changes regarding the RSP “benefit of product use” can be the same as those in the previous two types.

Product renting/sharing and product pooling

As in the case of a product lease, a provider retains the ownership of a product and is often responsible for its maintenance/repair. Users use the same product sequentially and pay regular fees, but do not have unlimited and individual access: sequential/simultaneous use of a product among users. Changes in the RSPs “risk reduction” and “benefit of product use” are mostly the same as those in the RSP of the PSS type “product lease.” Since sequential use of a product limits the right of customers to use the product, a new function of arranging sequential/simultaneous utilization reduces the RSP “availability of product,” as shown in Figure 6.

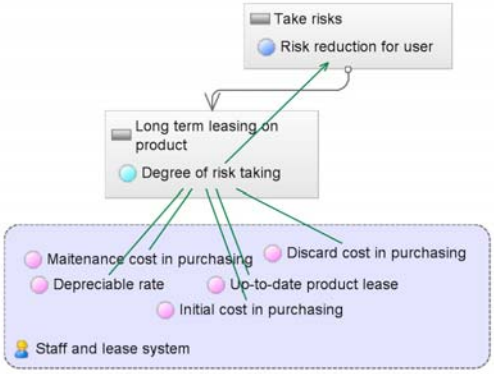

Figure 5: Product lease service for the RSP “risk reduction” for user.

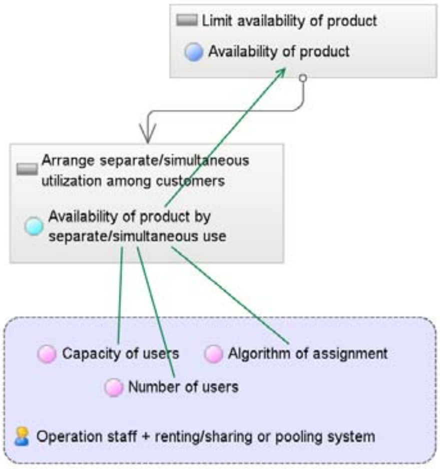

Figure 6: Product renting/sharing and product pooling service for the RSP “availability of product.”

Pay per service unit

In this PSS type, a user buys the output of a product according to the level of use. Pay per service unit is normally incorporated in the business models of product lease or rental. It may have an advantage of reducing the monetary cost because the charges are based on the number of service units used. Here, the product structure needs to be changed so as to implement a new function of recording and reporting the number of units used. Users evaluate the RSP “monetary cost” by comparison with the regular fee in the case of non pay per service unit.

Activity management

In this PSS type, a part of an activity of a customer is outsourced to a third party. Most of the outsourcing contracts include performance indicators to control the quality of the outsourced service. Some of customer’s activities are replaced with provider’s new activities. This type is characterized as product use and management by a provider who is more conversant with the product than the user is. Thus, the product structure and its function can be optimized for achieving the contracted performance. In Figure 8, since no additional functions of a product are essential for the provider, the monetary cost of the service can be calculated from the operational cost and the cost incurred by the basic functions. The RSP “benefit of product use” is replaced with a new RSP “contracted performance” with the product use by the provider. This implies a qualitative change in the target RSP according to changes in service contents.

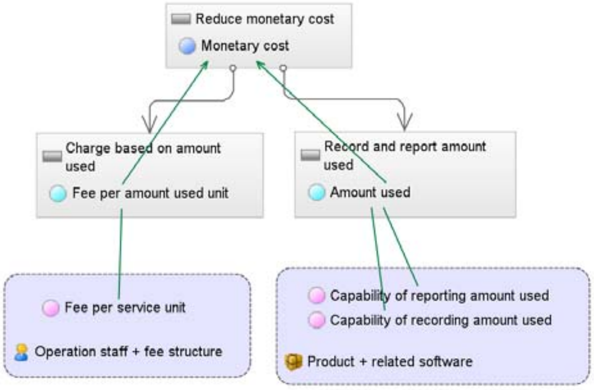

Figure 7: Pay per service unit for the RSP "monetary cost."

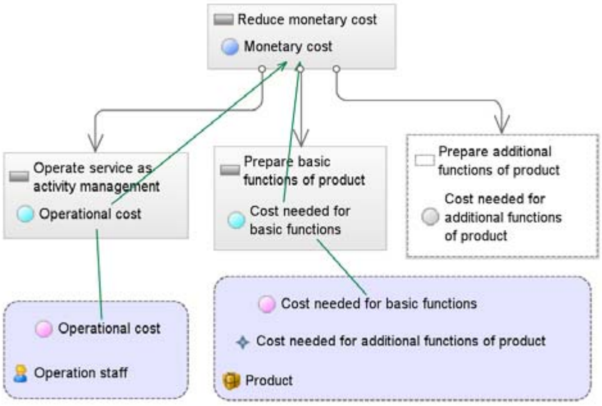

Figure 8: Activity management service for the RSP "monetary cost."

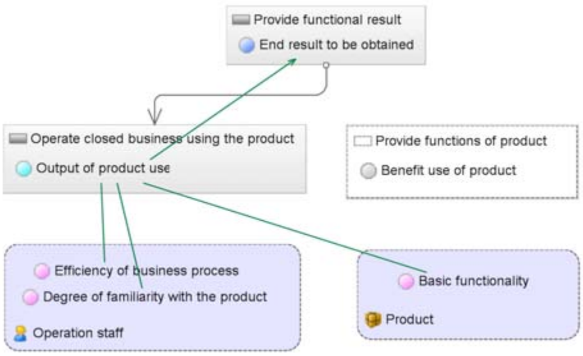

Figure 9: Function result service for the RSP "end result to be obtained.""

Functional result

In this PSS type, a provider and a user agree on an end result without specifying how the result is delivered. The RSP "benefit of product use" is replaced with a new RSP "end result to be obtained" as shown in Figure 9. As in the case of activity management, since the product is used and managed by the provider, the product structure and its function can be optimized for obtaining the end result.

4 CONCLUSION

To establish design methodologies of PSS, theories of modular representation are crucially important. In PSS research, modular representation has not been studied in detail, although extensive studies on classification of PSSs convey us a basic understanding of PSS. This paper analyzed structures of eight types of PSSs for addressing modular representation of PSSs from three viewpoints: the state of receivers, functions, and attributes of entities. Some findings of the analysis are as follows:

- In PSS types that have a high proportion of products, product structure may be changed to facilitate additional and complementary service activities, whereas the product function itself is not changed. On the other hand, in pay per service unit, both the product function and structure are changed to charging based on the number of service units used.
- By means of product use by the provider, the product function and structure can be minimized and/or optimized in the case of activity management and a functional result service.
- A synergistic relationship between a product and service activities can be found in PSS types that have changes in the RSP "benefit of product use." A complementary relationship between a product and service activities can be found in PSS types that have changes in the RSP "risk reduction."
- In types of activity management and functional result services, it is found that it is important to model a service from the viewpoints of "who uses the product" and "who acts" in a service process. This requires a technique of service process modeling so as to equivalently describe a customer's activity and a provider's activity, including interactions among them.

The proposed method covers not only the contribution of products and human activities in the service individually, but also the evaluation criterion, including a functional perspective. Modules constructed on the service CAD system can be shared and reused among PSS developers. This result will contribute to configuring modules of product-service combination toward a design of new PSS. Future work includes to elaborate models based on more case studies (e.g., in the paper [16]).

5 REFERENCES

[1] Tukker A., 2004, Eight types of product-service System: Eight ways to sustainability? Experiences from SusProNet. Business Strategy and the Environment, 13: 246–260.

[2] Williams A., 2007, Product service systems in the automobile industry: contribution to system innovation? Journal of Cleaner Production, 15(11–12): 1093–1103.

[3] Tukker A. and Tischner U., 2006, Product-services as a research field: past, present and future. Reflections from a decade of research. Journal of Cleaner Production, 14(17): 1552–1556.

[4] Lindahl M. and Ölundh G., 2001, The meaning of functional sales. Life cycle engineering: Challenges and Opportunities, in 8th International Seminar on Life Cycle Engineering, CIRP: Varna, Bulgaria.

[5] Alonso-Rasgado T., Thompson G., and Elfstrom B.O., 2004, The design of functional (total care) products. Journal of Engineering Design, 15(6): 515–540.

[6] Tischner U., Verkuijl M., and Tukker A., 2002, First Draft PSS Review. SusProNet report.

[7] Sakao T., Sandstr, m G., lundh, and Matzen D., 2009, Framing research for service orientation of manufacturers through PSS approaches. Journal of Manufacturing Technology Management, 20: 754–778.

[8] Arai T. and Shimomura Y., 2004, Proposal of service CAD system - A tool for service engineering. CIRP Annals-Manufacturing Technology, 53(1): 397–400.

[9] Sakao T. and Shimomura Y., 2007, Service Engineering: a novel engineering discipline for producers to increase value combining service and product. Journal of Cleaner Production, 15(6): 590–604.

[10] Hara T., Arai T., and Shimomura Y., 2009, A CAD system for service innovation: integrated representation of function, service activity, and product behaviour. Journal of Engineering Design, 20(4): 367–388.

[11] Yoshikawa H., 1981, General design theory and a CAD system, in Man-Machine Communication in CAD/CAM, T. Sata and E. Warman, Editors, North-Holland Publishing Company: Amsterdam. 35–38.

[12] Rizzo A., Pasquini A., Di Nucci P., and Bagnara S., 2000, SHELFS: Managing critical issues through experience feedback. Human Factors and Ergonomics in Manufacturing, 10(1): 83–98.

[13] Kimita K., Shimomura Y., and Arai T., 2009, Evaluation of customer satisfaction for PSS design. Journal of Manufacturing Technology Management, 20: 654–673.

[14] Kano N., Seraku N., Takahashi F., and Tsuji S., 1984, Attractive quality and must-be quality. Quality, 14(2): 39–48.

[15] Kahneman D. and Tversky A., 1979, Prospect Theory: An analysis of decision under risk. Econometrica, 47: 269–291.

[16] Li-hsing Shih and Shing-shuen Lu, Strategy Selection for Product Service Systems Using Case Based Reasoning, Proc. of the 6th International Symposium on Environmentally Conscious Design and Inverse Manufacturing (EcoDesign2009), 2009.

Service Design and Product-Service Systems

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Abstract

Product designers have been the main design competence to be employed in product oriented businesses. When it comes to the design of Product-Service Systems, employing product design competences would be a conservative approach. Design theorist Buchanan identifies design orders spanning from graphic, over product and interaction, to systemic design, explaining important differences in perspctives. Contemporary studies on design disciplines show that differences are significant, and it becomes important to know how to select and direct adequate design work. Methods and tools service designers use are typically serviceblueprints, customer journeys, prototypes etc, all focused on processes and value-in-use, where product desigerns focus on form and function. In this paper we show how service designers relate to industrial design in the context of PSS. We review the profile of service designer and compare design disciplines. We conclude that service designers are well suited to deal with PSS design, with their focus on value in use, together with product designers. We also highlight that busineess need to develop competent judgement and design management to get the appropriate design competence.

Keywords

Service design, design competence, buying design, service innovation, PSS design, design methods

1 INTRODUCTION

For traditional manufacturing oriented businesses the choice of design competence to involve has naturally been a product designer. As businesses turn towards an expanded view of their offering, and product-service-systems come into focus, the competence of designers involved will also need to change.

In the 1980's service design appeared in literature on service marketing [1], and has since developed in different directions in service management, service operations, service engineering and service quality. Within the research area of design, research on product design and related disciplines has a long-standing tradition. The younger discipline digital interaction design started out around 1968 and has since developed into one of the largest research areas within design. The much younger service design discipline developed in the early 1990's [2], [3] and has only recently gained momentum [4], [5]. Some foundational research has been presented lately, developing theoretical frameworks rather than solely focusing on design methods [6]. [7].

Service design is a growing and multidisciplinary area of knowledge, collecting its fundaments from disciplines such as anthropology, cognitive science, marketing, computer mediated communication, and others. Current research can be found through design conferences such as Nordic Service Design and Service Innovation, Nordic Design Research Conference, European Academy of Design, Design Management Institute, IASDR, and in some books [8][9].

Given the differences often described between a product orientation and a service orientation [10], [11] it would be assumed that there are differences when dealing with the different design objects under the different business orientations.

The aim of this paper is to provide an overview of the differing profiles of design competencies that PSS-oriented businesses might need to use, develop and direct.

2 DESIGN ORDERS

Design and design research has a long history mainly through architecture, and received increased attention through the work of William Morris [12] in the 19th century, and, e.g. in Scandinavia through the work of Paulsson in the early 20th century [13] and the Paulsson's [14] and Hård af Segerstad [15] in the 1950's. During the latter half of the 20th century design research has gained in speed as well as in volume.

By the turn of the century design theorist Buchanan [16] in a seminal article describe and define four different orders of design. Buchanan describes these as representing places "for rethinking and reconceiving the nature of design' [12, p10], moving from 'symbols' and 'things' to 'interactions' and 'environments".

These design orders describe different foci of attention that designers shift between when working on design tasks. As a consequence these orders elaborate on differences between design disciplines. These differences become visible in terms of differences between the primary design objects and the way these objects are viewed. The design objects are Signs, Products, Actions and Thoughts. In the original paper, the corresponding design disciplines are Graphic Design, Industrial Design, Interaction Design and Environmental Design [12]. Some additional changes need to be made, though.

It is more correct to talk about Product Design as the corresponding discipline, than industrial design. The term "industrial" denotes the conditions under which design is performed. And any design discipline may work under such conditions. An assumption of this paper is that the design of PSS is performed under such industrial conditions.

From time to time there is also confusion with the term "interaction design". In Buchanan's terminology this is not limited to digital interaction design, but includes design of all interactions and actions: 'how human beings relate to other human beings through the mediating influence of products' [12, p11]

It is harder to find an alternative name for "Environmental Design". The term Environmental is easily misunderstood as inscribed within a sustainability discourse, which it should not be restricted to. Rather, the term should be understood as any environment that is conducive of directing our systems of value, decision making; our thoughts. Alternative terms could be "systemic" or "context" or "strategy" or "policy". But, these also carry connotations with a risk of reducing the scope of the design order. In Table 1 the terms used in this paper are presented.

Primary design object	Design discipline
Signs	Graphic design
Products	Product design
Actions	Interaction design
Thoughts	Systemic design

Table 1: The four design orders as termed in this paper.

3 COMPARING DESIGN DISCIPLINES

In a comparison between digital interaction design and product design Edeholt & Löwgren [17] developed a framework of characteristics. The framework was developed to analytically highlight the characters of interaction and product design. The characteristics are grouped in three main *areas*; Process, Material and Deliverables. Each *area* then consists of dimensions, which in turn have certain characteristics (see Table 2).

Area	Dimension	Characteristics
Process	Design process	Explorative Analytical
	Design representation	Depictive Symbolic
	Production process	Physical Virtual
Material	Material	Tangible Virtual
	Dimensionality	Spatial Temporal
	Aesthetic	Visual Experiential
Deliverable	Scope of deliverable	Product Use
	Flexibility of deliverable	Final Customisable
	Customer for deliverable	Mass market Organizational support

Table 2: The comparative framework from [17]

In an expansion on this framework, to include service design, several characteristics were added [18]. The degree to which the different characteristics play a role for the different design disciplines are depicted in Figure 1, 2 and 3, additions summarized in Table 3.

Most of these additions are based on the fact that services, just as interactions, are ongoing processes and activities where the user/customer is part of creating value.

The additions are also consistent with other analyses of how design relates to PSS. For example Morelli [19] identifies three areas that set design of PSS apart from the design of goods; the relationship between users, designers and service providers; production and consumption times; and the material intensity.

Area	Dimension	Characteristics
Process	Design process	
	Design representation	Enactive
	Production process	Ongoing
Material	Material	
	Dimensionality	Social
	Aesthetic	Active
Deliverable	Scope of deliverable	Performance
	Flexibility of deliverable	Dynamic
	Customer for deliverable	Customer's customer

Table 3: Additions to the framework summarized [18]

As an example, from the diagrams (Figures 1, 2 and 3) we can see that the digital interaction design process is characterized by a higher degree of being analytic than the service design and product design processes. We can also see that the aesthetic of digital interaction design is characterized by a higher degree of being experiential than service and product design.

3.1 On the area Processes

In direct comparison to product design, service design is judged much higher on Enactive and Symbolic representations.

That is, product design processes rely less on representations that enacts the usage of the product, and relies to a larger extent on Depictive representations [20], [21]. The representation of a PSS requires several of these. An enacted representation often lacks in detail of the tangible product semantics, and a depictive representation of the product is insufficient to capture the scope of its usage and the PSS; such as insurance, service capacities, uptime, etc.

Service design is also judged much higher than product design on Virtual and Ongoing production processes.

What sets services apart the most from the perspective of Edeholt and Löwgren, is that product design and interaction design focus on artefacts. A service is not an artefact in that sense of the word, but a sequence of meaningful actions. The tangible parts of a service often are composed of readymade artefacts, inventory, IT-systems, artefacts produced during the process, etc. Intangible parts are typically the meeting as such, the culture of the actors involved, structures, policies, etc.

For service design the artefacts of the service are produced during the service experience. Sometimes the service experience as such can be viewed as a physical production process, where the client is a co-producer involved in the larger value-creating process through touchpoints. Instead of giving the physical process a wider meaning, this aspect of service design is called an Ongoing production process. This leaves the original concepts untouched [17], that is, that the production processes refer to activities before the usage or consumption. For a PSS this will mean that the physical process will refer to goods and products prepared before the service experience, while the virtual process will refer to software, manuscripts etc, and to the ongoing process of co-creation of value in a service experience.

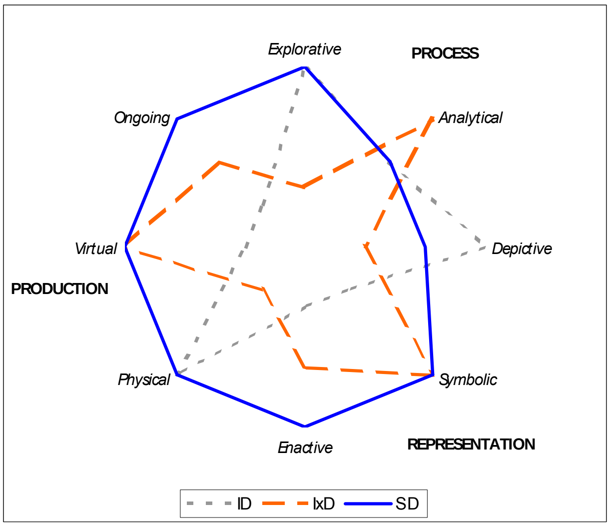

Figure 1: The dimensions of the Process area

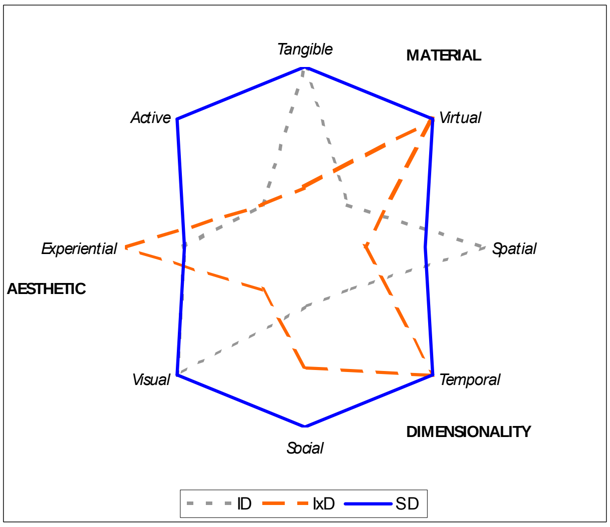

Figure 2: The dimensions of the Material area

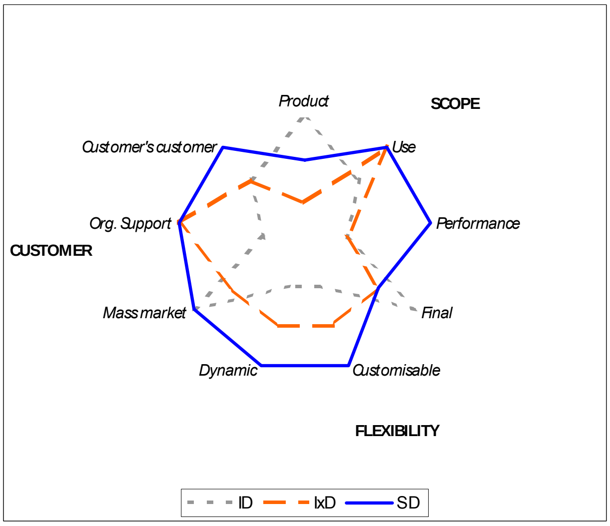

Figure 3: The dimensions of the Deliverable area

3.2 On the area Material

Product design is judged higher than service design on Spatial dimensionality, but much lower on Social and Temporal dimensionality.

A service is always a social construction performed in a physical setting. The inclusion of a social dimension finds support from design theory [14], [15], especially in relationship to the values produced in use [22]. The spatiality of a service mainly comes from how the physical environment is layed out, but for product design the Spatial dimensionality is the main design object.

Moreover, a service is temporal in its nature. It is hard to imagine a service that does not unfold over time. Diana, Pacenti & Tassi [23] differentiate between diachron and synchron representations of services. That is, from a PSS perspective, a product is a synchron representation of its use; the product is not a sequence in itself. On the other hand, a service is a representation based on time, which is equal to a diachron representation.

Product design is judged lower than service design on Active aesthetics, and equal on Visual and Experiential aesthetics.

A service is mainly experienced as it is co-created between several actors. Thus, the aesthetics of a service is created and re-negotiated as the service unfolds in a co-creative manner. As a consequence the aesthetics of an Activity need to be considered [24], [25]. An aesthetic focus which is active, re-establish the social relationship between the human agents in the service experience. For a product, in comparison, the main aesthetic principles are related to the tangibility of a product and the experiential aspects of the existence of a product [26].

3.3 On the area Deliverable

Product design is judged higher on the Product scope, but lower on the Use and the Performance scope of the deliverable.

The main deliverable of service design is based in a temporal structure where the experience of participation, action and contribution is at centre stage, but there will be artefacts and products embedded in this activity that are central for the experience of the service. This is one consequence of the heterogeneity of services.

The deliverable of a service designer can be regarded as a possibility to act out a Performance, not only by the customer, but also by the customer's customer. In general, product design includes knowledge about users in the pre-produced value of the product. As a contrast the value of a service design relies on the sequenced performance of the service business, its representatives and the customer of the service business.

Product design is judged higher on the Final aspect of flexibility, but lower than service design on being Customisable and being Dynamic.

As a consequence of the above the deliverable of a service design is not only possible to customize, but also extremely dynamic, as it will be possible, and sometimes necessary, to change between different performances.

Moreover, designing a service has great influence on how the organization works and views itself. The influence of a product design is limited in this sense.

From a PSS perspective this means that it will be a crucial capacity to develop for a company to differentiate the fixed aspects of a PSS and its dynamic aspects. Moreover, in recognizing this, part of implementing a PSS in an organisation might require extensive training of representatives. The most difficult part of such training programs will deal with attitudes towards customers, ability to identify needs for change and individual and organizational capacity to handle dynamic change and even transformation.

4 DESIGN METHODS AND TOOLS

In product design methods and tools have for a long time been applied and adapted to the conditions of delivering products. Some of these tools and methods are still valid when developing PSS. On a general level one should also look towards the area of Digital Interaction Design, where the primary design object since the beginning has been the interaction between humans mediated by computing technology [7], [21], [27], [28].

Methods and tools for design of PSS, based on knowledge developed in the service design field, can be viewed at different levels; an operational level that deals with specific design techniques, a tactical level that deals with general processes and models, and a strategic level that deals with strategy, policy, management and organisation. Here these will be presented in the order of tactical, operational and strategic.

4.1 Overall process

At the time being, it is one of the main ideas behind service design, that one should be open to both problem reframing and changing solutions. The service design processes drive and support divergence, convergence as well as selection. Morelli [19] proposes that service design should be viewed in analogue to the concept development phase in the process model suggested by Ulrich and Eppinger. Others have suggested an engineering framework for resolving design conflicts between product and service components of a PSS [29].

Looking at some of the publicly available presentations of projects done by service designers, and especially those that go further than only developing the service concept, Morelli's notion as well as that of Akayama et al puts too tight restrictions on the contributions of and the tools for service design.

In service design there are often emancipatory objectives, for example based on sustainability or transformation. Service design has an intrinsic cooperative approach where all actors are viewed as resourceful. Actors are involved in deep, rich and creative ways, which are demanding in relationship to those participating [7], [30].

4.2 Design techniques

Since Moritz' review of design techniques [20] a set of other studies of design techniques have been performed, e.g. resulting in an online repository [23]. The techniques used by service designers focus on user-involvement processes and value-in-use, whereas product designer's methods and tools focus on specification, form and function.

In a paper summarizing research and practice of user-centered methods in design Holmlid and Evenson [21] highlight the use of service prototyping during user research, modelling and requirements definition. Given the nature of services, prototyping experiences is at centre stage [43], and the use of user-generated props as a means of designing tools and touchpoints is commonplace (Figure 4).

In user research service designers employ different rich and generative research techniques based on ethnographic ideals [31], [33], [32]. One such technique is the design probe [34], often paired with a creative design technique [35]. The aims of these techniques are to get rich and authentic user research data, and to provide rich and qualitative descriptions that create empathy and can be used throughout a development process [36], [37].

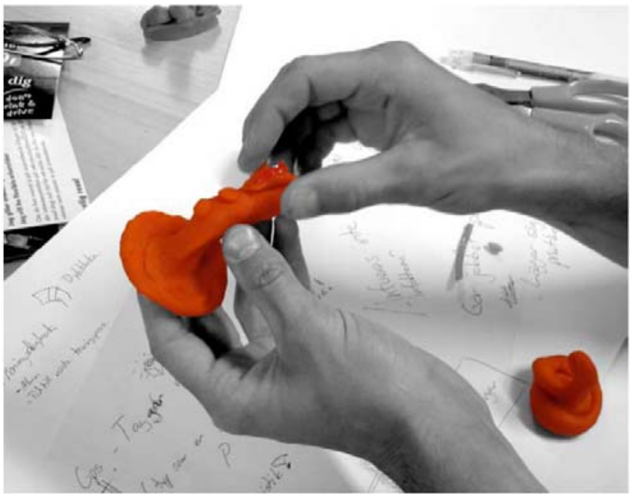

Figure 4: A user creates props for a service prototype

When modelling user research a variety of visualization techniques are used [37] such as blueprints, customer journeys, actor maps, scenarios, etc; see e.g. [38], [39]. In current practice there is a set of basic techniques, but also a long tail of less utilized techniques [40]. Most common is a set of technique referred to as 'journeys', then 'narratives' and 'personas' (see Figure 5 and 6). Even though blueprints often are viewed as a common technique, service designers seem to prefer other techniques, partly due to severe limitations as design tool [41]. A few designers use the blueprinting techniques to support initial research, or to communicate finished design work as a process mapping.

In the transition between 'what is' and 'what could be' a method often employed in design is to use exemplary artifacts. This also functions as a means to communicate and to build common ground in a design team. Product designers use other products as exemplars, but service designers tend to use exemplars describing processes and events, such as narratives [42].

4.3 Relationship to strategy and policy

Another focus of service design activities is the policy and strategy level [44], [45]. Often service designers employ a transformative approach where they help businesses transform from a non-user oriented business to a user-appreciative organisation [46].

Recent studies highlight that an organisation developing PSS in order to have a coordinated design management might need to rethink the way that design competencies are configured throughout the organisation [47], [48], [49], [50].

Other aspects that are relevant here are organisational culture and other systemic and structural perspectives.

Figure 5: The portrait of a persona in home-health care

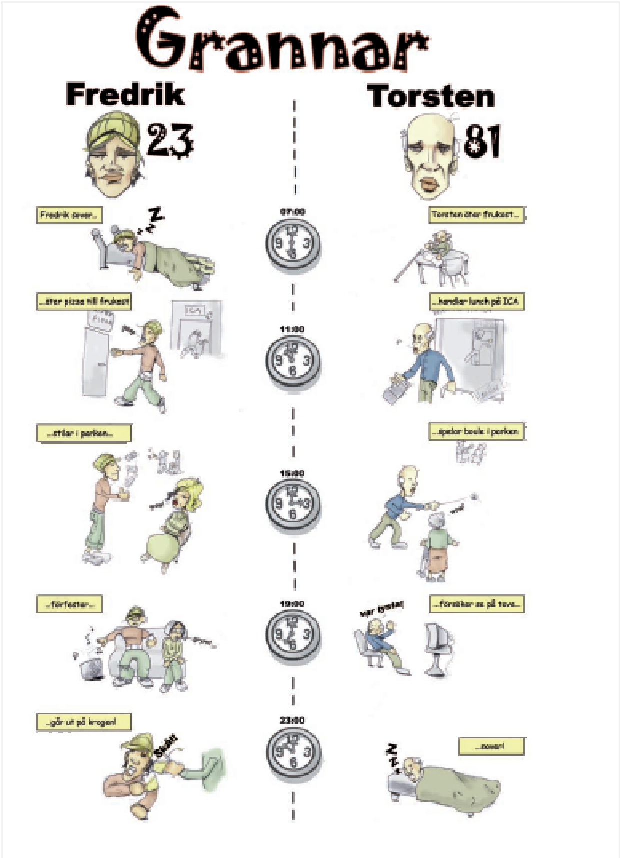

Figure 6: A narrative describing asynchronous life

5 DESIGN CONSEQUENCES

In order to work competently with design of PSS, one need to make sure that design is part of the innovation and development teams. It follows the same logic as the logic behind PSS; if adding a service at the end of a product development process is not sufficient to say that one is working with PSS, adding design at the end of a PSS development process is not sufficient to claim that the PSS is well designed.

5.1 Involving design competence

Managing design in non-product organisations requires attention to the fact that the object that is designed is the operations of the core business of the organisation [49], [50]. In a product developing organisation this is not the case, design is performed prior to production and sales. In an organisation with its focus on PSS, with a mix between products and services, the management of design resources should be performed as if the company was mainly a service organisation.

For many companies it might be a new direction, to involve designers in strategy work and in the fuzzy front end of innovation and PSS development.

5.2 Designers and PSS

Service designers are well suited to deal with PSS design, with their focus on value in use. In general it is not sufficient with a product designer, as their main concern is not the value-in-use but the value of the artefact in terms of form and function. Product designers, as well as graphic and interaction designers, on the other hand are needed to align product design with the overall design of PSS.

6 CONCLUSIONS

In this paper we have provided an overview of design disciplines involved in the development of product-service systems. We have showed how service designers relate to industrial design in the context of PSS. We reviewed the profile of service designer and compared design disciplines. We conclude that businesses need to develop competent judgement and design management to get the appropriate design competence for the design of product-service systems.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Shostack, L. (1984) Designing Services That Deliver," Harvard Business Review, January-February, 133-9.

[2] Manzini, E. (1993). Il Design dei Servizi. La Progettazione del Prodotto-Servizio. Design Management 4 (1993): 7-12

[3] Mager, B. (2004). Service design: A review. KISD, Köln.

[4] Holmlid, S., Evenson, S. (2008). Bringing Service Design to Service Sciences, Management and Engineering. In Hefley, B., Murphy, W. (eds) Service Science, Management and Engineering: Education for the 21st Century, Springer Verlag, pp 341-345.

[5] Sangiorgi, D., Holmlid, S. (2009). Rigor in Service Design Research. Special Session at IASDR, Rigor and Relevance in Design, 2009, Seoul.

[6] Sangiorgi, D. (2009). Building Up a Framework for Service Design Research. 8th European Academy Of Design Conference, (pp. 415-420). Aberdeen, Scotland.

[7] Holmlid, S. (2009). Participative, co-operative, emancipatory: From participatory design to service design. DeThinking Design, ReThinking Services – First Nordic Conference on Service Design and Service Innovation, 2009, Oslo.

[8] Miettinen, S., Koivisto, M. (2009) Designing services with innovative methods. TAIK, Helsinki, Finland

[9] Meroni, A., Sangiorgi, D. (2010) Design for Services. Gower Publishing.

[10] Vargo, S. L., & Lusch, R. F. (2004). Evolving to a new dominant logic for marketing. Journal of Marketing , 68 (January), 1-17.

[11] Vargo, S., L. & Lusch, R., F. (2008). Service-dominant logic: continuing the evolution. Journal of the Academy of Marketing Science, 36(1):1-10.

[12] Morris, W. (1892). News from nowhere: or, An epoch of rest : being some chapters from a utopian romance. 3. ed. London: Reeves & Turner

[13] Paulsson, G. (1919). Vackrare vardagsvara. Edited by the Swedish Society of Arts and Crafts, Stockholm. [More Beautiful Things for Everyday Use]

[14] Paulsson, G., Paulsson, N. (1957). Tingens bruk och prägel. Stockholm: Kooperativa förbundets bokförlag. [The use and qualities of things]

[15] Hård af Segerstad, U. (1957). Tingen och vi. Stockholm: Nordisk rotogravyr. [The things and us]

[16] Buchanan, R. (2001) Designing research and the new learning. Design Issues, 17(4):3-23.

[17] Edeholt, H., Löwgren, J. (2003). Industrial design in a post-industrial society: A framework for understanding the relationship between industrial design and interaction design. In Proc 5th Conf. European Academy of Design, Barcelona.

[18] Holmlid, S. (2007) Interaction Design and Service Design: A Comparison of Design Disciplines. Nordic Design Conference 2007.

[19] Morelli, N. (2002). Designing product/service systems: A methodological exploration. Design Issues, 18(3):3-17.

[20] Moritz, S. (2005). Service design: Practical access to an evolving field. MSc thesis, KISD.

[21] Holmlid, S., & Evenson, S. (2007). Prototyping and enacting services: Lessons learned from human-centered methods. In proceedings from the 10th Quality in Services conference, QUIS 10, Orlando, June.

[22] Pacenti, E. (1998). La Progettazione dei Servizitra Qualità Ambientale e Qualità Sociale. Di Tec Milano, Politecnico di Milano.

[23] Diana, C., Pacenti, E., Tassi, R. (2009). Visualtiles – communication tools for (service) design. DeThinking Design, ReThinking Services – First Nordic Conference on Service Design and Service Innovation, 2009, Oslo.

[24] Maffei, S., Mager, B., Sangiorgi, D. (2005). Innovation through Service Design: From research and theory to a network of practice. A user's driven perspective. Paper presented at EAD 06, Joining forces, Helsinki.

[25] Holmlid, S. (2002). Adapting users: Towards a theory of use quality. Linköping Studies in Science and Technology Dissertation No. 765. Linköpings universitet, Sweden.

[26] Hallnäs, L., Redström, J. (2002). From use to presence: On the expressions and aesthetics of everyday computational thing. Transactions on Computer Human Interaction, 9(2):106-124.

[27] Sangiorgi, D., & Clark, B. (2004). Toward a participatory design approach to service design. Artful Integration. Interweaving Media, Materials and Practices, Participatory Design Conference. Toronto, 27-31 July.

[28] Holmlid, S. (2005). Service Design methods and UCD practice. Presented at workshop on User involvement in e-government development projects at Interact 2005, Rome. Available at http://www.effin.org/egovworkshop_ proceedings.html

[29] Akiyama, Y., Shimomura, Y., & Arai, T. (2009). A Method of Supporting Conflict Resolution for Designing Services. 1st CIRP Industrial Product-Service Systems (IPS2) Conference, 1-2 April 2009 (ss. 54-61). Cranfield: Cranfield university.

[30] Holmlid, S., Montaño, F. C., & Johansson, K. (2006). Gender and design: Issues in design processes. In Proceedings from Women in information technology, University of Salford.

[31] Segelström, F., Holmlid, S., Alm, B. (2009). Back to the Roots: A Case for a New Ideal for Ethnographic Research for Design. Accepted to IASDR 2009, Rigor and Relevance in Design, Seoul.

[32] Raijmakers, B., Gaver, W., W., Bishay, J. (2006). Design documentaries: Inspiring design research through documentary film. DIS 2006, University Park, Pennsylvania.

[33] Segelström, F., Raijmakers, B., Holmlid, S. (2009). Thinking and Doing Ethnography in Service Design. Accepted to Special Session on Rigor in Service Design Research at IASDR 2009, Rigor and Relevance in Design, Seoul.

[34] Mattelmäki, T (2006). Design Probes. University of Art and Design Helsinki, Helsinki.

[35] Wentzel, J., Holmlid, S. (2009). Speed sketching with designers: User inspired brainstorming. In Proceedings from Designing Pleasurable Products and Interfaces 2009, DPPI 09, Compiegne, France.

[36] Sleeswijk Visser, F. (2009). Bringing the Everyday Life of People into Design. Delft: Technische Universiteit Delft.

[37] Segelström, F., Holmlid, S. (2009). Visualization as tools for research: Service designers on visualizations. Nordes, Nordic Design Research Conference, 2009, Oslo.

[38] Kolterjahn, E., Adolfsson, Å., Holmlid, S. (2009). The journey through the care system as mentally disabled. Touchpoint, 1(2):94-97.

[39] Kolterjahn, E., Adolfsson, Å., Holmlid, S. (2009). The dilemma of the care recipient. Touchpoint, 1(2):90-93.

[40] Segelström, F (2009) Communicating through Visualizations: Service Designers on Visualizing User Research. DeThinking Design, ReThinking Services – First Nordic Conference on Service Design and Service Innovation, 2009, Oslo.

[41] Arnell, O., Gonzàlez. N., Mårtensson, I., Wreiner. T., Holmlid. S., Segelström, F. (2009). Designing for a car park operator. Nordic Conference on Service Design and Innovation, Oslo 2009.

[42] Blomkvist, J., & Holmlid, S. (2009). Exemplars in Service Design. DeThinking Service, ReThinking Design: The First Nordic Conference on Service Design and Service Innovation. Oslo..

[43] Buchenau, M., Fulton Suri, J. (2000). Experience prototyping. DIS 2000, ACM.

[44] Junginger, S. (2007). Designing Change and Changing By Design: Thoughts on Drifters, Accommodators and Transformers. DRS Wonderground conference, Lisbon.

[45] Junginger, S., Sangiorgi, D. (2009). Service Design and Organizational Change: Bridging the Gap Between Rigour and Relevance. IASDR 2009, Seoul.

[46] Parker, S. and Heapy, J. (2006) The journey to the interface: How public service design can connect users to reform. London: Demos. ISBN 1-84180-164-X. Available at: www.demos.co.uk.

[47] Holmlid, S. (2008). Towards an understanding of the challenges for design management and service design. Design Management Conference, Paris.

[48] Holmlid, S. (2006). Interaction design and design management: Challenges for industrial interaction design in software and system development. Wonderground, Design Research Society International Conference, november 2006, Lisbon.

[49] Holmlid, S. (2009). Implications for strategic arena design: Integrating digital interaction design and service design. Design Research Journal, 2: 34-39.

[50] Holmlid, S. (2009). Managing interaction design and business innovation: Understanding interaction design as a key activity of the operating core. Aesthesis, International journal of art and aesthetic in management and organizational life, 2(3):99-105

Generation of Concepts for Product-Service System

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Abstract

Product-service system (PSS) provides a strategic alternative to product-oriented economic growth and severe price competition in the global market. The objective of this research is to develop a systematic methodology to generate concepts for new PSSs, called a PSS concept generation support system. The models and strategies of more than ninety existing PSS cases are analyzed, and the insights extracted from the analysis are used to facilitate the concept generation process. The generated PSS concepts, after some screening and elaboration, can evolve to new business models for PSS.

Keywords

Product-service system, PSS Concept, PSS Development, PSS Model

1 INTRODUCTION

Today, world governments and industries pursue green and service-oriented growth for sustainability and competitiveness. Thus, they may consider the introduction of product-service systems (PSSs) to the marketplace to accelerate the growth. A PSS is "a specific type of value proposition that a business (network) offers to (or co-produces with) its clients. A PSS 'consists of a mix of tangible products and intangible services designed and combined so that they jointly are capable of fulfilling final customer needs'" [1]. Representative examples of the PSS are car-sharing, chemical management services (CMS), launderettes, lighting system solution and document management solutions [2, 3].

A PSS designer can follow the generic process of PSS development to develop new innovative PSSs: 1) strategic planning, 2) PSS concept development, 3) detailed PSS process design, and 4) implementation. The designer analyzes the internal and external environments of the company and customer needs that he/she faces in the first step. A clear understanding of customer needs is essential in this step. Then, the designer develops PSS concepts in the second step. The concepts should be adequate and innovative enough to solve customer needs in a better way. Based on these concepts, the designer structures a detailed process in the third step. Stakeholders, products, services and interactions among any of these should be expressed in the process. Testing, marketing, and introducing the PSS business model to retailers are the last step. During the process, each step must be properly evaluated to have the balance for successful PSS development.

This research focuses on the PSS concept development step, with an emphasis on generating innovative PSS concepts. Here, PSS concept means the broad outline of a PSS business model. The concept should solve customer needs and describe what to offer, how to offer it, what its benefits are and who the stakeholders are. The generation of adequate and innovative PSS concepts is a kernel part for successful PSS development since the concept describes the general picture of the PSS which will be developed. Proven and appropriate research on methodology supporting the PSS concept generation is required to realize the potential of PSS.

This research proposes a systematic methodology to support the PSS concept generation, called the PSS concept generation support system (PSS CGSS). This research assumes that the strategic planning is done and customer needs are identified and given for use in the PSS CGSS. Simply, its philosophy is to reduce a real problem into a general problem and then provide a general solution to the general problem. A real solution is then generated based on the general solutions. It was developed based on the analysis of 94 PSS cases. It consists of a set of 4 tools and the PSS concept generation procedure. The tools are the general needs table, the PSS models table, the PSS case book and the concept generation support matrix (PSS CGSM), and the procedure consists of 3 phases: 1) identify general needs, 2) consult existing PSS knowledge-base, and 3) generate PSS concepts.

The proposed PSS CGSS helps the designer generate a number of PSS concepts easily, by following the procedure and using the tools systematically. It explicitly and implicitly provides the expertise to generate innovative PSS concepts, by using the rich experiences of various existing PSS cases.

Section 2 provides the review of literature related with this research. Section 3 proposes PSS CGSS. Section 4 illustrates the proposed PSS CGSS through a case study on the laundry industry. Finally, Section 5 gives our concluding remarks.

2 REVIEW OF RELATED LITERATURE

Notwithstanding the rapid growth of the PSS literature [see, e.g. 1, 2, 3, 4, 5], development of a systematic methodology supporting PSS development has not been well addressed. Research related with PSS concept generation is briefly reviewed in this section. Research on concept development in the context of new product development (NPD) and new service development (NSD) is reviewed, and then existing PSS concept development is reviewed.

2.1 Review of the concept development in NPD and NSD

The product concept means "an approximate description of the technology, working principles and form of the product" [6]. Ulrich and Eppinger's NPD process generates product concepts through the 5 step method, which is 1) clarify the problem, 2) search externally, 3) search internally, 4) explore systematically, and 5) reflect on the solutions and the process, based on customer needs and target specifications [6].

Hideki [7] proposed a Quality Function Deployment (QFD) integrated systematic methodology for eco-product concept development, named the product life cycle planning (LCP) methodology. The LCP methodology consists of 5 steps and various supporting software tools. Ulrich [8] proposed an ideal eco-product concept development approach focusing directly on customer needs. It consists of 6 steps to develop a product concept unifying extreme ways to reduce specific environmental impacts. The RemPro-matrix [9] is a tool showing the relationship between essential product properties and the generic remanufacturing process steps. The matrix can be used to identify product concept properties facilitating the development of a remanufactured eco-product. Yang and Chen [10] proposed a method supporting eco-innovative product design using TRIZ [11] and case-based reasoning. The method helps develop an eco-product concept by retrieving the prior experiences of eco-innovative product cases. The method would become more powerful as more cases are accumulated in the case base.

The service concept defines what to offer to customers and how to offer it, and mediates between customer needs and the strategic intent [12]. The service concept development is considered an important step in various NSD process models. In Scheuing and Johnson NSD process [13], a service concept is developed based on the idea screened in the previous step. Fisher and Schutta [14] employee QFD to translate customer needs into the technical requirements of a service concept. Sakao and Shimomura [15] proposed a computer tool to develop functions based on identified customer needs, yielding a result analogous to a service concept. Chai et al. [16] proposed a problem solving model for new service concept development based on TRIZ. Kim et al. [17] proposed a systematic framework for developing new service concepts, with an emphasis on generating innovative convergence-type service concepts from the customer's perspective.

Though the aforementioned works are helpful to develop the product or service part of a PSS concept, it is highly limiting to use only the product or service perspective in developing a PSS concept. The PSS concept development methodology should consider both the product and service perspectives [18] of PSS.

2.2 Review of the concept development in PSS

Though the designer can consult NPD and NSD, the PSS development process should be different from NPD and NSD since a PSS is not just a product or service. The designer should consider issues such as the involvement of various stakeholders, the relationship of product and service and indistinct ownership. There is much less research on PSS development compared to NPD and NSD. Methodologies for product-service systems (MEPSS; [19]) and (Chen and Huang, [20]) are representative.

MEPSS proposed a 5 phase PSS development process, which is 1) strategic analysis, 2) exploring opportunities, 3) PSS idea development, 4) PSS development, and 5) implementation preparation. The designers build a PSS scenario in the second step and PSS idea in the third step. Conceptually, our term PSS concept has an intermediate meaning between the terms PSS idea and PSS scenario in MEPSS, in terms of the degree of description level (scope). A PSS idea defines the precise and detailed definition of what the PSS is going to offer, how the core function could be delivered" and "stakeholders of the PSS and the interactions among them". It is represented through various tools such as the offering diagram, the stakeholder system map and the interaction table. A PSS scenario is a draft version of a PSS idea in MEPSS.

MEPSS provides more tools, such as the stakeholder involvement planning tool, the system analysis tool and the inventory of sustainability indicator, than the tools mentioned above to develop the scenario and the idea. They help designers generate appropriate concepts based on the PSS philosophy. MEPSS is useful in terms of its comprehensive coverage of the whole PSS development process through a step-by-step procedure with the supporting tools. However, it does not provide a sufficient knowledge-base for scenario and idea development. It explains how to use the tools to get the content of a PSS model, but the designer still must create the content independently. A tool that supports this task would make the process faster and easier.

Chen and Huang proposed the TRIZ based eco-innovation methodology to generate PSS ideas. The term PSS idea in their paper is analogous to the term PSS concept in this paper. The methodology provides 1) the rules for planning new PSS and related TRIZ inventive principles with the rules and 2) the PSS items and evolution trends and ideal final results of the items for PSS innovation. These help the designer generate PSS ideas more easily. However, the methodology does not help designers choose the rules and the items appropriate to their specific PSS problems. Their research just leaves the task to the designer. Also just altering TRIZ to PSS is not appropriate in many cases because of inherent differences between a physical product and a PSS. Designers need a systematic approach to when and how to use the outputs of this research.

The proposed methodology PSS CGSS aims to provide a systematic procedure and supporting tools for the generation of innovative new PSS concepts. It provides the knowledge-base telling how and where to get the knowledge for concept generation. Moreover, it provides guidelines to determine which solutions are appropriate to solve the customer needs that are the problems of the company.6 points after the equation, as indicated in the Equation style on the Word template.

3 PSS CONCEPT GENERATION SUPPORT SYSTEM

Figure 1 shows the overview of the proposed PSS CGSS approach. First, given customer needs are transformed to general customer needs (general needs) using the general needs table. Second, PSS models and PSS cases to solve the general needs are identified using the PSS CGSM, the PSS models table and the PSS case book. Third, PSS concept that solves customer needs is generated based on the knowledge from PSS models and the PSS cases and represented in the representation scheme. The upper half and the lower half of Figure 1 represent the problem of the designer and the solution of the problem, respectively. Customer needs are generalized as they are transformed to the general problem and PSS concept is generated based on the general solutions. The aforementioned tools and PSS concept generation procedure are explained below.

3.1 General needs table

Customer needs vary widely since they are highly dependent on the specific PSS case. A specific solution (concept) for a specific customer need is not easy to find in the real world.

If the customer needs are reduced to their core (general) meaning, the solution is much easier to find. In this sense, the PSS CGSS suggests 22 general needs. The 22 general needs are ordered according to the PSS life cycle from the customer's perspective: purchase (#1 to #3) – use/maintenance (#4 to #19) – disposal (#20 to #22). They are described in the general needs table. Table 1 shows three examples. The designer can transform specific customer needs into general needs using the table. Thus, the customer needs "Customer wants to use the product engine in the best condition." and "Customer wants to know the most suitable way to use cosmetics." can be transformed into general need #7 (need of optimized use).

3.2 PSS models table

A PSS model is a reference model that helps the designer solve customer needs. Existing PSS cases such as CMS, car sharing, or document management systems can be classified in line with PSS schemes that company used. The CMS, for example, helps customers more conveniently keep chemicals safe and dispose of them. The need is solved through services to control chemicals safely and to dispose of them for the customers. The first service is a control service scheme. The second one is an agent service scheme. Other companies can adopt those control service and agent service schemes to solve similar customer needs. In this research, those schemes are classified as PSS models. A control service scheme is classified as PSS model #5 (maintenance service) and an agent service is classified as PSS model #10 (broker & agency service). The proposed PSS CGSS provides 26 PSS models to support the PSS concept generation.

The 26 PSS models are described in the PSS models table. The models are ordered according to the degree of relationship with PSS category [5]: product-oriented PSS (#1 to #16) - use-oriented PSS (#17 to #21) - result-oriented PSS (#22 to #24) - others (#25 and #26). Table 2 shows three examples.

3.3 PSS CGSM

The 22 general needs and the 26 PSS models are thought to be highly related. For example, CMS solves general need # 7 (need of optimized use) by PSS model # 10 (broker & agency service). The PSS CGSM is the matrix showing all the need solving relationships (processes). Figure 2 shows a small portion of the PSS CGSM. The first column of the matrix shows the 22 general needs and the first row shows the 26 PSS models. Intersections of the column and the row show the numbers of the PSS cases. Thus, the designer can identify which the PSS models were used to solve a certain general need and which cases are related.

The 94 PSS cases are stored in the PSS case book in the Microsoft Office Excel format. They are described through several categories: 1) no., 2) company name and PSS title, 3) target customers, 4) customer needs solved, 5) PSS models used, 6) what to offer, 7) how to offer it, 8) stakeholders, 9) benefits, and 10) reference. The contents of the PSS case book are not shown in this paper due to the lack of space, but can be provided upon request.

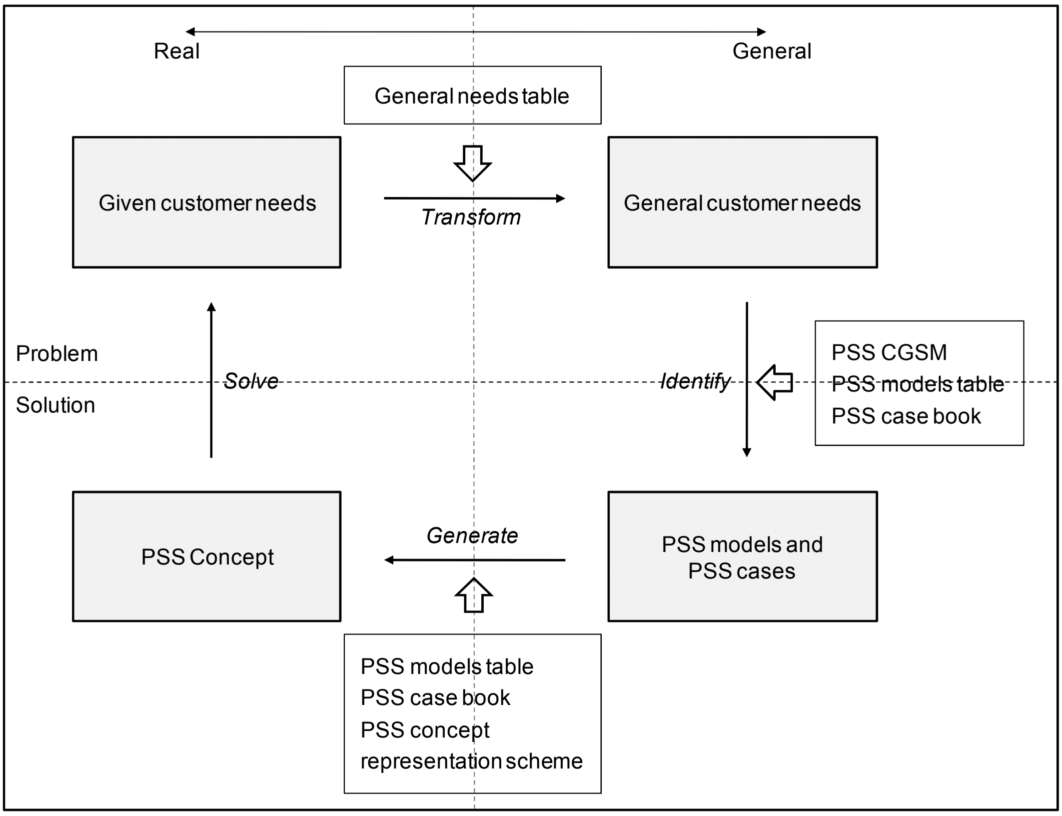

Figure 1: The approach of the proposed PSS CGSS.

General needs	Description
4. Information providing service	Give customer needed information over products/services life cycle.
7. Optimized use	Customer wants to use optimized products/services in the best condition/environment.
17. Expansion of an access route of use	Create and offer new way to access products/services.

Table 1: General needs - three examples.

PSS Models	Description
5. Maintenance service	Control, repair, monitor products/services.
10. Broker & agency service	Conduct work instead of customers.
22. Guarantee contract & authorization	Guarantee an excellent result of products/services use. Customer authorizes almost everything about products/services use.

Table 2: PSS models - three examples.

PSS models / General needs		Product-oriented PSS								
		M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	…
Purchase	N 1		81, 82		90					
	N 2									
	N 3			2, 4	3, 51, 83, 90		3, 43, 50, 83, 93	11, 44, 49, 57, 93		
Use	N 4									
	N 5	77								
	N 6					37, 76, 77, 86	*	37		
⋮										

(*): 9 16 17 76 77 83 88

Figure 2: Format of CGSM.

Phase	Step	Supporting Tools	Outputs
1. Identify general needs	1.1. Refine customer needs → 1.2. Transform customer needs into general needs	- General needs table	- The general needs of the customer needs
2. Consult existing PSS knowledge-base	2.1. Identify PSS models → 2.2. Identify PSS cases	- PSS CGSM - PSS models table - PSS case book	- PSS models selected to solve the general needs - PSS cases of the need solving processes
3. Generate PSS concepts	3.1. Generate ideas for PSS concepts → 3.2. Form PSS concepts → 3.3. Represent PSS concepts	- PSS models table - PSS case book - PSS concept representation scheme	- PSS ideas to solve the customer needs - PSS concepts - Final PSS concept representation

Figure 3: The PSS concepts generation procedure.

3.4 PSS concepts generation procedure

Figure 3 shows the PSS concept generation procedure, supporting tools and outputs of each phase. The procedure consists of 3 main phases and 6 sub steps. PSS CGSS assumes that customer needs are given as the input information. General needs are identified in phase 1. The existing PSS knowledge-base is consulted in phase 2. Finally, PSS concepts are generated in phase 3. Detailed explanations of each sub step follow.

Various specific customer opinions are refined to customer needs in Step 1.1. The requirements of refinement are 1) customer need should be expressed in terms of what the product has to do, not in terms of how it might do, 2) customer need should be expressed in positive, not negative phrasing, and 3) customer need should avoid the words “must” and “should” [6]. Once the specific customer needs are refined, they are transformed into general needs, using the general needs table in the Step 1.2. A customer need can be transformed to several general needs, and several customer needs can be transformed to a general need.

PSS models to solve the general needs are identified using PSS CGSM and PSS models table in Step 2.1. PSS cases in which the need solving process occurred are identified, using PSS CGSM and the PSS case book in the Step 2.2.

Based on the knowledge from phase 2, various innovative ideas to solve the needs are generated by brainstorming in Step 3.1. PSS concepts are formed based on these ideas in Step 3.2. An idea can be expanded to a concept or similar ideas can be integrated to a concept through affinity diagramming. Every generated PSS concept is represented in the representation scheme in Step 3.3. The scheme defines the scope and the needed information of a PSS concept. It consists of 1) the number of the concept, 2) its name, 3) a short description, 4) problems that it solves, 5) target customers, 6) what to offer, 7) how to offer it, 8) stakeholders, and 9) benefits.

4 CASE STUDY ON A LAUNDRY INDUSTRY

A case study was conducted on an imaginary company to validate and verify the usefulness and reliability of the proposed PSS CGSS. The company manufactures washing machines and provides related services. Eleven hypothetical customer needs were generated. Then, they were refined and transformed to 12 general needs using the general needs table in the first phase. Various PSS models and cases to solve the needs were identified and consulted using the PSS CGSM, the PSS models table and the PSS case book in the second phase. Four different PSS concepts were formed based on the ideas generated using the knowledge consulted in the third phase. They are 1) Cleaner life 2) A fabric cleaner 3) A good laundry man 4) V.I.P washer. Finally, they were represented in the representation scheme.

Figure 4 shows how the “Cleaner life” PSS concept was generated. First, customer needs i, ii and viii were refined and transformed into general needs #4, #15 and #7 & #17 respectively. Second, various PSS models (e.g. total package solution and sharing) and cases (#13, #57, etc.) were identified and consulted. The PSS models and cases highlighted by dotted lines in Figure 4 were especially fruitful for the concept generation (see the case #13: Intelligent bedroom PSS of Panasonic [21], #57: Greenstar village e-commerce centre PSS [22] and #67: Painting solution PSS of PPG [23]). Third, several ideas were generated to solve the general needs. Fourth, the concept was formed based on the ideas. The generated “Cleaner life” PSS concept provides a washing machine with wastewater sanitation function or device through various services to protect water supplies. Finally, it was represented in the representation scheme (see Table 3).

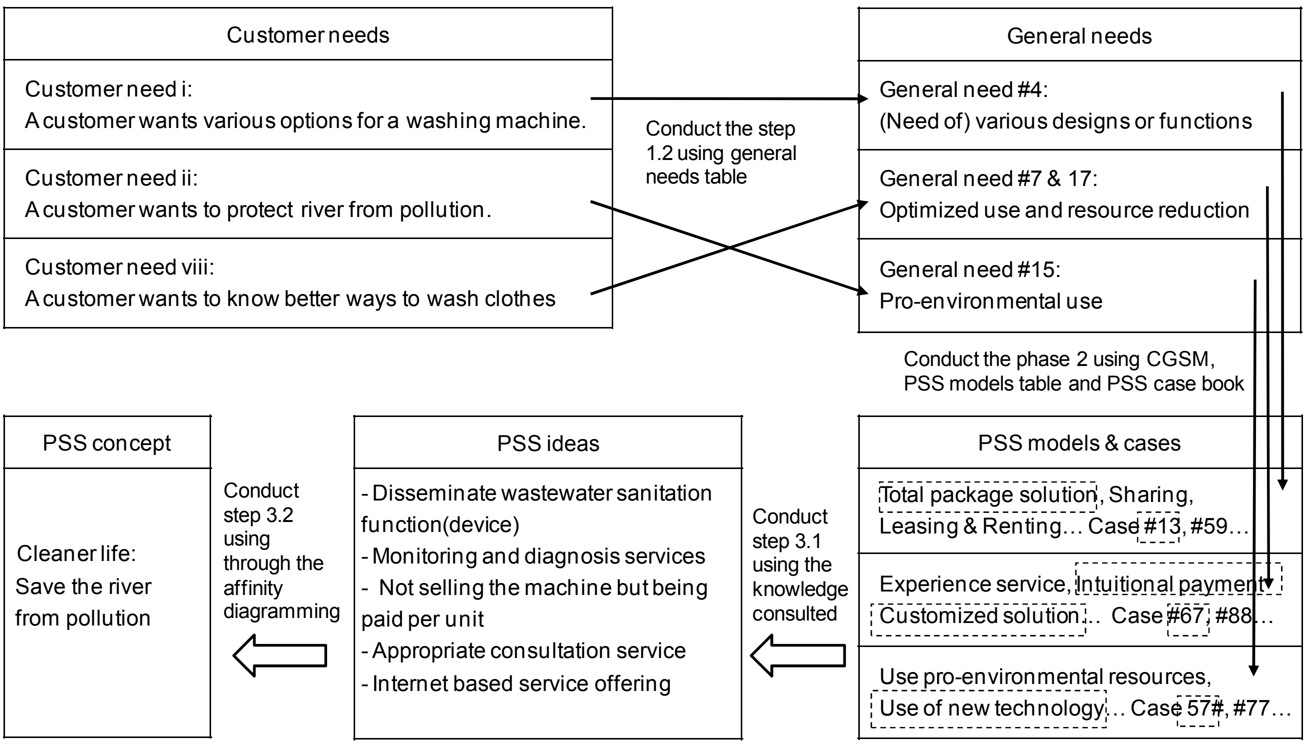

Figure 4: Generation of the “Cleaner life” PSS concept is generated.

No. 1: Cleaner life: Save the river from the pollution - Provide a washing machine with wastewater sanitation function or device through various services.	
Problems - Not various washing machines designs or functions - Concern about polluted river	Target customers - Customers who are sensitive with environmental issues - Customers who are looking for better way to wash clothes - Customers who are interested in new technology, such as early adopters
What to offer - Washing machine with function or device to make wastewater clean - Monitoring and diagnosis services to analyze pollution - Customized maintenance and consultation services to discharge the least pollution	How to offer it - Product and services are offered in the packaged form - No additional charge to the function or device when washing machine is upgraded - Maintaining, monitoring, diagnosing and consulting through wireless communication - PSS is paid per liter of water used based on the membership contract
Stakeholders - Washing machine manufacturer - Technology owner - Customers - Government or organizations concern environmental issues	Benefits - Economic values added: high customer loyalty, guaranteed profit, possible tax exemption, high entry barrier - Environmental & social values added: pollution decrease, pro-environmental atmosphere of society

Table 3: Cleaner life.

The “A fabric cleaner” PSS concept provides a fabric cleaning service, not a washing machine product only. The provider guarantees clean fabrics based on a pay per week contract. The “A good laundry man” PSS supplies used washing machines to appropriate places such as undeveloped countries or other poor areas. The provider contracts with various governments and attracts customers by sharing profits created or upgrading products. The “V.I.P. washer” provides a membership service to use washing machines and consults with customers on how to use washing machine better. Leasing service is offered based on pay per month contract, and the consulting service is provided through internet.

Economic values-added such as high revenue creation and market share increase can be achieved through environmental incentives by offering well integrated product-services [24, 25]. Environmental and social values-added also can be achieved through economic values-added. It is notable that the PSS concepts generated in the case study create economic, environmental and social values-added through both economic and environmental incentives. For example, the “Cleaner life” PSS concept attracts pro-environmental customers by introducing the wastewater sanitation function, an environmental incentive. The washing machine manufacturers can create economic values-added through the concept. The “A good laundry man” PSS concept attracts customers by the profit share which is the economic incentive. The companies and governments can create environmental and social values-added through the concept.

After the case study, it was felt that the knowledge-base of the CGSS can help PSS designers generate innovative PSS concepts in a systematic manner. The concepts that were generated may have been quite difficult to devise just in a conventional brainstorming without a systematic support. Moreover, the concept generation process of the case study was simple and easy to follow. In summary, the proposed PSS CGSS can be an efficient and effective aid to PSS designers for PSS development..

5 CONCLUDING REMARKS

This paper proposes a methodology to support PSS concept generation, called the PSS CGSS. It is developed based on the analysis of 94 PSS cases. It consists of a set of 4 tools and the PSS concept generation procedure. The designer can identify PSS models and PSS cases to solve customer needs using the PSS CGSM. He/she can generate the PSS concepts to solve the needs based on the knowledge in the models and the cases. The procedure systematically supports the generation process. A case study was also conducted to verify and validate the proposed PSS CGSS, and the result was satisfactory.

Generating adequate innovative PSS concepts is a kernel part of successful PSS development as mentioned in the Section 1. This research is the first to support the PSS concept development systematically. The tools reflect rich prior experience of various existing PSS cases. The knowledge-base infrastructure provided by the tools materializes the potential of PSS (potential to create economic, environmental and social values-added) through both economic and environmental incentives. Thus, these tools can be used to generate innovative PSS concepts addressing a variety of customer needs in many different contexts.

Also, the systematic procedure is clear and easy to follow. The designer can generate PSS concepts easily and naturally while following the procedure. He/she only needs customer needs data as the seeds of the generation. In conclusion, PSS CGSS use increases the success likelihood of PSS development and decreases the amount of trial and error. This research should accelerate research on adequate PSS development methodology.

There are several issues for the further research to improve the PSS CGSS to a widely used generic platform for the many companies' PSS development. First, more PSS cases should be collected and analyzed since the core value of the PSS CGSS depends on good empirical study. It will become more effective, efficient and reliable as more innovative cases are analyzed and offered. Second, both the comprehensiveness and exclusiveness of the lists of general needs and PSS models should be improved through systematic and continuing validation/verification. Third, the link among general needs, PSS models and PSS cases also should be improved through the validation/verification. Case studies on real companies are required.

6 ACKNOWLEDGEMENT

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7 REFERENCES

[1] Tukker, A. and Tischner, U., 2008, Product-services as a research field: past, present and future. Reflection from a decade of research, Journal of Cleaner Production, vol. 14, 1152-1156.

[2] Mont, O., 2000, Product Service-Systems. Final report, IIIEE, Lund University.

[3] T S Baines et al., 2007, State-of-the-art in product-service systems, Part B: Journal of Engineering Manufacture, vol. 221, 1543-1552.

[4] Kang, M. J., Wimmer, R., 2008, Product service systems as systemic cures for obese consumption and production, Journal of Cleaner Production, vol. 16, 1146-1152.

[5] Tukker, A., 2004, Eight types of Product Service System: Eight Ways to Sustainability Experiences from SUSPRONET, Business Strategy and the Environment Bus. Strat. Env., 13, 246-260, 2004.

[6] Ulrich, K. and Eppinger, S., 2007, Product Design and Development (4th ed.), McGraw-Hill.

[7] Hideki Kobayashi, 2005, Strategic evolution of eco-products: a product life cycle planning methodology, Research in Engineering Design, vol. 16, pp 1-16.

[8] Ulrich Nissen, 1995, A methodology for the development of cleaner products: The ideal-eco-product approach, Journal of Cleaner Production, vol. 13, No. 1-2, 83-87.

[9] Sundin, E. and Bras, B., 2005 Making functional sales environmentally and economicly beneficial through product remanufacturing, Journal of Cleaner Production, Vol. 13, 913-925.

.

[10] Yang, C. J. and Chen, J. L., 2009, An Eco-Innovation Method for Product Design based on TRIZ and Case-Based Reasoning, 16th CIRP international conference on life cycle engineering, 65-70.

[11] Kim, H. J., 2004, Creativity of thinking TRIZ (in Korean), Jihye.

[12] Susan Meyer Goldstein, Robert Johnston, JoAnn Duffy, Jay Rao, 2002, The service concept: the missing link in service design research?, Journal of Operations Management, vol. 20, 121-134.

[13] Scheuing, E. and Johnson, E., 1989, A proposed model for new service development, Journal of Service Marketing, Vol. 3, 25-34.

[14] Fisher, C. and Schutta, J., 2003, Developing New Services, ASQ Quality Press.

[15] Sakao, T. and Shimomura, Y., 2007, Service Engineering: a novel engineering discipline for producers to increase value combining service and product, Journal of Cleaner Production, Vol. 15, 590-604.

[16] Kah-Hin Chai, Jun Zhang, Kay-Chuan Tan, 2005, A TRIZ-based Method for New Service Design, Journal of Service Research, Volume 8, 48-66.

[17] Kwang-Jae Kim, Dae-Kee Min, Jin-Bum Yook, Jeong-Seok Park, Jee-Hyung Lee, Jae-Kyung Choi, Kyung-Seok Ryu, 2006, Development of Customer-Centered Convergence Service Concepts: A Systematic Framework and a Case Study in Telecommunications Industry (in Korean), IE Interfaces, Vol. 19, No.2, 140-152.

[18] Fitzsimmons, J. A., Fitzsimmons, M. J., 2008, Service Management, McGraw-Hill.

[19] Halen, C., Vezzoli, C., Wimmer, R., 2005, MEPSS Innovation, Van Gorcum.

[20] Chen, J.C. and Huang, C.-P., 2009, A TRIZ Based Eco-Innovation Method for PSS, 16th CIRP international conference on life cycle engineering, 177-182.

[21] www.panasonic.com

[22] www.greenstar.com

[23] http://corporateportal.ppg.com/ppg/

[24] Lindahl, M. and O ¨ lundh, G., 2001, The meaning of functional sales, Life Cycle Engineering: Challenges and Opportunities: 8th International Seminar on Life Cycle Engineering, Varna.

[25] Tischner, U., Verkuijl, M. and Tukker, A., 2002, First Draft PSS Review, SusProNet Report, draft 15 December, available from Econcept, Cologne, Germany; TNO-STB, Delft, or available at: www.suspronet.org

PSS design based on project management concepts

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Abstract

Customer loyalty can be obtained under the condition that isolated offerings proposed by manufacturers are replaced by integrated value adding solution composed of a product and one or more product-service. The design of such solution requires to take account of four narrowly overlapping dimensions: the product, the product-service, the process and the organization. Objective of this paper is to present a method to support PSS design taking all the dimensions and managerial changes into account; analyzing how they are linked and how they allow to design coherent value adding solution using the most appropriate methodologies and tools whatever their belonging scientific discipline. To reach this objective, we propose to analyze PSS development using a project management centric view as it encompasses the firm's environment, core competence, process, organization, benefits, risks and value concepts. A special focus will be devoted to the definition and characterization of these two latest concepts.

Keywords

PSS design, service value, service engineering

1 INTRODUCTION

Service activities have become since few years a current way to differentiate from competitors and make customers loyal. Manufacturers propose services around the main product they deliver and customer loyalty can be obtained under the condition that isolated offerings are replaced by integrated value adding solutions composed of products and services [1]. Consequently they must be thought and designed together before being sold in a global offer.

Even if currently the way of doing of industrialists is far from a co-design product- service system concept [2], a survey performed during the summer 2008 [3] has shown that most of the services proposed by big manufacturing companies are dedicated to the core product and that they are developed accordingly. For the most part, they are completely integrated in the product offer (for 75% of them) and performed by the manufacturing company (for 95%). Underlying objective of profitability can be reached under the condition that firms manage all the changes that are necessary to deliver a service, as well as the transition allowing to reach the stable condition of product-service high value solution provider.

Changes to control can be split in: (i) Strategic changes due to the necessity to define common organization, management and control principles, (ii) Marketing changes as the analysis and understanding of the customers requirement to provide the good service (high value) is crucial, (iii) Commercial changes to determine the differentiation potential regarding competitors to valorize the offer and make it worth in the eyes of the customer, (iv) Economical changes as the product functionalities centric discourse had to be changed in an integrated value centric one to convince the customer and (v) Cultural modifications of firm employee's skills and focus that must be less technical and back office and more commercial and front office. The design and delivery of the global offer requires to take account of four narrowly overlapping dimensions related to: (i) the product (object that corresponds to the firm core competence, initial object of the selling), (ii) the product-service (service supplied in addition to the product and increasing its value for the customers), (iii) the processes (used to create the product and/or the product-service) and the organization (the context in which the process unfold is launched). Figure 1 represents the AS-IS and TO-BE situations and the dimensions to manage for each one while mastering the abovementioned changes (Figure 1).

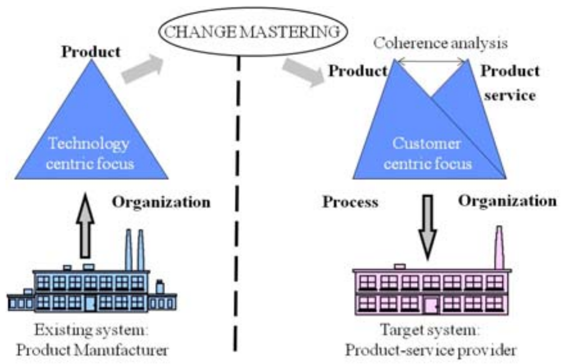

Figure 1: From manufacturing business to product-service solution providers business.

Service research which led to the development of a service theory in the 1970's is wide and integrates different communities who have already responds to some problematic manufacturers are facing today [4], [5], [6], [7] but as Wild et al. mentioned it "each discipline involved in service research appears to have their own dogma and mythology, and all too often end up with minimal interaction with relevant areas" [8]. The service science whose objective is to understand the nature and behaviour of service system, to get deeper level of knowledge integration, optimisation and sustainability by a cross disciplinary approach could be useful to combine the points of views, analysis methodologies and tools to properly cover all the aspects of the complex service to deliver and complex system to set up (from the design to the delivery) and to help characterize the stable abovementioned condition.

The challenge is then to propose a method to support firm core competence widening taking all the dimensions and changes into account, analyzing how they are linked and how they allow to design the coherent value adding solution using the most appropriate methodologies and tools whatever the discipline is concerned. To reach this objective, we propose to analyze new product-service development using a project management centric view as it naturally encompasses the management of costs, delays and customers' satisfaction prerequisite for loyalty. Moreover, a project management centric view allows to look after the firm's core competence and knowledge, the process, the risks and the whole organization of the new development.

2 PRODUCT-SERVICE DESIGN AS A PROJECT OF NEW DEVELOPMENT

Based on the previous hypothesis, we assume that the project of product-service development can be split as any project in four main steps: (i) a starting sequence, (ii) a definition sequence, (iii) a realisation sequence and, (iv) a closing sequence (Figure 2.) [9].

During each sequence, operational and support activities are performed. Operational activities correspond to the purpose of the sequence.

- The first common step consists in a starting sequence and allows to analyze customer expectations and to explore the positioning of the firm. This rests on a strategic diagnosis and on a marketing analysis. The strategic diagnosis based on the study of environmental factors and on the study of the firm potential and ability to mobilize it allows to determine the strengths, weaknesses, opportunities and threat of the new development. The marketing analysis allows to identify the customers' expectations and value sources using the 4P's of mix marketing. Consequently, at the end at this step, deciders or managers will have an idea about the strategic domains on which they can act. This step is discussed in section 3.
- The second step is a definition sequence that allows to precise the specifications of the product-service to deliver and its value distribution among the functions it might satisfy for both the customer and the manufacturer. Based on a functional analysis and a value engineering approach, value results can be gathered in a matrix that can be used as a strategic tool to analyze the relevance of a product-service offer integrating the costs of design and delivery as well as the mercantile strategy. This step, developed in section 4, will lead to a strategic choice.
- The third step called realization sequence corresponds to the strategic deployment whose objective is to define: (i) the processes from the design of the product-service chosen in section two to its delivery and, (ii) the organization to support the process according to the core product development. The definition and modelling of the processes and of the organization is out of the scope of that contribution.
- The fourth and final step is the closing sequence. It corresponds to the real service system delivery to the customer and capitalization of project experience. This aspect is also out of the scope of this paper.

Support activities concerning delay, organization, cost, risk, communication and knowledge management specific to any project and mandatory to ensure the new development success must be managed during each phase. Main aspects of their concern are skimmed over in Figure 2

It is to note that as the project must come within the scope of the firm and be coherent with the core product development, existing process and organization, these three dimensions have to be watched not only in step 3 but also in the others. This implies that all the data related to these three dimensions have to be compiled with data coming from the operational and support activities as sort of control.

3 STARTING SEQUENCE

The starting sequence objective is to give an idea to manufacturers of the strategic domains on which they can act. To reach this objective, it is necessary to lead two parallel studies. The customers' needs identification by the way of a marketing analysis will determine the customers' demands in term of new development while the second study will analyse the strength weaknesses, opportunities and threats of the firm to respond to some

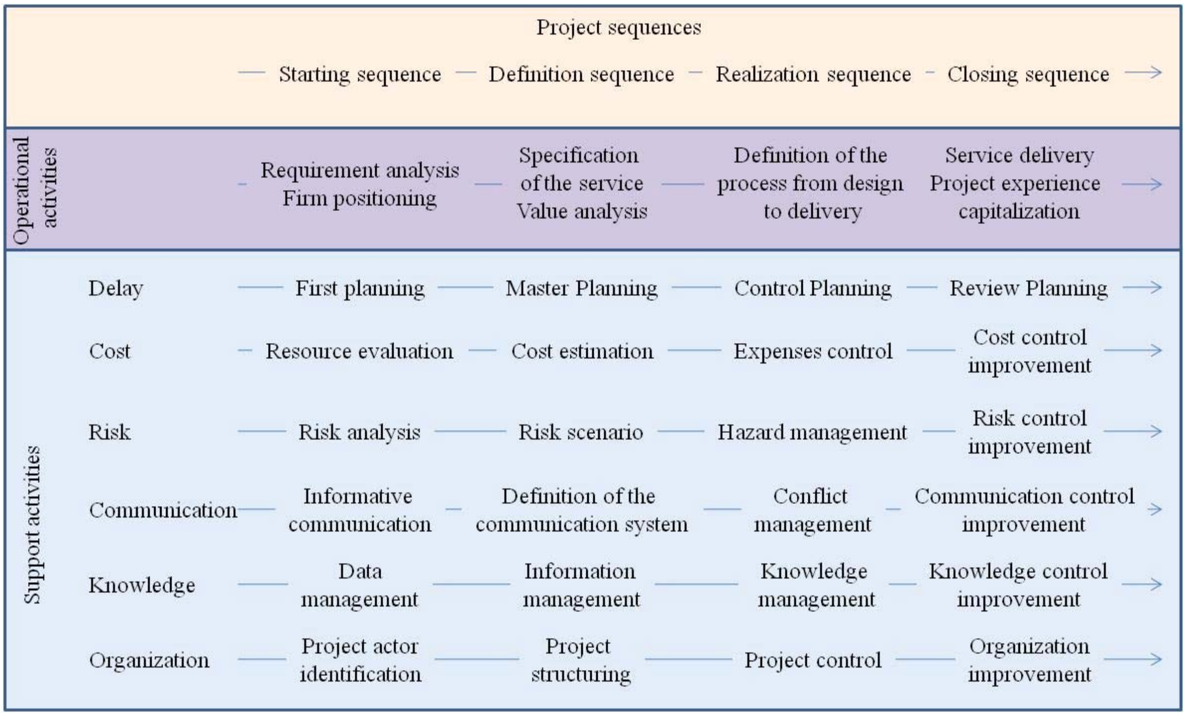

Figure 2: Sequences and activities of a project of new product-service development

needs regarding its internal capacities and its external environment.

3.1 The marketing analysis based on the SIVA approach

In a product-service new development, the manufacturing company pursues a special “product” innovation and then tries to develop a market for the product-service. The marketing research is conducted primarily to ensure that profitable market segment(s) exist for the innovation. A successful innovation requires a well understanding of the customers' requirements that can be obtained by a customer-focused marketing. The SIVA (solution, information, value, access) approach ([10]) provides a demand/customer centric version alternative to the well-known 4Ps supply side model (product, price, place, promotion) of marketing management.

Consequently, the characterization of the product-service in term of SIVA items will lead companies to focus their activities and products on consumer demands and then define strategic activity domain on which they can act. Factors to ensure product-service viability and company profitability concern:

- the definition of the product-service system as a solution for a specific need,
- the identification of the value it represents for the customer,
- the conditions of accessibility,
- the information related to the solution.

3.2 The strategic diagnosis

The strategic diagnosis makes it possible to position a company and its competitors on a given market. The diagnosis is carried out in two directions: the environment in terms of sector attractiveness (opportunities, threats), and the company in intrinsic terms of potentialities (strengths and weaknesses). Consequently, it rests on the analysis of the macro and micro environment of the company and on the analysis of its human, financial, material and technological capacities and skills to mobilize them to reach the customer demand.

The Strengths, Weaknesses, Opportunities and Threats can be gathered in a SWOT matrix. Initially, the SWOT analysis gathers key pieces of information in two main categories: internal factors and external factors. It is a tool for auditing an organization and its environment and can help managers to determine if their objective -in term of new development for example- is attainable or not by the identification of these key factors useful to achieve them.

List of internal factors: strengths and weaknesses

The definition of a relevant strategy for a company consists in measuring its present and future capacities which will thereafter be implemented within the framework of the adopted strategic plan. It is necessary to take account of a double aspect: an analysis of the entrepreneurial resources on the one hand, and on the other hand, an analysis of the ability of the company to mobilize these resources (resources can indeed be identified without any possibility for the company to mobilize them. An audit performed by the company will give a progress report on its current and potential resources making it possible to support the adopted strategic process. One distinguishes in term of resources the following elements:

- The human resources (human capital) that must be analysed from a qualitative and quantitative point of view. From a quantitative point of view, one can obviously measure the number of employees present in the company taking account of the halftime employees, of the number of employees really present each day… From a qualitative point of view, it is essential in a strategic approach to insist on the employees' competences and know-how so as to identify the competing main strengths of the company. The human capital enhancement goes through the set up of training plan to increase the potential of the employees present. Others factors can concern the motivation, involvement, project team, project manager, top management commitment, contact personnel training, contact personnel quality, sales team, etc.
- The financial resources as a strategic process often requires financial resources whose availability depends on several factors. The company internal proper resources represented by the capacity of self-financing measure the financial flows generated by the company present or anticipated activity which could be reinvested by itself during its activity. The company external proper resources provided either by shareholders or by financial establishments for which the company can measure its ability to gather them. Then factors can deal with results, benefits, possibilities of investment and investors
- The technological resources that can be defined as a set of knowledge and techniques used to design and manufacture a product. The knowledge of the technological inheritance of the company is essential as it is a key element of its present and future competitiveness and as it often conditions the use of other available resources. Then factors coming from design (technological innovation potential, R&D opportunities) and production (Capacity/load ratio; Delay; Partners relationship; Resource competencies, stock level Production, service definition, process definition identified procedures) are relevant to analyze product-service development.
- The material resources that correspond to the set of capital assets held by the company and registered in its active assessment. Most of the time, a strategic process results in an increase of the needs in fixed assets (ground, materials, machines…). The company must thus give a progress report on its production capacities and on their real rate of use.

Factor	**Factor classification** Significant benefit=5 Benefit=3 Minor benefit=1 Neutral=0 Minor risk=-1 Risk=-3 Significant risk= -5	**Relevance profitability** S/W highly relevance=5 S/W medium relevance=3 S/W law relevance=1 Neutral=0 O/T high probability=-5 O/T medium probability=-3 O/ T low probability=-1	**Strategic impact** High = 5 Medium = 3 Low = 1 Undetermined = 0
Product to integrate	Neutral	S/W highly relevance	High impact
Project team	Minor benefit	S/W medium relevence	Medium impact
Manufacturing resources	Benefit	S/W law relevance	Low impact
Technological potentiality	Significant benefit	S/W medium relevence	High impact
Operations/ process	Benefit	S/W highly relevance	Medium impact
Partners relationship	Minor benefit	O/ T low probability	Low impact
Brand image	Significant benefit	O/T high probability	High impact
Cost base	Risk	O/T medium probability	Medium impact
Cash flow	Minor risk	O/ T low probability	Low impact
Sales team	Significant risk	O/T high probability	High impact
Distribution	Risk	O/T medium probability	Medium impact
Political environment	Minor risk	O/T low probability	Low impact
Economic outlook	Significant risk	S/W highly relevance	High impact
Cultural changes	Neutral	O/T medium probability	Low impact
Technical context	Benefit	O/T high probability	High impact
Customers position	Benefit	O/T high probability	High impact
Suppliers position	Neutral	O/T high probability	High impact
Competitors position	Neutral	O/T high probability	High impact
Substitute	Neutral	O/T high probability	High impact

Table1: Risks and benefits of a new product/product service development

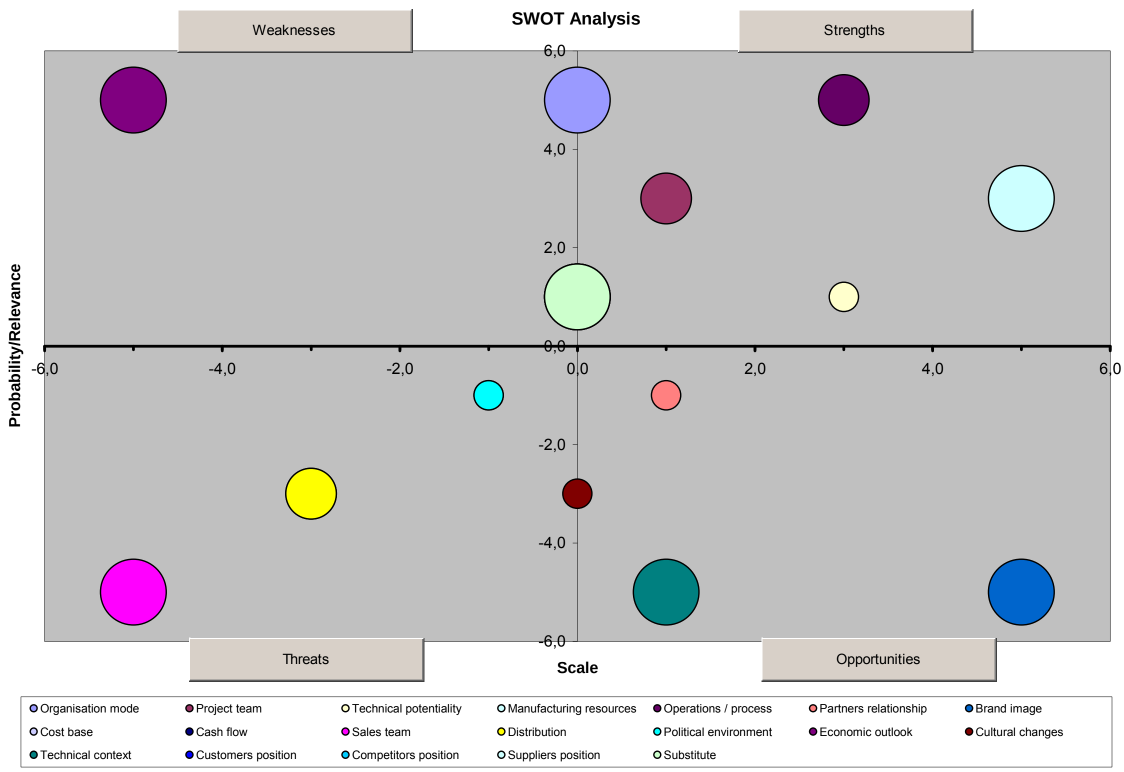

Figure 3: Example of a chart

The analysis of the inheritance of the company (human, financial, material or technological) is essential to any relevant strategic process. It remains that this analysis is not enough sufficient if it is not accompanied by a deep study of the ability of the company to mobilize those resources regarding a strategic project. From this point of view, an analysis of the organisation of the company is essential to evaluate its ability to change regarding a new strategy. Then internal factors may stem from firm culture and organization: enterprise identity, brand image, organization structure mode; industry specialization; project experience, membership, sales office, etc. The justification of each factor and sub factor is given in [11].

List of external factors: opportunities and threats

External factors stem from the study of the micro-, macro- and meso-environment of the firm. The Macro-environment picture can be obtained by the way of a PESTEL analysis where each letter stands for Political, Economic, Social, Technological, Ecological and Legal. The PEST factors can be used to assess the market for a business or organisational unit strategic plan.

The micro-environment picture can be obtained by analysing the firm' strength on its sector of activity regarding the relationship with its customers, with its suppliers, the threat of new competitors and the substitute products [12]. The company has then to weigh the terms and conditions of trade within its market and select its customers and its suppliers on strategic criteria otherwise it can increase its vulnerability.

The Meso-environment focuses on person that could influence the economical relations in a market. The list of external factors and sub factors of interest is detailed in [10].

3.3 Definite list of factors

The factors abovementioned can be gathered by aggregation and according to their relevance in the following set: Project team, Manufacturing resources, Technological potentiality, Operations/ process, Partners relationship, Brand image, Cost base, Cash flow, Sales team, Distribution, Political environment, Economic outlook, Cultural changes, Technical context, Customers position, Suppliers position, Competitors position, Substitute, Product to integrate.

Note that we do not mention if an internal factor is a strength or a weakness as there is a continuum between both; id. for the threats and opportunities. The project team leader will first have to determine the consequences of a factor: whether it is a benefit (strength or opportunity) or a risk (weakness or threat).

Subsequently, the relevance of each internal factor as well as the probability of occurring of each external factor will be defined. Finally the impact of each factor on the organisation could be discussed and results plotted in a chart (see © Copyright MarketWare International 2001-2004). An example is given in Figure 3.

- The X-axis measures the scale or magnitude of each SWOT factor,
- The Y-axis is used to plot the relevance of strengths or weaknesses and the probability of threats or opportunities,
- The Z-axis is used to plot the strategic impact of the factor.

Factors scale, relevance and impact are valuated according to predetermined quotations (see table 1).

- This chart can be interpreted via the following keys:
- Items plotted close to the (0,0) are the least significant, either because they are not rated as important or the relevance or probability is very low.
- Those that are at the extremes of the chart are rated as most important and are rated as highly relevant or a high probability of occurring.
- The size of the bubble indicates the strategic impact of the SWOT factor.

A visual representation of the risks and benefits of a new product-service development could be obtained and compared to other ones. The position of the firm will result from the comparison that takes parameters relative to the product, organisation and processes into account by the way of the factors.

4 DEFINITION SEQUENCE

The definition sequence consists, once the development direction is chosen, in defining the solution that will be profitable for both new manufacturer and customers; to determine its position in the portfolio of the firm and its legitimacy to be proposed and enhance firm competitiveness and profitability.

This second stage rests on the use of the value analysis methodology and compares the value of the offer for the manufacturer taking account of its expected benefits and the value of the same offer for the customers defined by the way of expected quality criteria. All these developments are based on the assumption that the value can be defined by the ratio between the performance of some functions and their cost [13].

Currently two functions are defined:

- "basic function" which correspond to anything that makes the product work or sell and,
- “secondary functions” or "supporting functions" that describe the manner in which the basic function(s) are implemented

4.1 Product-service value analysis: from the manufacturer point of view

We assume that the functions which participate to the definition of the value for the provider focus on the expected benefits of a product-service proposal. Based on [14] and a literature review in the management area, benefits usually mentioned concern:

- the construction of a customer loyalty by the building of dependency relationships between a consumer and a provider that can lead toward profitability,
- the search for differentiation that allows retaining and attracting consumers,
- the increase and stabilizing of firms' turnover due to the possibility to generate regular income and to have cash flow disposal,
- the corporate image reinforcement linked to technological advanced, product quality...
- the occupation of an existing or new market to participate to market share division,
- the possibility to create alliance with service providers and to share risks,
- the possibility to increase the quickness of a design or production process using product-service based on information and communication technologies,
- the possibility to shorten sales delay or negotiation phase using financial services and,
- the search for a product-service system that is designed to have a lower environmental impact than traditional business models [15].

Each benefit can be defined as expected performances that stem from a strategy and have priorities one to the other. Quantifiable criteria can be associated to each one whose level also stem from the strategy. The level really measured, that reflect the performance of the function, compared to the global cost of the service allows to determine the value of the service for the firm.

Costs to take into account can be divided in direct and indirect costs. Regarding product-service characteristics, several costs can be addressed that depends:

- on its degree of tangibility,
- on the degree of interaction that is necessary between the firm contact personnel and the customer to deliver it and,
- on the degree of standardization of the product-service delivery process. They can encompass component costs, cost of labour, and overheads.

The description of the functions from the manufacturer point of view and the consciousness of the product-service costs allow to build a value analysis matrix (see Table 2).

4.2 Product-service value analysis: from the customer point of view

According to [16], customers challenge the overall value of an offer to its complete cost. The overall value refers to the different advantages obtained, supported by the firm brand image. Advantages may gather both benefits expected on technical functionalities and subjective criteria as lots of studies have shown that customers are waiting for something from the exchange with the firm. [17] has proposed a list of criteria and dimensions allowing to evaluate the quality of a standard service These criteria can be associated to implicit functions whose fulfilment can lead to customer loyalty and value increase.

Then, the list of functions of a product-service expected by customers consists in:

- the product-service raison d'être: help choosing, acquiring or using the main product,
- secondary functions linked to its interactions with the contact personnel, users and means necessary to realize it, the partners, environmental and legislative constraints and the realization constraints as mentioned previously and,
- the implicit functions coming from quality criteria discharged from the functions that refers to the delivery process: to obtain a tangible service.

The value determined by the firm from the customer point of view will be determined by putting in opposite the previous list of function and the distribution of the above mentioned costs via another value analysis matrix (see Table 3).

4.3 Synthesis

Using aggregation operator, it is possible to deduce the whole value of the product-service proposed by a manufacturing firm. This one can have two positions: high or low and can be analyzed regarding two dimensions: the customer dimension and the firm dimension Figure 3.

		Firm value	
		High	Low
Customer value	High	Profitable and interesting	No profit but interesting
	Low	Profitable but No interest	No profit, no interest

Figure 3: Value matrix

- The value is high for the customer and for the firm. The product service is profitable for the firm and satisfies customers. It might accompany the product. To make the customer loyal, the company may propose the service but found solution to increase its value by decreasing its price if it is worth in the eye of the consumer or adding others services located in the high/high value.
- Firm value is high and costumer value is low. This position is synonymous of customer loyalty if the customer participates or if the cost of the offer is not too important. Otherwise, he won't be interested by this list of sales point. The abandon of the product-service or not will depend on the cash that is necessary to provide it or on the delivering difficulties
- Firm value is low and costumer value is high. To make the customer loyal, firm may propose the service but found solution to increase its value by decreasing its price if it is worth in the eye of the consumer or adding others services located in the high/high value.
- Both values are low. The abandon of the product-service or not will depend on the cash that is necessary to provide it or on the delivering difficulties.

The value analysis of each product-service coherent with the firm position from the two points of view will provide a synthetic view of the equilibrium of the global offer. To ensure firm global profitability, the portfolio of product-services has to be shared out between all categories (High/low).

5 CONCLUSION

We have proposed in this contribution the two first steps of a methodology in four steps to support manufacturing firm core competence widening by the furniture of product-service taking account of the changes that are necessary to become a "service provider" and the dimensions that seems to be mandatory for the success of such a strategy: i.e. the product, the organization, the processes and the product-service. The methodology we propose to use stem from a project management process and allow to manage both operational activities and support activities inherent to any project that relate to risks, delays, costs, knowledge, organization and communication.
The first step proposes to choose an orientation between several product-service by analyzing the potential of the company as well as its environment and the customer demand.
The second step allows to analyze the relevance of a product-service offering based on its value analysis.
The originality of the methodology is that it gathers tools, methods and practices of different research communities. Further works include the definition of tools to help characterize the two last steps as well as a refinement of the two first one and application on real study cases.

6 REFERENCES

[1] Furer, O. : Le rôle stratégique des services autour des produits. In Revue Française de Gestion, mars-avril-mai, pp 98--108, (1997)

[2] Baines, T. S. et al.: State-of-the-art in product-service systems. Proceedings of the Institution of Mechanical Engineers. Part B. Journal of engineering manufacture, vol. 221, no 10, pp. 1543--1552. Mechanical Engineering Publications, London (2007)

[3] Alix, T., Touzi, W., Vallespir, B.: Product-service value analysis: two complementary points of view. In: Proc of the 13th IFAC Symposium on Information Control Problems in Manufacturing (2009)

[4] Berry, L.L.: Relationship marketing of services – growing interest, emerging perspectives. Journal of the Academy of Marketing Science, vol. 23, no.4, pp.236—45, (1995).

[5] Fisk, R.P., Grove, S.J., John, J.: Services Marketing Self-Portraits: Introspections, Reflections, and Glimpses from the Experts. American Marketing Association, Chicago, IL. (2000)

[6] Lovelock, C., Wirtz, J. and Lapert, D.: Marketing des services. Pearson Education (2004)

[7] Zeithaml, V.A., Berry, L.L., Parasuraman, A.: The behavioral consequences of service quality. Journal of Marketing, vol. 60, no. pp.31--46, (1996)

[8] Wild, P.J., Clarkson, P.J., Mc Farlane, D.C.: A framework for Cross Disciplinary Efforts in Services Research. In: Proc of CIRP IPS2 Conference, pp.145--152. Cranfield Univeristy Press, United Kingdom (2009)

[9] Alix, T., Vallespir, B.: A framework for product-service design for manufacturing firms. In: Proc of the APMS'09 conference (2009)

[10] Dev, Chekitan S.; Don E. Schultz.: In the Mix: A Customer-Focused Approach Can Bring the Current Marketing Mix into the 21st Century. Journal of Marketing Management, vol 14, no 1, (2005)

[11] Alix, T., Vallespir, B.: New product development: material versus immaterial. In: Proc of Extended Product and Process Analysis aNd Design EXPPAND workshop (2009)

[12] Porter, M.E.: The Competitive Advantage: Creating and Sustaining Superior Performance. N.Y. Free Press (1985).

[13] Goyhenetche, M. : Le marketing de la valeur, Créer de la valeur pour le client. INSEP (1999)

[14] Baglin, G., Malleret, V.: Le developpement d'offres de services dans les PMI. Cahier de recherché du groupe HEC (2005)

[15] Ucalgary, 2004, Functional Cost Analysis, online at http://www.ucalgary.ca/~design/engg251/First%20Year%20Files/funct_cost_analysis.pdf.

[16] Hermel, L., Louyat, G. : La qualité de service, AFNOR Saint Denis la Plaine, France (2005)

[17] Zeithmal, A., Parasuraman, A. Berry, L.: Delivering quality service, The free Press (1991)

	Total cost	%Cost	Function (FC)							
			Make	Search	Increase	Reinforce	Occupy	Share	Increase	Shorten
			Customer loyal	For differentiation	Firm turnover	Corporate image	New market	Risks	Process quickness	Delays
			FC1	FC2	FC3	FC4	FC5	FC6	FC7	FC8
Elements										
Consumables										
Physical support										
Direct cost labour										
Indirect cost labour										
Overheads										
			Cost of FC1	Cost of FC2	Cost of FC3	Cost of FC4	Cost of FC5	Cost of FC6	Cost of FC7	Cost of FC8
		% cost	FC1 percentage of importance	FC2 percentage of importance	FC3 percentage of importance	FC4 percentage of importance	FC5 percentage of importance	FC6 percentage of importance	FC7 percentage of importance	FC8 percentage of importance

Table 2: Value analysis matrix from the product-service provider point of view

	Total cost	%Cost	Function (FC)							
			Help	Make	Satisfy	Satisfy	Satisfy	Satisfy	Satisfy	Satisfy
			Choosing, acquiring or using the main product	Service tangible	function concerning interactions with contact personnel	function concerning interactions with users	function concerning interactions with means	function concerning interactions with partners	Environment or legislative constraints	Realisation constraints
			FC'1	FC'2	FC'3	FC'4	FC'5	FC'6	FC'7	FC'8
Elements										
Consumables										
Physical support										
Direct cost labour										
Indirect cost labour										
Overheads										
			Cost of FC'1	Cost of FC'2	Cost of FC'3	Cost of FC'4	Cost of FC'5	Cost of FC'6	Cost of FC'7	Cost of FC'8
		% cost	FC'1 percentage of importance	FC'2 percentage of importance	FC'3 percentage of importance	FC'4 percentage of importance	FC'5 percentage of importance	FC'6 percentage of importance	FC'7 percentage of importance	FC'8 percentage of importance

Table 3: Value analysis matrix from the customer point of view

Towards Consolidation on Product-Service Systems Design

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Abstract

Research on Product-Service Systems (PSS) has been carried out for many years and in various disciplines. Nevertheless, design guidelines and standards for industrial application are hardly available. Even a standardized terminology has not yet been developed. Consolidation of PSS approaches among research projects and industrial branches is rudimentary. This is an obstacle for companies to incorporate and deploy PSS design approaches and to introduce efficient work or communication processes with customers and suppliers. Meanwhile, standardization on PSS design is "moving into" research agendas. This paper is based on literature analysis, experience in industrially applied research, and standardization practice of the authors. The contribution elaborates on various viewpoints and frequently raised issues in PSS research, which are important in order to consolidate PSS design approaches.

Keywords

Guidelines, standards, terminologies, communication, viewpoints, models

1 INTRODUCTION

Motivation for this article is our research in the area of Product-Service Systems (PSS) design and experiences made in different types of collaboration activities and interest groups on PSS. The exploding amount of PSS research projects (cp. [1] for instance), domains jumping up on the "PSS train", PSS publications, conceptual work, and the growing variety of PSS design methodologies drives a need for consolidation in order to make PSS research results applicable for industry and to make these compatible with established development methodologies.

In the following sections, we reflect on our experiences in PSS design research and literature reviews to discuss common views on PSS and areas where consolidation is needed. We start with a brief introduction, discuss the need for consolidation, work out several viewpoints on PSS, illustrate commonalities, and close with a proposal for some major PSS design dimensions.

This paper is a first step towards standardization. It attempts to provide an overview of cutting-edge research results on PSS design. The paper is based on some 50 publications on PSS design, and catches up the latest advances by referring to more than 30 articles published for the last three years. Readers are suggested to look into those references for more detailed information.

1.1 Product-Service Systems

Product-Service Systems (PSS) is a concept to integrate products and services in one scope for planning, development, delivery, use, and EOL (end of life) treatment, thus for the whole lifecycle. It is predominantly used in academia but widely unknown by industry. Nevertheless, solutions integrating products and services are attracting attention, even if not explicitly planned and developed in integrated processes. Some providers consider themselves as solution providers who essentially offer solutions including products and services. An extension of business models to incorporate product-service systems is an ongoing movement, for instance, in manufacturing industry. Furthermore, PSS often means that a provider takes over more responsibility in product operation (the products may even remain in the ownership of the provider) and what a PSS customer actually buys or pays for is the functionality or performance of the products in a form of service. Therefore, this business scenario is thought of as a special case of *servitization* or *servicification*, where an integrated product and service offer brings added value to the customer. Finally, PSS is a means to implement sustainability; cp. references [2] to [8].

1.2 Need for Consolidation

Research on product-service systems has been carried out for many years and in various disciplines. Nevertheless, design guidelines and standards for industrial application are hardly available. Even a consolidated set of terminologies has not been established (see an earlier attempt in [9]). A common understanding of PSS is arising, but a common meta-model has not been released beyond research project borders. PSS is attacked on many levels of abstraction, beginning on a product and service integration level, going up to business strategies based on PSS concepts and offerings. Although consolidation among research projects and industrial branches is rudimentary, standardization on PSS design is increasingly put on research agendas and first results in standardization have been achieved. For instance, the German DIN PAS 1094 (Public Available Specification) about hybrid value creation has been set up by German researchers and has been released by the end of 2009 [10]. Interest groups, such as the PSS Design Research Community [w1] or the PSS Benchmark Club, were installed and started to concentrate on common challenges of PSS business and research; industry becomes aware of PSS.

1.3 Drivers of Consolidation

Missing consolidation is an obstacle for companies to adopt, incorporate, and deploy PSS design approaches and to introduce efficient work and communication processes with customers and suppliers of products and services. Furthermore, for an implementation of efficient software tools, a common understanding of a system and its structure (elements and relations) is needed to build standard interfaces and model types for data exchange and interoperability.

The development of IT systems supporting engineers in PSS engineering would be beneficial and an enabler to deploy the PSS theory faster. At least, there is some research, which can be used for such an IT system development: For instance, modelling of service support systems is proposed in [11]. A framework to represent service knowledge and service ontology is developed in the IT system context [12]. In addition, a methodology to build a service ontology in order to capture and reuse design knowledge by object oriented concepts and ontologies has been developed, see [13]. Furthermore, a service CAD system has been proposed to describe and evaluate design objects [14] [15]. Müller et al. [7] describe a new PSS planning and modelling method, called PSS Layer Method, which was implemented as a plain software prototype in MS Visio. In addition, a CAD tool supporting systematic design effectively is being developed [16].

Compared to software solutions for virtual product creation and process modelling, PSS engineering is far behind. There are hardly any IT solutions available, which are mature for industrial application. Those, which are available, do not share the same meta-model or system understanding of a PSS. Thus, there is still a big gap between PSS research and practice in industries.

1.4 Content of Consolidation

Design methodologies provide elements such as mindsets, a system understanding (meta-models), generic development process models, and methods or matrices for systematization, design and modeling. PSS design researchers have released many of such elements during the last years, e.g. [3]. Although consolidation should cover all those elements, we concentrate on the PSS mindset and meta-model in this article due to the space limitation.

2 VARIOUS VIEWPOINTS

2.1 Multi-Domain Influences

As described in [17], opportunities to incorporate findings from other domains exist in PSS design research. PSS development and its related research need inputs from fields as marketing, psychology, socio-technology, and eco-design, in general. From recent research, for instance, a service offering development framework has been developed in the marketing area [18], which can be connected with PSS design/development. Insights gained in the area of service design have been applied into PSS design/development [19]. Discussions have been raised about integrating PSS in corporate strategy [20]. In addition, an attempt to incorporate knowledge and experiences in social technology was found in the field of energy services [21]: Barrier theory [22] is adopted to gain options improving energy services. However, the research results available at present are insufficient.

2.2 (In)Consistent Levels of Abstraction

PSS is attacked on different levels of abstraction without a clear, consistent model breaking the strategic level down to deeper levels of the value creation process.

The following list contains some arbitrarily chosen examples for different levels of abstraction:

- *Business strategy level:* "PSS is a business model that tries to decrease environmental loads through collaborations of various stakeholders throughout product lifecycle" [23]
- *Value level:* "A PSS is an integrated product and service offering that delivers value in use" [4].
- *Artefact level:* "A Product-Service System (PSS) is an integrated combination of products and services" [4].

Levitt for instance argued that "everybody is in the service industry" and presented the idea of a production-line approach to service industry more than three decades ago [24]. This is in line with the definition of service given in [8]. (In contradiction to these interpretations, many companies actually present their services in the category "products".)

Figure 1 summarizes different views and statements on PSS abstraction levels (original statements from literature are marked with an asterix *).

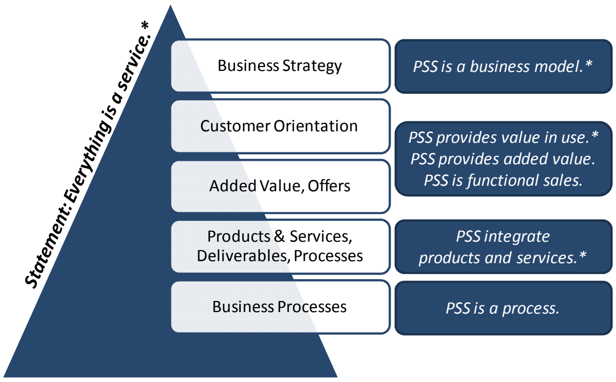

Figure 1: PSS abstraction levels.

A consistent "value traceability" is necessary to set up a robust PSS theory and to make PSS approaches more interesting for industry. Namely, there is a need for means to measure and assess how far product and service integration really supports added value and therefore business.

2.3 PSS Design and PSS Design Evaluation

From the design perspective, it is important to evaluate the potential of solutions as well as to generate new solutions. Relatively little research was conducted on the PSS evaluation, although PSS is proposed as means to make better business and to implement sustainable solutions. After [17] here we use the classification of the research "targets" into "PSS offer modelling", "PSS development process", and "PSS potential". The first two, i.e. offer modelling and development process, have been basic targets of engineering design research as presented in [25] and [26].

Table 1 illustrates the targets of the reviewed literature that were taken from international journals, mainly from [27] and [28] after 2009.

Table 1 reveals that more literature addresses "PSS offer modelling" and "PSS development process", while very little addresses "PSS potential". This implies that there exist research opportunities for "PSS potential". In PSS research in general, the environmental potential of PSS has been among the largest concerns. Furthermore, the potential of not only environmental but also economic aspects is still a hot research issue [45]. Social effects of PSS are not researched intensively, so far.

Table 1: Classification of PSS design literature (journal articles) into the three targets

Research target	Before 2008	After 2009
PSS offer modelling	[11, 29-32]	[12-15, 33-35]
PSS development process	[30, 36, 37]	[12, 34, 38-41]
PSS potential	[42, 43]	[44]

Note: Some articles appear only in one target in this table, which should be interpreted to be the main target of the articles, although they may address two or three.

2.4 PSS Offering, Customer and Provider

As raised in [17] the three dimensions *offering, provider, and customer/user* are fundamental for PSS development. The offering dimension addresses the elements and activities in the offering's lifecycle. It includes the product lives of physical artefacts, as well as service activities, i.e. the part of the offering towards the customer or users. The provider dimension addresses the evolvement of organizations providing products, services, and operation. The customer/user dimension addresses the evolving needs of service receivers. In principle, any PSS development is supposed to address at least something on all these three dimensions, since service includes customer and provider activities and products. These three dimensions partially share the three perspectives proposed in [46]: people, product, and process. However, the three dimensions after [17] differentiate between the provider and the recipient.

The latter proposition emphasizes relationships between those three dimensions. Namely, from the design perspective, the offering dimension is influenced by the customer dimension, as customer needs should be reflected on the offering characteristics. In addition, the offering dimension influences the provider dimension, because service activities and thus resources of the provider should be designed to deliver the offering. Figure 2 depicts the relationships.

Figure 2: Influences among the three dimensions.

3 FREQUENTLY RAISED ISSUES ON PSS DESIGN

3.1 Interpretation as System

It is widely accepted that PSS can be classified as systems. Nevertheless, the system border of a PSS is not necessarily evident and can be set differently. From systems theory, two views on systems can be identified. One view, the hard systems view, is apt to deal with information related to technical systems, since the boundary of technical systems can easily be determined. It is useful for developing technical artefacts. The other view, the soft systems view, has the capability to address goals that humans strive to achieve by performing activities. To consider customer information adequately for PSS, both views on systems seem necessary, due to integrating products, i.e., technical artefacts, and services, i.e., human activity systems using the technical artefacts for specific purposes [6].

3.2 Product and Service Integration

Integrating products and services (result, process, and resources) implies that what customers need should be represented on a higher level than simply products or services. This is where customer value becomes necessary to be addressed. Creating customer value can be a target of applying PSS as proposed in [29]. However, in practice, companies often keep adopting the same product as provided as a product alone and added value is limited. Reasons for this effect could be explained in specific economic theories. For instance, if a company focuses on a core competence when designing the physical product, it will be a strong reason to stick to a product as designed for traditional business (see e.g. [47]). In these cases, this becomes a so-called core product.

3.3 Internal and External Actors

As depicted in Figure 2, a provider has considerable impacts on a PSS. A product manufacturer alone may not be able to implement a PSS. This is why actors are an important aspect of PSS. Actors might be users or operators of a machine, service technicians, or staff of finance institutions. A customer is one of the actors, who realize value in the end. According Bullinger and Scheer [48] and other references, he is an "external factor" in a value co-creation process. In addition, a customer is crucial as a source of customer needs. This is particularly important in PSS, since customer value should be addressed.

3.4 Lifecycle Orientation

The lifecycle of a product, which covers all phases of a product or service, is a dominating issue. The lifecycle perspective supports engineers to design or develop PSS. This has been mentioned by different researchers. For instance, Aurich et al. highlights the importance of a "lifecycle oriented design" for the "product and technical service design processes" integration [30]. Östlin et al. discusses the importance of lifecycles in the context of remanufacturing [32]. McAloone [49] expands the perspective of product lifecycles, by additionally considering a customer relationship cycle spanning the customer activities during product use. Concepts like Total Cost of Ownership (TCO) or Life Cycle Costs (LCC) focus on the economic dimension within a lifecycle.

3.5 Customer Orientation

Customer orientation is one of the major drivers for PSS in many references. This has already been explained in section 2.3 and 2.4.

3.6 Application of Business and Operation Models

PSS has characteristics of a business model, which includes a value proposition, delivery architecture (process and resources) and a revenue model. The following classification of services is widely utilized in combination with PSS business models: product-oriented, use-oriented, and result-oriented service [45]. It is noteworthy to point out that these three are types of design solutions but not necessarily helpful in the development process, since they refer to just results of design and on its billing. The business model is shared between a provider and a customer in the form of a contract. This is why a contract is an essential element of a PSS. Establishing contracts is important for every type of business. However, it is more important in PSS than in product-sales business, as business with PSS spans longer time and lifecycle periods framed by contracts.

3.7 ICT as an Enabler

Today, many functions of modern products and services base on information and communication technologies (ICT). ICT became inevitable for product and service delivery and value implementation. Cross border service deployment and delivery in remote areas is enabled by ICT. For instance, deployment of remote services at a customer's site provided by a manufacturer through ICT networks is an example [47]. Thus, ICT is regarded as an enabler of PSS. Empirical results, obtained from designing services at a manufacturer, who had implemented information and communication networks at customers' sites and adopted a structured method to design services, are reported in [38]. For instance, condition-monitoring solutions to provide proactive and preventive maintenance services are typically based on sensors and embedded IT.

3.8 Sustainability (Environmental, Economic and Social Potential)

Although PSS has a historical background partially in eco-design [50], a PSS is not automatically sustainable. However, PSS are considered as a means to implement sustainability (cp. [43]) and thus many research projects focus on PSS and sustainability. For instance, smart product pooling or sharing strategies combined with supporting services are an example to demonstrate potential of dematerialisation in order to face limited resources. Another example is the extension of product lifecycles by maintenance, repair overhaul, upgrades etc.

4 TOWARDS CONSOLIDATION

4.1 PSS Commonalities

The analysis presented in sections 2 and 3 enables us to state that a PSS should fit to the following definition.

[Necessary criterion] Product-Service Systems (PSS) are customer, lifecycle, and foremost sustainability oriented systems, solutions, or offers, integrating products and services.

[Sufficient criterion] Business models framed by contracts align incentives of the customer and the provider, aim at assuring functionality throughout system lifetime and aim at implementing added value to satisfy customer needs.

[Phenotypes] (i) Explicit PSS are planned, developed, delivered, and utilized in integrated processes. (ii) Implicit PSS are not explicitly planned, developed, delivered, and utilized in integrated processes but already existing in today's markets.

4.2 Main PSS Design Dimensions (Meta-Model)

We assume that nine main PSS design dimensions can be defined that cover most aforementioned PSS issues, including the divergent viewpoints (section 2) and frequently raised issues (section 3):

Customer *needs* (dim. 1) are satisfied by customer *values* (dim. 2), which a customer perceives. Such values have to be generated by *deliverables* (dim. 3) which have a value for a customer. The deliverables are results of delivery processes, i.e. *lifecycle activities* (dim. 4). To implement a lifecycle activity chain resources are needed. *Actors* (dim. 5), *core products* (dim. 6) *and periphery* (like IT infrastructure or public transport systems) (dim. 7) are such resources. *Contracts* (dim. 8) frame the entire value creation process, including *billing* (dim. 9), offerings, and finally the entire business model.

The following subsections describe all nine dimensions in detail.

Customer needs (customer view)

This dimension summarizes customer needs. The idea is to capture non-solution-oriented needs, for instance the need for access to broadcast information. Nevertheless some needs will be solution or context related. For instance, the need to operate a TV set and radio with a solar home system is an example [7]. This dimension does not contain requirements and specifications, which are descriptions towards how a system function has to be designed, cp. [6].

Customer value (customer view)

"Value is what I get for what I give" according to one finding which Zeithaml retrieved based on an empirical study [51]. We assume that from an economic viewpoint, the value can be expressed as monetary benefit in the end. However, a differentiation of value types is helpful to show differences in how PSS ideas and concepts work to meet customer needs. In our view, the customer value is equal to the benefit a customer gains by a deliverable. The major four types of benefits are economic, environmental, social, and technical benefits. Less precisely defined benefits are information and knowledge advantages, saved time, health preservation, protection, or enhancement, prestige, or advanced process robustness, agility, flexibility etc. Briefly, the protection and enhancement of a customer's market position belong to this dimension.

To link such values to customer satisfaction, scales and target ranges should be defined for each value. (Using the example above, the bandwidth and the time range to access broadcast information can be defined, measured, and compared to the customers' actual state, in order to capture the customer value and the satisfaction of his need.)

Deliverables

Deliverables is what the PSS provider delivers to its customer. Deliverables can be material or immaterial. Technical artefacts, software, information, or knowledge are the main deliverables. It is important, that a deliverable is a result of an activity or an activity chain, which can be interpreted as part of a service or business process. Not every deliverable has value for a customer. For instance, the delivery of out-dated information might be contra-productive for a customer. Thus, it is important to differentiate between deliverables and customer values.

Lifecycle Activities

This dimension contains activities performed by the PSS provider and/or the customer. Activity chains result in deliverables, which are supposed to have value for the customer (and of course for the PSS provider). Sometimes, it can also be used to change or optimise already existing deliverables.

Actors

Single actors (players), stakeholders, enterprises and enterprise units or divisions as well as even software agents are classified as actors. Actors participate in activities and have an aim and a perception of delivered values. Software agents also have aims and interact although they are not physical. Allowing software agents as actors might be important in case of replacing a manually executed service by a technical artefact communicating with a provider agent platform.

Core Products

Products, which have to be designed or at least offered in a package by the PSS provider, are captured by this dimension. The most important aspect of core products is that they have high relevance for the final PSS value generation. Products, which have to be designed, adopted or configured viz. those where conventional engineering tasks have to be performed by the PSS provider (network), are captured within this dimension.

Periphery

Support equipment, technical periphery, tools, infrastructure, or PSS execution systems, which are type of a platform, outer condition, support, or constraint for the PSS delivery, should be captured in this dimension.

Contract

As the contract is one basic element of the product-service system, remarks on the contract design should be made early, to detail out the business model. Examples are implementations of obligations, options, exception handling, duration, fines, regulations of payment, take-back conditions, warranty, transfer of ownership, responsibilities etc. An offering has the same meaning.

"Billing" (Revenues, Finance mechanism, Monetary dim.)

This dimension shows when a customer is paying for deliverable(s) and how much. For instance, flat rates, pre-paid, scheduled or incremental (down-) payment and payment on tickets may be possible. (The name of this dimension is finally not fixed and thus set in ticks.)

Figure 3 illustrates all nine dimensions and their relations. The figure shows all relations bottom-up. Analogue relations are immanent top-down (viz. customers having needs demand for values, perceived values depend on deliverables, and so on).

4.3 Implicitly contained PSS issues

The described meta-model frames services, business models, and PSS offerings implicitly. This was intended to become independent from thinking too much "in products and services" in early development phases.

Services

Service results are captured by deliverables (dim. 3), service processes are represented by lifecycle activities (dim. 4) and service potentials (resources, capabilities) are represented by the dimensions actors (dim. 5), core products (dim. 6) and periphery (dim. 7).

If an activity provides a deliverable, includes an external factor (e.g. a customer in person) and consumes resources all together becomes implicitly a service.

Business model

The value proposition of a business model is captured by values (dim 2) and the deliverables (dim 3). The value creation architecture, including the process and resources of the value delivery, is build by lifecycle activities (dim. 4), actors (dim. 5), core products (dim. 6), and periphery (dim. 7). The revenue model is addressed by contract (dim 8) and "billing" (dim 9).

Offering

Offerings are framed by contracts (dim 8). Offerings propose customer values (dim 2) and deliverables (dim 3).

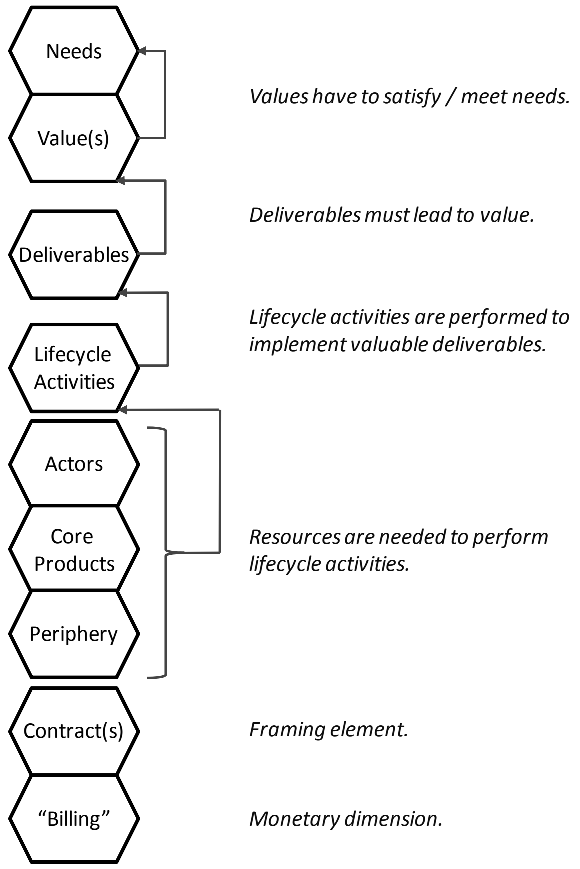

Figure 3: PSS design dimensions and relations.

4.4 Implementation

These nine dimensions have been introduced in the DIN PAS 1094 [10] to support PSS concept design. A modelling method incorporating these nine dimensions and the application case "solar home systems for rural electrification in Africa" has been published in [7]. This modelling method implements each design dimension as one element class represented by a horizontal layer. In each layer, elements of the PSS are modelled over the PSS lifecycle. A first software prototype has been implemented to support this modelling method and some industrial applications have been made in PSS planning workshops. So far, we found no severe complications to explain PSS ideas and concepts holistically by our nine design dimensions. (One may argue that nine dimensions are too much; but we state that fewer dimensions do not cover the most relevant PSS issues and do not support "value traceability" as mentioned in section 2.2.)

In our elaborations, we did not mention flows in a PSS. Nevertheless, we considered material, signal, energy, and cash flows, if necessary.

5 SUMMARY AND OUTLOOK

A conclusion one can draw is that there exist plenty of product, service and PSS design approaches. This contribution is concentrated on different but also common viewpoints, which exist in PSS research. Most approaches address particular aspects in design, often there are overlapping views, but few address the frequent-raised issues mentioned in section 3 entirely. Nevertheless, the résumé is not that such approaches are obsolete. Rather we stated that consolidation of terminology and a basic system understanding is needed to compile a holistic PSS theory. Thus, we plan to continue our work in order to define and consolidate a PSS meta-model which is suitable for all levels of abstraction and which is applicable to design and to evaluate PSS. Our concrete future works include validating our findings and model in different business cases on market places. We hope some readers will contribute to our discussion in the future.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] R. Knackstedt, J. Pöppelbuß, A. Winkelmann, 2008, Integration von Sach- und Dienstleistungen – Ausgewählte Internetquellen zur hybriden Wertschöpfung, Wirtschaftsinformatik, DOI 10.1365/s11576-008-0050-0.

[2] G. Salvendy W. Karwowski, eds. Introduction to Service Engineering. 2009, Wiley. 720.

[3] T. Sakao M. Lindahl, eds. Introduction to Product/Service-System Design. Springer's global publishing programme in engineering and management. 2009, Springer: London. approx. 300.

[4] Bains, T.S., Lightfoot, H.W., Evans, S., Neely, A., Greenrough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J.R., Angus, J.P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I.M.., Wilson, H., 2007, State-of-the-art in product-service systems. In Proceedings of ImechE, Vol 221, Part B: J. Engineering Manufacture:1543-1552.

[5] Mont, O., 2002, Clarifying the concept of product-service system, Journal of Cleaner Production, 10: 237-245.

[6] Å. Ericson, P. Müller, T. Larsson, R. Stark, 2009, Product-Service Systems – From Customer Needs to Requirements in Early Development Phases, CIRP IPS2 Conference, Cranfield.

[7] P. Müller, N. Kebir, R. Stark, L. Blessing, 2009, PSS Layer Method - Application to Microenergy Systems, In: Introduction to Product/Service-System Design, Sakao and Lindahl, Editors. Springer: London.

[8] T. Tomiyama, 2001, Service Engineering to Intensify Service Contents in Product Life Cycles, Research in Artifacts, Center for Engineering, The University of Tokyo.

[9] D. Matzen, T. Sakao, G. Ö. Sandström, 2007, Design Research on Manufacturing Firms Moving from Products to Services. In 16th International Conference on Engineering Design, Paris.

[10] DIN working group, 2009, Product-Service Systems – Value Creation by Integrating Goods and Services. Public Available Specification 1094, DIN PAS 1094.

[11] T. Alonso-Rasgado, G. Thompson, B. Elfstrom, 2004, The design of functional (total care) products, Journal of Engineering Design, 15: 515-540.

[12] A. Doultsinou, R. Roy, D. Baxter, J. Gao, A. Mann, 2009, Developing a service knowledge reuse framework for engineering design, Journal of Engineering Design, 20: 389 – 411.

[13] S. K. Moon, T. W. Simpson, J. Shu, S. R. T. Kumara, 2009, Service representation for capturing and reusing design knowledge in product and service families using object-oriented concepts and an ontology, Journal of Engineering Design, 20: 413 – 431.

[14] T. Hara, T. Arai, Y. Shimomura, 2009, A CAD system for service innovation: integrated representation of function, service activity, and product behaviour, Journal of Engineering Design, 20: 367-388.

[15] T. Sakao, Y. Shimomura, E. Sundin, M. Comstock, 2009, Modeling Design Objects in CAD System for Service/Product Engineering, Computer-Aided Design, 41: 197-213.

[16] H. Komoto T. Tomiyama, 2009, Systematic generation of PSS concepts using a service CAD tool, In: Introduction to Product/Service-System Design, Sakao and Lindahl, Editors. Springer: London. In print.

[17] T. Sakao, G. Ö. Sandström, D. Matzen, 2009, Framing research for service orientation through PSS approaches, Journal of Manufacturing Technology Management, 20: 754-778.

[18] D. Kindström C. Kowalkowski, 2009, Development of industrial service offerings: a process framework, Journal of Service Management, 20: 156-172.

[19] T. Fischer, H. Gebauer, A. Gustafsson, L. Witell, 2009, Managerial recommendations for service innovations in different product-service systems, In: Introduction to Product/Service-System Design, Sakao and Lindahl, Editors. Springer: London.in print.

[20] A. Tan, T. McAloone, D. Matzen, 2009, Service-Oriented Strategies for Manufacturing Firms, In: Introduction to Product/Service-System Design, Sakao and Lindahl, Editors. Springer: London.in print.

[21] P. Thollander, J. Palm, T. Sakao, 2010, Increasing industrial energy efficiency through energy services – an interdisciplinary approach with engineering- and social science aspects. In The 2nd CIRP International IPS2 Conference. Linköping

[22] S. Sorrell, J. Schleich, S. Scott, E. O'Malley, F. Trace, U. Boede, K. Ostertag, P. Radgen, Barriers to Energy Efficiency in Public and Private Organisations, 2000.

[23] Institute for Global Environmental Strategies (IGES), 2007, Business for Sustainable Society Project Summary Report.

[24] T. Levitt, Production-Line Approach to Service, in Harvard Business Review. 1972.

[25] S. Finger J. R. Dixon, 1989, A review of research in mechanical engineering design. Part I: Descriptive, prescriptive, and computer-based models of design processes Research in Engineering Design, 1: 51-67.

[26] S. Finger J. R. Dixon, 1989, A review of research in mechanical engineering design. Part II: Representations, analysis, and design for the life cycle Research in Engineering Design, 1: 121-137.

[27] R. Roy D. Baxter, 2009, Special Issue - Product-Service Systems, Journal of Engineering Design, 20: 327 – 431.

[28] R. Roy, E. Shehab, D. Baxter, 2009, Special issue on Product-Service Systems, International Journal of

Manufacturing Technology and Management, 20: 545-778.

[29] T. Sakao Y. Shimomura, 2007, Service Engineering: A Novel Engineering Discipline for Producers to Increase Value Combining Service and Product, Journal of Cleaner Production, 15: 590-604.

[30] J. C. Aurich, C. Fuchs, C. Wagenknecht, 2006, Life cycle oriented design of technical Product-Service Systems, Journal of Cleaner Production, 14: 1480-1494.

[31] M. Dausch C. Hsu, 2006, Engineering service products: the case of mass-customising service agreements for heavy equipment industry, International Journal of Services Technology and Management, 7: 32 – 51

[32] J. Östlin, E. Sundin, M. Björkman, 2008, Importance of closed-loop supply chain relationships for product remanufacturing, International Journal of Production Economics, 115: 336-348.

[33] V. Panshef, E. Dörsam, T. Sakao, H. Birkhofer, 2009, Value-Chain-Oriented Service Management by Means of a 'Two-Channel Service Model', International Journal of Services Technology and Management, 11: 4-23.

[34] N. Maussang, P. Zwolinski, D. Brissaud, 2009, Product-service system design methodology: from the PSS architecture design to the products specifications, Journal of Engineering Design, 20: 349-366.

[35] J. C. Aurich, N. Wolf, M. Siener, E. Schweitzer, 2009, Configuration of product-service systems, Journal of Manufacturing Technology Management, 20: 591-605.

[36] T. Alonso-Rasgado G. Thompson, 2006, A rapid design process for Total Care Product creation, Journal of Engineering Design, 17: 509 - 531.

[37] N. Morelli, 2003, Product-service systems, a perspective shift for designers: A case study: the design of a telecentre, Design Studies, 24: 73-99.

[38] T. Sakao, H. Birkhofer, V. Panshef, E. Dörsam, 2009, An Effective and Efficient Method to Design Services: Empirical Study for Services by an Investment-machine Manufacturer, International Journal of Internet Manufacturing and Services, 2:

[39] E.-M. Molloy, C. Siemieniuch, M. Sinclair, 2009, Decision-making systems and the product-to-service shift, Journal of Manufacturing Technology Management, 20: 606-625.

[40] K. Kimita, Y. Shimomura, T. Arai, 2009, Evaluation of customer satisfaction for PSS design, Journal of Manufacturing Technology Management, 20: 654-673.

[41] E. Sundin, M. Lindahl, W. Ijomah, 2009, Product Design for Product/Service Systems - Design Experiences from Three Manufacturing Companies from Sweden, Journal of Manufacturing Technology Management, 20: 723-753.

[42] S. Evans, P. J. Partidário, J. Lambert, 2007, Industrialization as a key element of sustainable product-service solutions, International Journal of Production Research, 45: 4225 - 4246.

[43] A. Tukker, 2004, Eight Types of Product-Service System: Eight Ways to Sustainability? Experiences from Suspronet, Business Strategy and the Environment, 13: 246 – 260.

[44] A. Azarenko, R. Roy, E. Shehab, A. Tiwari, 2009, Technical product-service systems: some implications for the machine tool industry, Journal of Manufacturing Technology Management, 20: 700-722.

[45] A. Tukker, U. Tischner, 2006, New Business for Old Europe, Greenleaf Publishing, Sheffield.

[46] Å. M. Ericson T. C. Larsson, 2009, People, Product and Process Perspectives on Product/Service-System Development, In: Introduction to Product/Service-System Design, Sakao and Lindahl, Editors. Springer: London.in print.

[47] G. Allmendinger R. Lombreglia, Four Strategies for the Age of Smart Services in Harvard Business Review. 2005.

[48] H. J. Bullinger and A. W. Scheer, 2006, Service Engineering, 2nd Edition, Springer Verlag, ISBN: 10 0-3-540-25324-6.

[49] T. C. McAloone, 2007, Competence-Based Approach to Sustainable Innovation Teaching, Experiences within a New Engineering Program, Journal of Mechanical Design, ASME.

[50] T. C. McAloone, M. M. Andreasen, 2004, Design for Utility, sustainability and societal virtues: Developing Product Service Systems. Proceedings of the International Design Conference.

[51] V. A. Zeithaml, 1988, Consumer Perceptions of Price, Quality, and Value: A Means-End Model and Synthesis of Evidence. Journal of Marketing, Vol. 52, 2-22

8 WEB LINKS

[w1] The International PSS Design Research Community, http://www.pssdesignresearch.org/

[w2] IPSE, International Product and Service Engineering, project website, http://www.ipse.se

[w3] Transregio 29, Engineering of Industrial Product-Service Systems, project website, http://www.tr29.de

Last request of all websites on March 12th, 2010.

Session 3B:
Business Model

What Does a Service-Dominant Logic Really Mean for Manufacturing Firms?

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Abstract

Service infusion is a major global business trend in manufacturing industries. This means that firms strategically increase their service orientation in order to increase profit margins. In parallel to this development, the service-dominant logic has emerged as arguably the most challenging recent scholarly marketing debate. Positioning service as dominant in marketing logic clearly challenges traditional practice, given that much of marketing theory originated from a goods-dominant view. However, there are several misconceptions of what this logic means, leading to erroneous managerial implications. Therefore, the objective is to (1) explain the distinct difference between a product-service transition and a transition from goods-dominant to service-dominant logic, and (2) discuss what these transitions mean for industry and academia. For example, a transition to service-dominant logic implies much more than an increased emphasis on the firm's product-service systems; it implies a reframing of the purpose of the firm and its collaborative role in value co-creation.

Keywords

Service-dominant logic, Service infusion, Value-in-use, Solutions

1 INTRODUCTION

In industrial markets, services have often been seen as an add-on to the core product offering and as a necessary evil that is needed for future product sales [1, 2]. However, as industries reach a mature stage, commoditization tends to erode the competitive differential potential of product markets. With attempts to remain competitive and avoid a deteriorated financial position, manufacturing firms increasingly turn to the provision of industrial services and solutions such as product-service systems (PSS) [3, 4, 5]. In the last few decades, GE, Ericsson, IBM, Toyota Industries, Xerox, and other leading-edge manufacturing firms have increasingly 'moved downstream'. This so-called service infusion is frequently seen as a transition path from transactional product sales to relational services and solutions provision [6, 7, 8, 9].

In parallel to the growing attention the service infusion phenomenon is receiving in academia (e.g. though special issues and conferences), the Service-Dominant (S-D) logic, proposed by Vargo and Lusch [10] and extended in subsequent works [11, 12, 13, 14], has emerged as arguably the most important scholarly marketing debate for a decade. For example, the seminal paper in which the foundational premises were introduced has been the most cited article in the Journal of Marketing the last decade and it has initiated several academic forums and special issues. Vargo and Lusch have put forward their S-D thesis for examination and debate as a possible foundation for evolving a general marketing theory. What they emphasize is how a supplier's knowledge resources and core competencies are fundamental to firms' value propositions, which are the basis for business interactions in networks of relationships. Interaction between buyers and suppliers is critical to understanding their logic, as this is the enabler of innovation and co-creation of value with customers and suppliers.

However, there are many misconceptions of what the S-D logic actually means (see e.g. the Industrial Marketing Management (2008) Special Issue on the migration from product(s) to service(s) or the proceedings of the 1st CIRP IPS2 Conference for some examples), leading to misinterpretations and erroneous managerial implications. Thus, the objective of this article is (1) to explain the distinct difference between a product-service transition and a transition from goods-dominant to service-dominant logic, and (2) to discuss what this means for industry and academia. In the following section, the foundations of S-D logic are introduced and S-D logic is contrasted with Goods-Dominant (G-D) logic. Then, the distinction between the two service transitions is discussed and finally, implications for practitioners and research are presented. Since the article is conceptual, empirical examples from different industries are given to illustrate some of its main tenets.

2 SERVICE-DOMINANT LOGIC AS A PARADIGM

Discussing S-D logic in an industrial context is of undoubted interest due to the increasing strategic importance of services and PSS for manufacturing firms [1, 4]. This has led to calls for integration of goods and services offerings and solutions focusing on the customer's business capabilities [15, 16, 17]. This growing attention to manufacturers' service operations by academics and practitioners alike is most commonly understood as a necessary accommodation of services in today's business world.

However the S-D logic orientation goes further, treating any knowledge-laden interactions between buyer and supplier as a service. In order to better understand the principles of S-D logic, it can be contrasted with G-D logic. The marketing logic that has traditionally prevailed in industrial firms is referred to by Vargo and Lusch [10] as the G-D logic, which they argue, is built on the assumption that economic value is added through industrial processes, embedded in goods, distributed, and then realized in exchange in a transactional manner (i.e., value-in-exchange).

Under S-D logic, on the other hand, goods are seen as distribution mechanisms for service provision. Furthermore, the value of goods is based on their **value-in-use** and determined by the customer, which clearly goes beyond conventional value-in-exchange (i.e., market value, price). And more controversially, this way of thinking reframes the value-in-use derived from goods as a customer service. In other words, all goods (including raw materials and part-formed goods) are exchanged for their value-in-use, and until 'used up', goods act as service appliances in the hands of a customer. The role of the supplier then becomes that of a collaborative resource integrator and co-creator of value with the customer. One controversial aspect of this agenda underneath the semantics is that every business becomes a service business. That is, the service-ability of goods in use is what is purchased. In S-D logic, service provisioning is what firms do, and customer assessments of value are made in direct interactions with suppliers, as well as interactions with goods. A distinction is made between **operand resources**, which are usually tangible, static resources that require some action to make them valuable and **operant resources**, which are usually intangible, dynamic resources that are capable of creating value [10, 18]. Whereas the emphasis is on operand resources under G-D logic, operant resources are the key to competitive advantage from an S-D logic perspective.

Furthermore, the time logic of marketing exchange becomes open-ended, from pre-sale service interaction (e.g., pre-bid activities such as requirements definition) to post-sale value-in-use (e.g., post-project activities such as post-deployment support and operational services), and may develop further as the relationships evolve [19, 20]. However, S-D logic is not another 'breaking free from product marketing' attempt [21] but a more radical set of propositions which might potentially 'break all of marketing free from manufacturing' [22] (p. 334). The ten foundational premises (FPs) of S-D logic are summarized in Table 1. Some of the premises have profound implications for manufacturing firms (FP1, FP3, FP6, FP7, FP8, FP9, FP10) and are therefore relevant to further discuss.

2.1 The inversion of exchange and the subordination of goods

S-D logic views goods as one method of service provision with **service** as the common denominator of the exchange process, and service is what is always exchanged [23]. Service is defined as 'the application of specialized competences (knowledge and skills), through deeds, processes, and performances for the benefit of another entity, or the entity itself' [24]. This inversion of exchange as traditionally understood is illustrated in Figure 1.

Despite goods being subordinated to service in terms of classification and function, goods are not inferior in terms of importance and value because customers are the arbiters of value. For example, the engineering group Sandvik's high technology stainless steel and cemented-carbide tools are distribution mechanisms for service provision that require knowledge-intensive research and manufacturing, and that can have major impact on the customer's value-creating processes. If value creation is in focus, the traditional distinction between goods and services is nor relevant. There is a nested relationship that needs to be recognized; the function of goods is to deliver service. Furthermore, as Gummesson [25] states, both things (i.e. goods) and activities (i.e. services) render service, which create value.

Many of the ideas behind the S-D logic are in line with contemporary management and marketing thought in service marketing, relationship marketing, and knowledge management theory, the resource-based view of the firm, network perspectives, and the interaction perspective in industrial marketing. Vargo and Lusch have brought together ideas from different sources and their theoretical contribution lies in the way these ideas are synthesized [26, 27].

Foundational premise	Comment/explanation
1. The application of specialized skill(s) and knowledge (i.e. service) is the fundamental unit of exchange	The application of operant resources (knowledge and skills), "service," as defined in S-D logic, is the basis for all exchange. Service is exchanged for service
2. Indirect exchange masks the fundamental basis of exchange	Because service is provided through complex combinations of goods, money, and institutions, the service basis of exchange is not always apparent
3. Goods are a distribution mechanism for service provision	Goods (both durable and non-durable) derive their value through use – the service they provide
4. Operant resources are the fundamental source of competitive advantage	The comparative ability to cause desired change drives competition
5. All economies are service economies	Service (singular) is only now becoming more apparent with increased specialization and outsourcing
6. The customer is always a co-creator of value	Implies value creation is interactional
7. The enterprise cannot deliver value, but only offer value propositions	Enterprises can offer their applied resources for value creation and collaboratively (interactively) create value following acceptance of value propositions, but can not create and/or deliver value independently
8. A service-centered view is inherently customer oriented and relational	Because service is defined in terms of customer-determined benefit and co-created it is inherently customer oriented and relational
9. All social and economic actors are resource integrators	Implies the context of value creation is networks of networks (resource integrators)
10. Value is always uniquely and phenomenologically determined by the beneficiary	Value is idiosyncratic, experiential, contextual, and meaning laden

Table 1: Foundational premises of S-D logic [13, p. 7].

2.2 Two views of value: distribution and creation

Under S-D logic, business innovation is repositioned and made possible through value created in co-created offerings. The shift in focus, from producer to customer perspective [25, 28] and then from customer perspective to value-in-use, is a shift from the means of production to the means of utilization. From this perspective, the supplier role is as a resource integrator, and value is always determined by the customer as value-in-use, whether in direct interaction with the supplier or in indirect interaction through goods in use. Everything else the firm does is resource integration or a **value proposition** [10].

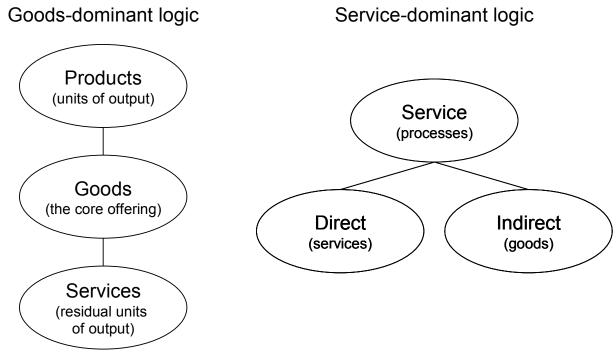

Figure 1: The hierarchy of exchange in G-D logic and S-D logic [20].

Ramírez [29] made a distinction between the prevailing industrial view and what he called the co-productive view of value creation and his comparisons share many similarities with the comparisons between G-D logic and S-D logic made by Lusch and Vargo [12]. In S-D logic, customers are seen as the arbiters of co-created value and suppliers as resource integrators. The comparisons between G-D logic and S-D logic concepts are set out as Table 2.

G-D logic concepts	Transitional concepts	S-D logic concepts
Goods	Services	Service
Products	Offerings	Experiences
Feature/attribute	Benefit	Solution
Value-added	Co-production	Co-creation of value
Profit maximization	Financial engineering	Financial feedback/ learning
Price	Value delivery	Value proposition
Equilibrium systems	Dynamic systems	Complex adaptive systems
Supply chain	Value chain	Value-creation network
Promotion	Integrated marketing communications	Dialogue
To market	Market to …	Market with …
Product orientation	Market orientation	Service orientation

Table 2: Conceptual lexicon of marketing [12, p. 286].

Table 2 is not seen as a final lexicon but as one that invites further work; indeed an evolution of ideas [18]. However, the lexicon of key constructs does reflect the dimensions of the cognitive shift involved in any transition from G-D logic to S-D logic. The lexicon does not necessarily imply that G-D logic concepts are discarded. Rather, it suggests how G-D concepts **logically** might be subordinated to the S-D concepts. For an industrial firm mainly involved in manufacturing activities, these transitional concepts have implications in the form of potential challenges and opportunities [20].

For example, price becomes part of the concept of value proposition, because value propositions are exchanged, one for another. And value-in-use expands the time horizon for a supplier firm to remain involved with the customers' use and experience of goods sold. Marketing **to** customers dominates conventionally, but under S-D logic, in line with Normann [30], the interactive process of marketing is **with** customers and other stakeholders. Hence, the offering may have a price set or negotiated as part of the value proposition, but this price is not confirmed as value until it is assessed or experienced by the customer in use. In other words, value is not necessarily confirmed at point of sale through the medium of the exchange price.

Marketing with customers to co-create value involves improving a firm's value propositions, supported by supplier resource integration, knowledge, and skills, something which Vargo and Lusch [10] argue is very difficult for competitors to replicate. It involves rethinking the firm's resources application in time and place contexts. Normann's [30] idea of resource density aligns well with S-D logic's concept of value creation through resource integration. Many processes can be dematerialized and traditional enterprises can be unbundled in terms of place, time, actor, and actor constellation, and thereby be re-bundled into new offerings. Further, this re-bundling can be facilitated by interaction and reciprocity between the actors involved, as S-D logic suggests. For example, new generations of microprocessors or telecom networks contain more embedded operant resources than previous generations and therefore enable more opportunities for value creation. Microprocessors have higher levels of density than previous technologies because of the way they enable the mobilization of resources for time-space-actor units. Complex offerings such as electricity supply and other large technical systems which are embedded with more resources in order to increase density have the potential to enhance the suppliers' and customers' competitiveness by increasing their opportunities to create value-in-use [31]. However, this is not a matter of simply following a new instruction manual. What follows are transitional shifts to move from a product (G-D) focus to a service (S-D) focus.

G-D logic	S-D logic
Making something (goods or services)	Assisting customers in their own value-creation processes
Value as produced	Value as co-created
Customers as isolated entities	Customers in context of their own networks
Firm resources primarily as operand	Firm resources primarily as operant
Customers as targets	Customers as resources
Primacy of efficiency	Efficiency through effectiveness

Table 3: Transition for practitioners [18, p. 259].

For practitioners, S-D logic directions are summarized in Table 3. Thus, a transition to S-D logic implies much more than an increased emphasis on the manufacturing firm's product-service systems; it implies a **reframing** of the purpose of the firm and its collaborative role in value co-creation.

3 TWO DISTINCT SERVICE TRANSITIONS

In the light of the dominance and growth of the service sector, and the service infusion in manufacturing firms, one may intuitively interpret the S-D logic as reflecting this major shift. However, S-D logic does not reflect the transition from an industrial era to a service era [23]. Instead, Vargo and Lusch argue that service have **always** been exchanged for service. The idea that goods are embedded with value emerged from economics during the Industrial Revolution (at a time when 'science' equalled Newtonian mechanics) and has ever since been the dominant paradigm [32]. Furthermore, from the S-D logic perspective, manufacturing is a form of service provision. That is, service concerned with the synchronized application of complex, specialized extraction, development, design, management, assembly, accounting, distribution, etc., of knowledge and skills. As Vargo and Lusch observe, 'much of the apparent move to a service economy is nothing more than a further refinement and subsequent outsourcing of these operant resources' [23, p. 45].

Thus, the product-service transition (i.e., service infusion) and the transition from G-D to S-D logic are to be seen as two distinct dimensions; the first one reflecting a strategic repositioning of the manufacturing firm in the marketplace though the addition of new services to its core offering, and the second one reflecting a new perspective on value creation. This means that service infusion and a focus on S-D logic may, or may not, be parallel shifts. It also means that many firms in service industries may have a G-D logic perspective.

For instance, 'marketing continues to point firms toward producing service instead producing goods, rather than providing service. It continues to suggest that all that is needed is a change in the unit of output from the tangible to the intangible. This is a logic that not only misleads manufacturing firms, but one that has mislead what are traditionally thought of as service industries' [18, p. 256]. Similarly, a manufacturer that pursues advanced research and developing new products in close collaboration with key customers, suppliers, and other partner firms may be regarded as a product firm rather than a service provider; yet, the manufacturer can have an S-D logic perspective on value creation.

The two distinct transition paths are illustrated in Figure 2. Most traditional manufacturing firms can be seen in cell I. As firms move along the product-service transition line they eventually reposition themselves to cell II. However, firms in cell II focus on 'units of intangible output' rather than providing service for the benefit of the customer. Firms in cells III and IV have an S-D logic perspective and have therefore shifted their focus from products and output (tangible and intangible) to customer-centric value co-creation.

For example, IBM has been developing and implementing a service science business model for which it claims S-D logic as a theoretical foundation, based on thorough research coordinated by its Almaden Research Center in California [20]. Although somewhat simplified, IBM has moved from cell I to cell II over the last decades, and more recently to(wards) cell IV. Due to the strong position that G-D logic has among managers, engineers, and other firm employees, such a sequential transition seems to be the most likely (and perhaps the only viable in many cases) towards an S-D logic perspective. This means that the service infusion can act as a catalyst for increased service focus. Thus, a manufacturing firm without a significant service and/or PSS business is likely to experience major difficulties when trying to shift business logic [1]. One can therefore expect few firms to be positioned in cell III. On the other hand, many service firms can be found in cell II. This means that although the firm operates in the so-called service sector, it nonetheless has a G-D logic perspective on value and customers (cf. Table 3). In Sweden, for example, triple play services operators such as Com Hem have often been ranked at the bottom in performance satisfaction indexes due to their poor value-in-use (even if value-in-exchange may be high).

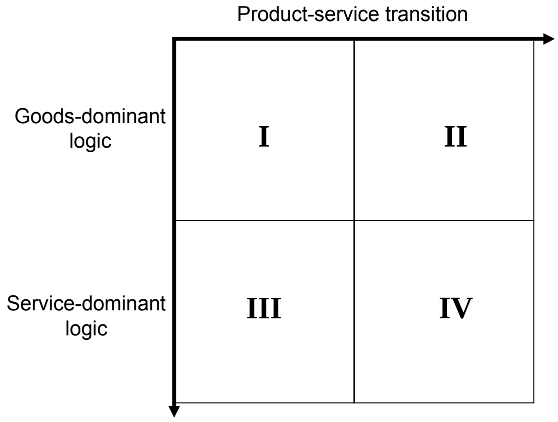

Figure 2: The two distinct service transitions.

4 DISCUSSION AND CONCLUSIONS

4.1 Managerial implications

S-D logic does not imply that firms should focus solely on services and outsource manufacturing activities, which is a common misunderstanding. For instance, even if a majority of the Fortune 100 firms claim to offer solutions the question is whether solutions are a major part of their business or if it is merely a fashion statement. Day [33] claims that it is unlikely that most firms are pursuing a 'true' solutions strategy from the perspective of S-D logic (i.e., cell IV in Figure 2). Instead, most firms are still to be found in cells I and II. This means that firms are far from capitalizing on the value-creation possibilities as they, for various reasons, are still in the rather early stages of the transition to an S-D logic.

Despite being a mindset and perspective on value creation rather than a theory, S-D logic offers some normative guidelines for practitioners [24, p. 415]:

1. The firm should be transparent and make all information symmetric in the exchange process. Since the customer is someone to collaborate with, anything other than complete truthfulness will not work.

2. The firm should strive to develop relationships with customers and should take a long-term perspective.

3. The firm should view goods as transmitters of operant resources (embedded knowledge)… The firm should focus on selling service flows.

4. The firm should support and make investments in the developments of specialized skills and knowledge that is the fountainhead of economic growth.

Symmetrical information exchange

Related to the first guideline, studies of asymmetrical information exchange show that balanced knowledge sharing and symmetrical information exchange is critical for successful value constellations and propositions [34]. The need for symmetric information becomes particularly evident in major industrial partnerships, such as the one between the global technology company ABB and the pulp and paper company Fletcher Challenge Canada Limited (FCCL). ABB signed a full service level agreement with FCCL to service its three Canadian pulp mills. When signed in 2000, it was the largest-ever full service agreement ABB had undertaken. The two firms created a 50-50 partnership employing 380 people to maintain all of the mills' assets (electrical equipment, automation systems, the boilers for process steam, kraft pulp processing equipment, and pollution control systems).

However, even if an ideal position would be if all information exchanges between firms were symmetric, clearly this is not the case in practice [20]. For example, customers may be more or less willing to share information and also within the manufacturing firm, different functions and business units may be unwilling to share information. Politics and power play can make the idea of symmetric information very challenging in reality. This is clear in research on service infusion, where product and service units have very different cultures and often are unwilling to cooperate [35, 36, 37].

A long-term perspective

Following S-D logic orientation and the open ended time-logic that applies, the second guideline means that the ability to participate in co-creating superior lifetime value-in-use for the customer [20] and to derive an equitable part of that value is vital. A focus on lifetime value implies that firms need to apply a holistic perspective on value creation and customer relationships, and not only view all product and service sales separately and static. It relates to the concept of balanced centricity [38]; that is, that the interests (needs and wants) of customers and other stakeholders need to be secured. Again, however, if customers have a G-D logic orientation it may not only be difficult, but also unprofitable to engage in close, long-term collaboration with some customers [31].

Compared to G-D logic approaches to where the value emphasis is on value-in-exchange, the relative emphasis of the value propositions for customized PSS solutions needs to be based on the customer perceived value-in-use [31]. This requires not only an integrative approach to PSS development, but also a genuine understanding of the customers' unique usage contexts, in which the value is created [13]. It also means that when demonstrating the value of the offering, firms need to have methods and tools in place to show the offering's potential value-in-use convincingly beforehand.

For example, a European manufacturer of outdoor power products developed a number of highly complex spreadsheet applications used to show the value-creating potential of their new PSS offerings, identifying reduced total costs and increased total revenue. However, since these spreadsheets can be too complicated to use for some salespersons, the firm has also developed stripped down versions illustrating key points, such as customer profitability, in interactive diagrams and graphs. More sophisticated methods include case studies from major reference customer and scenarios. Since virtual simulations nowadays are accessible for almost all industries, scenario discussions are becoming more and more interesting, allowing advanced visualizations also for non-technical and non-economic aspects of the offering [39].

New opportunities for innovation

Developing customer and supplier relationships also relate to the third guideline. Under S-D logic, customers and suppliers are potentially part of the co-innovation process. This means that not only active, but also passive customers unwittingly co-design 'patterns of behaviour' that supplier firms can use to improve their offerings. For example, by replacing barcode tags with RFID (Radio Frequency Identification) tags, the new data that is possible to capture can be used to understand such patterns [40]. There are also numerous examples of explicit co-creative innovation in research and long-term partnerships. Firms like Alstom Transport and Ericsson share information with their key customers in an open, consultative, and informal way at multiple levels across organizational functions (Davies and Hobday 2005). By working together, the supplier and the customer can identify opportunities for innovation in which future value can emerge. However, G-D logic tends to emphasize output, such as production-ready, tangible components without recognizing opportunities for relationship lifetime value creation arising from the process itself. Therefore, S-D logic theory can extend existing G-D views on product development and business innovation [20]. It is however vital that firms recognize the differences between product and service development, as well as the strategic linkages between the two areas [36].

Investments in specialized skills

Finally, the fourth guideline emphasizes a long-term financial orientation that does not necessarily fit well with the short-term financial goals that tend to drive Western capital markets [41]. Financial feedback is a multi-dimensional, long-term oriented metric in S-D logic. It does not equal profit (although it can include profit) as it may include cash flow, market share, sales, growth, etc. [24]. However, despite the normative goal to emphasize value-in-use and customers' long-term well being, for most firms it is difficult to always emphasize value-in-use [31], for example, due to the customer focus on products and transactional exchange value. If that is the case (e.g., that customers focus on a low purchasing price), managers in the supplier firm need to have the ability to understand why this is the case. Explanations may include not only the customer's financial directives or strong budgetary constraints, but also the firm's own poor demonstration of value potential [31].

Furthermore, even if firms have the ability to propose a competitive value proposition and to convince the customer that the firm is committed to the offering, not all manufacturing firms have the organizational capabilities, knowledge about customer processes, and risk-management skills required to pursue a solutions strategy with PSS offerings that focuses on value-in-use [33]. This means that in many cases, investments (both long-term and short-term) in the specialized skills required for the provision of competitive offerings are needed. Unfortunately, PSS managers often struggle internally to allocate the resources required to develop and provide new offerings [36], a situation that has even worsened due to many firms' cost-cutting excesses in the recent financial downturn.

Summary

In opposite to many consumer firms pursuing mass marketing activities, many manufacturing firms in the business-to-business (B2B) sector view customers as resources with whom to interact and focus on offerings with high value-in-use. Albeit by no means a straightforward matter, this means that a transition from G-D logic to S-D logic can be less strenuous for B2B manufacturing firms undertaking a product-service transition than for consumer firms.

To sum up, applying S-D logic as a market orientation also means that the traditional division of goods sales from after-sales services and solutions are no longer discrete functions, and this elevates the strategic importance of lifetime value of the customer relationship, regardless of its combination of services and goods [20]. For practitioners, this has implications for how to organize in order to offer customized PSS solutions. For instance, it means that research and development, sales, service, finance, human resources, and other local and central organizational functions need to work together [1].

4.2 Research implications

S-D logic shifts the unit of analysis from products to value creation. However, it is a mindset and an organizing framework, rather than a theory [18]. The dominant position of G-D logic in academia and business, and its restricted view on value creation, means that many opportunities for value creation and competitive advantage may be obscured. G-D logic concepts are also commonly used when analyzing service infusion. This may make sense if firms are only changing their offerings through the addition of new services and solutions, but it may be insufficient if firms shift their business focus towards S-D logic. In such cases, the knowledge gained may be limited due to the inadequate constructs used. For example, it is interesting to note that the definition of IPS2 is 'an integrated product and service offering that delivers value in use'. In line with S-D logic, value-in-use (i.e., not only value-in-exchange) is emphasized. However, value is being seen as delivered rather than co-created, a view that obviously has G-D logic connotations.

Even if the service infusion phenomenon is often referred to as a product-service transition, it does not imply abandonment of prior offerings to the benefit of new offerings with higher service content. Rather, firms tend to increase the breadth of the PSS offering which they need to manage and coordinate. In accordance with S-D logic, knowledge (renewal) is regarded as the fundamental source of competitive advantage [10, 19], and the acquisition of specialized skills and knowledge is often a prerequisite for the ability to offer new types of services and PSS. This means that effective organizational learning as well as the ability to unlearn G-D practices and mindsets is needed, which can be difficult. For example, it can be difficult to unlearn things such as a salesman's focus on product sales and a service technician's working method for maintenance and repair activities [1].

A final comment on S-D logic is that the conceptual polarization of G-D and S-D logic is not fully reflected in and supported by studies of service infusion [1]. For example, firms' traditional business logics, which overall are congruent with G-D logic rather than S-D logic, also share some central components with S-D logic, such as viewing customers as resources with whom to interact (rather than as isolated entities which are passive targets of marketing). Not only leading service firms but also many manufacturing firms have highlighted the importance of long-term customer relationships, where social aspects such as trust, commitment, and even friendship links are important ingredients. Thus, the shift from product sales to service provision must not be equated with a shift from transactional routines to long-term relationships.

Future research could investigate in-depth manufacturing firms' transition paths in Figure 2. Since little empirical research has analyzed S-D logic practices, such studies should investigate firm performance, value propositions, offerings, and customer relationships. For instance, it would be relevant to study whether or not there are significant differences in firm performance between firms with G-D and S-D orientations. Furthermore, despite the trend to 'go downstream', there are firms moving in the opposite direction (i.e., focusing more on manufacturing activities) [15]. A better understanding of antecedents and drivers for downstream and upstream transitions is another future research avenue.

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] Kowalkowski, C, 2008, Managing the Industrial Service Function, Published doctoral dissertation, Department of Management and Engineering, Linköping University, Linköping, Sweden, available online at: http://liu.diva-portal.org/smash/record.jsf?searchId=2&pid=diva2:162 (accessed 1 February 2010).

[2] Robinson, T, Clarke-Hill, CM, Clarkson, R, 2002, Differentiation through service: A perspective from the commodity chemicals industry, The Service Industries Journal, 32: 149−166.

[3] Davies, A, Brady, T, Hobday, M, 2006, Charting a Path Toward Integrated Solutions, Sloan Management Review, 47: 39-48.

[4] Gebauer, H, 2008, Identifying service strategies in product manufacturing companies by exploring environment–strategy configurations, Industrial Marketing Management, 37: 278-291.

[5] Sakao, T, Lindahl, M, eds., 2009, Introduction to Product/Service-System Design, Springer, London, UK.

[6] Gebauer, H, Friedli, T, 2005, Behavioral implications of the transition process from products to services, Journal of Business & Industrial Marketing, 20: 70-78.

[7] Mathieu, V, 2001, Service strategies within the manufacturing sector: benefits, costs and partnership, International Journal of Service Industry Management, 12: 451-475.

[8] Oliva, R, Kallenberg, R, 2003, Managing the transition from products to services, International Journal of Service Industry Management, 14: 160-172.

[9] Penttinen, E, Palmer, J, 2007, Improving firm positioning through enhanced offerings and buyer-seller relationships, Industrial Marketing Management, 36: 552-564.

[10] Vargo, SL, Lusch, RF, 2004, Evolving to a New Dominant Logic for Marketing, Journal of Marketing, 68: 1-17.

[11] Lusch, RF, Vargo, SL, 2006, The Service-Dominant Logic of Marketing: Dialog, Debate, and Directions, M. E. Shape, Armonk, NY.

[12] Lusch, RF, Vargo, SL, 2006, Service-dominant logic: reactions, reflections and refinements, Marketing Theory, 6: 281-288.

[13] Vargo, SL, Lusch, RF, 2008, Service-dominant logic: continuing the evolution, Journal of the Academy of Marketing Science, 36: 1-10.

[14] Vargo, SL, Lusch, RF, 2008, Why "service"? Journal of the Academy of Marketing Science, 36: 25-38.

[15] Davies, A, 2004, Moving base into high-value integrated solutions: a value stream approach, Industrial and Corporate Change, 13: 727-756.

[16] Matthyssens, P, Vandenbempt, K, 2008, Moving from basic offerings to value-added solutions: Strategies, barriers and alignment, Industrial Marketing Management, 37: 316-328.

[17] Möller, KEK, Törrönen, P, 2003, Business suppliers' value creation potential: A capability-based analysis, Industrial Marketing Management, 32: 109-118.

[18] Vargo, SL, Lusch, RF, 2008, From goods to service(s): Divergences and convergences of logics, Industrial Marketing Management, 37: 254-259.

[19] Ballantyne, D, Varey, RJ, 2006, Creating value-in-use through marketing interaction: the exchange logic of relating, communicating and knowing, Marketing Theory, 6: 335-348.

[20] Kowalkowski, C, Ballantyne, D, 2009, Relationship value through the lens of the service-dominant logic, Proceedings from the 17th International Colloquium in Relationship Marketing (ICRM '09), Maastricht, The Netherlands.

[21] Shostack, GL, 1977, Breaking Free from Product Marketing, Journal of Marketing, 41: 73-80.

[22] Vargo, SL, Lusch, RF, 2004, The Four Service Marketing Myths: Remnants of a Goods-Based, Manufacturing Model, Journal of Service Research, 6: 324-335.

[23] Vargo, SL, Lusch, RF, Service-dominant logic: what it is, what it is not, what it might be, in Lusch, RF, Vargo, SL, eds., The Service-Dominant Logic of Marketing: Dialog, Debate, and Directions, M. E. Shape, Armonk, NY, 2006, 43-56.

[24] Lusch, RF, Vargo, SL, Service-dominant logic as a foundation for a general theory, in Lusch, RF, Vargo, SL, eds., The Service-Dominant Logic of Marketing: Dialog, Debate, and Directions, M. E. Shape, Armonk, NY, 2006, 406-420.

[25] Gummesson, E, Relationship Marketing; Its Role in the Service Economy, in Glynn, WJ, Barnes, JG, eds., Understanding Service Management, Oak Tree Press, Dublin, Ireland, 1995, 224-268.

[26] Aitken, R, Ballantyne, D, Osborne, P, Williams, J, 2006, Introduction to the special issue on the service-dominant logic of marketing: insights from The Otago Forum, Marketing Theory, 6: 275-280.

[27] Day, GS, 2004, Achieving Advantage with a New Dominant Logic: Invited Commentaries on "Evolving to a New Dominant Logic for Marketing", Journal of Marketing, 68: 18-19.

[28] Grönroos, C, 2007, Service Management and Marketing - Customer Management in Service Competition, John Wiley & Sons Ltd, Chichester, UK.

[29] Ramírez, R, 1999, Value co-production: intellectual origins and implications for practice and research, Strategic Management Journal, 20: 49-65.

[30] Normann, R, 2001, Reframing Business - When the Map Changes the Landscape, John Wiley & Sons, Ltd, Chichester, UK.

[31] Kowalkowski, C, 2008, Value propositions in business markets: insights from the service-dominant logic of marketing, in Layton, R, Vargo, SL, Lusch, RF, eds., Forum on Markets and Marketing: Extending Service-Dominant Logic, Sydney, Australia, 107-128.

[32] Vargo, SL, Morgan, FW, 2005, Services in Society and Academic Thought: An Historical Analysis, Journal of Micromarketing, 25: 42-53.

[33] Day, GS, 2006, Achieving advantage with a service-dominant logic, in Lusch, RF, Vargo, SL, eds., The Service-Dominant Logic of Marketing: Dialog, Debate, and Directions, M. E. Shape, Armonk, NY, 85-90.

[34] Mascarenhas, O, Kesavan, R, Bernaccchi, M, 2008, Buyer-seller information asymmetry: challenges to distributive and corrective justice, Journal of Macromarketing, 28: 68-84.

[35] Gebauer, H, Fleisch, E, Friedli, T, 2005, Overcoming the Service Paradox in Manufacturing Companies, European Management Journal, 23: 14-26.

[36] Kindström, D, Kowalkowski, C, 2009, Development of industrial service offerings – A process framework, Journal of Service Management, 20: 156-172.

[37] Nordin, F, Externalising services - Walking a tightrope between industrial and service logics, 2005, Stockholm School of Economics, Stockholm, Sweden.

[38] Gummesson, E, 2008, Extending the service-dominant logic: from customer centricity to balanced centricity, Journal of the Academy of Marketing Science, 36: 15-17.

[39] Kowalkowski, C, Kindström, D, 2009, Value Visualization Strategies for PSS Development, in Sakao, T, Lindadl, M, eds., Introduction to Product/Service-System Design, Springer, London, 159-182.

[40] Mannervik, U, Ramírez, R, 2006, Customers as Co-Innovators: An Initial Exploration of Its Strategic Importance, in Edvardsson, B, Gustafsson, A, Kristensson, P, Magnusson, P, Matthing, J, eds., Involving Customers in New Service Development, Vol. 11, Imperial College Press, London.

[41] Payne, AF, Storbacka, K, Frow, P, 2008, Managing the co-creation of value, Journal of the Academy of Marketing Science, 36: 83-96.

Identification of the IPS² business model in the early stage of creation

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Abstract

Industrial Product - Service System (IPS²) delivers industrial, customized solutions. By the analysis of customer needs by the IPS² provider an IPS² business model is defined, which affects the entire lifecycle phases.

This paper gives a definition of an IPS² business model, presents identified influences for different business models, extract seven significant questions and describe a tool for the identification of suitable IPS² business models. In the early stage of the IPS² development the requirements of the customer are mainly fuzzy and have to be specified in the following phases. It is shown how the questions are designed concerning these facts.

Keywords

Industrial Product-Service Systems, IPS², IPS² development, IPS² business models, customer business needs

1 INTRODUCTION

Nowadays companies have to deal with globalization. This leads to new marketing opportunities for German machine tool manufacturers on the market for high-tech industrial solutions. Concurrent the market competition, especially by the People's Republic of China, increases. The German Engineering Federation (VDMA) reports for 2008 that China raised the position of the biggest machine tool manufacturer, previous to Germany and USA. The global depression is noticeable for German machine tool manufacturers since the middle of 2009 and the downturn of production is predicted with 10 to 20 percent.

The traditional way of a machine tool manufacturer is selling respectively with the machine tool only a physical product. Related and relevant services are “designed” as add-on for this product. The potential for a more service oriented design is mainly not utilized by the companies, especially for the young micro production technology branch.

In summary the companies have the possibility to ensure an existing competitive advantage of Germany as a location for industry by the consistent creation and use of innovative businesses. This demands a customized solution over the entire lifecycle of Industrial Product-Service Systems (IPS²).

Industrial Product-Service Systems offer the possibility to realize these requirements. By the customer orientation of an IPS², it is important to characterize the possible business model, which fulfills the customer needs best, in an early stage of the IPS² creation phase. The IPS² business model represents the customer information, e. g. problem, needs, and requirements and is the entire description of the IPS² with e. g. the customer-provider relation. As an input for the definition of an IPS² business model a literature research is done. The state of the art is the basis for the new IPS² business model definition, presented in the paper. With this definition and the defined IPS² lifecycle the procedure for the identification of the IPS² business model is shown. A special tool (see 5) with respect to the early phase of the IPS² lifecycle can help to identify an initial IPS² business model by the given customer needs.

2 INDUSTRIAL PRODUCT SERVICE SYSTEMS (IPS²)

2.1 Introduction of PSS and IPS²

The term of Product-Service System (PSS) is used especially for the B2C market and focus on sustainability of such a system. An example for PSS is a cell phone with contractual use options, like flat rate and/or data packet volume. Whereas IPS² is related to the B2B market. By covering the industrial market, the requirements of IPS² are much higher than on PSS. The volume of B2B transactions is much higher than for B2C. Typical supply chains and industrial standards have to be taken into account, when delivering IPS².

2.2 Characteristics of IPS²

An IPS², as well as a PSS, is characterized by a combination of tangible product [1], [2] and intangible service shares [3] including the immanent software via the complete lifecycle to fulfill the customer needs [4], [5]. The IPS² provider offers a customized solution in terms of an IPS² business model to the customer [4].

To realize this IPS² in an adequate way it is important to capture the IPS² business model, which fits best the customer needs, in an early stage of IPS² creation. By these it is necessary to have the possibility to characterize the target IPS². Therefore the definition of relevant IPS² characteristics is needed.

The IPS² exhibits the following characteristics:

- Heterogeneity of shares,
- Integration of shares,
- Level of individualization and
- Possibility of substitution of both shares.

With these characteristics the possibility to fulfill the customer needs with an IPS² is given.

The *heterogeneity* describes the composition of an IPS² with product and service shares [6]. The level of heterogeneity in an IPS² solution can be differentiated by

- Number of different product and service shares and

- Diverseness of product and service shares.

With rising and/or larger variety of product and service shares the heterogeneity increases.

The specific possibility of the fulfillment of the customer needs leads to the *integration* of shares [7], [8]. For a methodic realization different dimensions can be taken into account:

- Dimension of potential,
- Dimension of process,
- Dimension of result and
- Dimension of market.

These dimensions are considered in the presented IPS² business model. The dimensions of potential, process and result can be used for a phase related definition of services [9].

The level of *individualization* [6], [8] of IPS² is enabling a customer specific solution. The individualization is described on the one hand by the individualization of disposal and otherwise on the variability of the IPS² share combinations. The level of individualization for the shares can range from standardization to individualization. Therefore a individual IPS² share can be combined concerning the customer needs.

Three characteristics for "hybrid systems" are defined by vom Brocke [10]:

- Heterogeneity,
- Coexistence and
- Competition.

Coexistence and competition are summarized under the *substitutability* of product and services shares. The substitutability of IPS² shares can result in a solution of product shares, service shares or among product and service shares. The initialization for this substitutability is that at least one customer need is identified, which can be fulfilled by a product and/or a service share.

The definition and the elements of an IPS² business model have to be given by the consideration of these characteristics of IPS².

3 IPS² BUSINESS MODELS

3.1 Definition of Business Models

To reduce the complexity of the solution range and to ensure an effective and efficient creation of IPS² the early knowledge about the customer specific IPS² business model is needed.

By analyzing the customer needs an IPS² business model can be identified by the IPS² provider [11]. The presented IPS² business model methodology is a basis for the IPS² provider to characterize the customer needs and to describe its customized realization depending on the IPS² business model. The business model combines all relevant elements of the IPS². That must contain e. g. the needed processes with the attached resources, product and service shares and the form of contract.

A literature research concerning existing business model definitions and descriptions are basis for the IPS² business model. The given definitions of business models are dealing mainly with e-business and digital market [12], [13]. Because of that fact the usability of such definitions in the context of IPS² has to be checked and a definition for IPS² business model must be given. Tukker reported about a business model definition for PSS [14]. The research results in the use of business model elements of Stählers definition [15] for the IPS² business model. These elements are also corresponding with the elements of a considered PSS business model [14].

3.2 IPS² Business Model

The IPS² business model is therefore defined by the following elements:

- Value Configuration,
- Value Proposition and
- Revenue Model.

Looking on an exemplary detailed IPS², these elements can be characterized.

The *value configuration* is mainly process oriented and deals with the generation of value for the customer. The IPS² provider and also his network partners use the value configuration, which generates costs that have to be covered by the IPS² revenue, to sell the IPS² value proposition. This "process" can contain different stakeholders with e. g. roles and responsibilities.

The *value proposition* describes which value the customer and IPS² provider has, by delivering a customized IPS². This value includes the constellation of network partners that bring the value proposition on the market.

The sources for the revenues of an IPS² for the IPS² provider are defined by the *revenue model*. Also the prospective revenues are named and thereby the potential of the sustainability of this IPS² is given. The revenue model includes contractual and government agreements between the IPS² provider and the customer and also between the IPS² provider and his network partners [4].

Three exemplary business models can be described [5], [11]. The IPS² specification can vary between function, availability or result oriented IPS² business models. The IPS² business models differ in the risks and the resultant responsibilities for the IPS² shares between IPS² provider and customer. This information is an important input for the entire IPS² lifecycle and especially for the service delivery.

Function (Product) Oriented IPS² Business Model

The *function* of a technical system is characterized by the transfer of element input under the provision of special parameters into element output. By this the task, which the system and the resulting IPS² should fulfill, is identifiable. Both elements can be built up of material, energy and information. Therefore it is possible that different subsystems, e. g. machine tool components, can realize this function. In a function oriented IPS² business model the undertaking to sell is the function of the IPS², which is guaranteed by the IPS² provider. The IPS² composed of all product and function related service shares with required employees are under the ownership and responsibility of the customer. In this business model the IPS² provider plans additional service shares in advance. This can realize a short response time between customer request and IPS² provider answer. The IPS² provider can deliver the service with needed resources as scheduled or by request. This service delivery can be carried out by the customer or the IPS² provider and his network partners [4]. By this delivery the responsibility can shift from the customer to the IPS² provider side.

Availability (Use) Oriented IPS² Business Model

The *availability* of a technical system is defined as the probability or dimension, in which the system is able to reach specific requirements in a fixed period [16]. By the agreement between customer and IPS² provider the period with downtimes is defined. Because of these requirements availability is an important economic parameter for the IPS² and the IPS² provider has to guarantee this by e.g. optimizing his service process delivery [4]. The availability is also a quality criterion of the technical system, e. g. the production with a machine tool without technical defect.

For an availability oriented IPS² business model the product shares are under ownership of customer and the availability relevant service shares are generally at IPS² provider side. The IPS² provider must provide all services with all needed resources to obtain the factor "availability". A condition monitoring system can inform the IPS² provider about the status of e. g. the wear of relevant product shares of the IPS². Thereby the service delivery can be triggered and carried out by IPS² provider. In this IPS² business model the time scheduling for service delivery has to integrate customer and IPS² provider with relevant network partners.

Result Oriented IPS² Business Model

A *result* is characterized as the output of a process. This process can be built up e.g. by activities and actions.

The customer has no ownership of product shares in a result oriented IPS² business model and pays only for the defined result of the IPS², e. g. for work piece quality and quantity. Therefore the responsibilities for all service and product shares are in the ownership and responsibility of the IPS² provider. In this case the IPS² provider can decide if he can accept downtimes or if he has to build up e. g. new production resources.

4 IPS² LIFECYCLE

4.1 Definition of IPS² Lifecycle

The IPS² lifecycle can be divided in three main steps:

1.) Creation of IPS²,

2.) Operation of IPS² and

3.) End of IPS².

The first and second steps are subdivided in several other steps. The main characteristic for the IPS² operation phase is the parallelism of processes of use of the IPS² product shares and delivery of the IPS² service shares. In the IPS² creation phase a much more sequential progression can be used.

The IPS² creation phase is built up by the planning and development phase of an IPS² (Figure 1).

For IPS² creation, especially in the IPS² planning phase, the specification of the IPS² business model is necessary. During idea generation the solution space for IPS² shares can be reduced by knowing the IPS² business model which fits best the customer needs. This is important to speed up the IPS² creation phase and thereby to optimize the relevant processes at the IPS² provider side.

4.2 Influences of the IPS² Lifecycle at the Business Model Elements

With the given definition of the IPS² business model elements (see 3.2) and the IPS² lifecycle it is important to name the interdependencies between IPS² business model and IPS² lifecycle. The different IPS² lifecycle phases have an impact on the IPS² business model elements and detail them. The questions concerning the

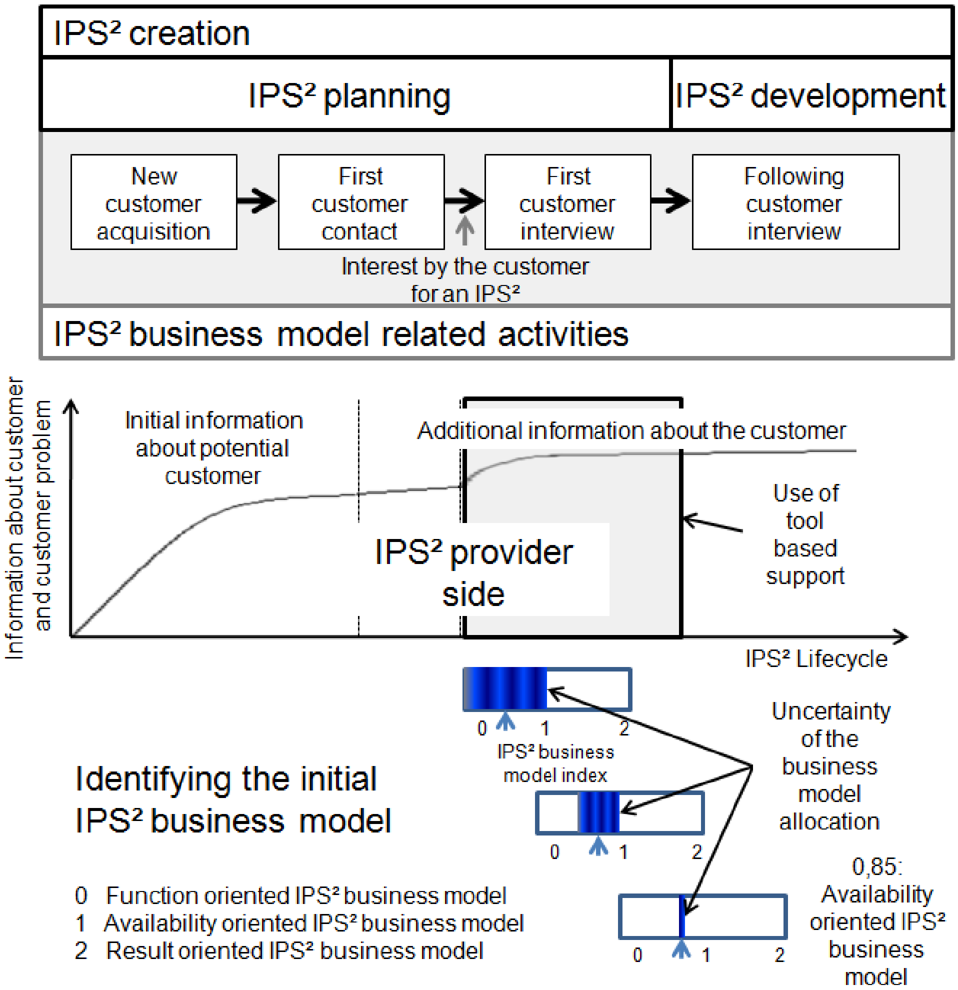

Figure 1: Information Flow and Uncertainty Reduction

IPS² business model, which have to be answered by the customer, have to deal with this fact.

The concretion of the IPS² business model element *value configuration* can be started with the planning phase of an IPS². The idea generation creates potential requirements for the IPS², so that an initial IPS² network is noticeable. By this the initial *value proposition* is defined. The relevant input for this model element is given in the development phase. The *revenue model* can mainly be determined after the creation phase of the IPS², when the value configuration and the value proposition are detailed. The value configuration is important for the implementation and setup of the IPS² shares and the needed potentials for the use of IPS² at the beginning of the IPS² operation phase.

5 TOOL TO IDENTIFY AN INITIAL IPS² BUSINESS MODEL

5.1 Information Flow

To ensure the identification of an initial IPS² business model a software tool is designed. The tool provides seven questions to characterize the target IPS² business model for a specific customer in an early phase of the IPS² lifecycle. In this phase the information search begins and the given information is mainly unspecific. Beside the IPS² lifecycle (see 4) the IPS² business model related activities by the IPS² provider can be named (Figure 1). These activities are needed to identify and detail the IPS² business model.

The information is related to customer and customer needs (customer problems). The acquisition of this information can be separated into four main process steps (Figure 1), whereas this information is detailed and transformed to customer needs. By the information about the customer, it is possible to characterize the customer processes with e. g. resources for the definition of the IPS² business model element “value configuration”.

In the first step the potential customer is identified and the initial customer information is collected by the IPS² provider. The amount of information arises by this investigation and can be used for a preparation of the first interview, which is the second process step (Figure 1).

The next step is the first, direct customer contact, which ends the customer acquisition process. This can be done by an interview via e. g. telephone, but mostly by customer visit of the IPS² provider. This contact affords more information, but the rise of information quantity is, because of the effective information search at the first step, lower (Figure 1).

After this step the letter of intent for an IPS² can be given by the customer. This will enable the following process steps and starts the real IPS² planning phase. A second interview can bring more detailed information of the customer problem and the tool can be used to characterize in a first prognosis an initial IPS² business model. In this process phase the prognosis for an IPS² business model is uncertain (Figure 2).

By the following interviews this uncertainty can be cleared and the collected information can now be related to the IPS² lifecycle phase. For example the questions now refer to the IPS² planning phase and aim at detailing a specific IPS² product share.

5.2 Graphical User Interface and Navigation

The software tool for the identification of an initial IPS² business model has a graphical user interface (GUI) to interact with the user. The user can be the customer or the interviewer of the IPS² provider (Figure 2).

The tool is platform independent and no installation has to be done. The requirement to run this tool is an installed web browser. By Hyper Text Markup Language (html) the design for the tool is created as a website and the data volume is therefore low. This affects an easy exchange of the tool.

The compatibility of the tool with different web Browsers is given. Logos and icons are integrated in the tool (Figure 2). To analyze the questions JavaScript is used.

The answers can be given by a sequence of seven questions. Each answer is related to one IPS² business model. The questions are verbalized in an adequate and precise way, so that all possible answers are relevant and

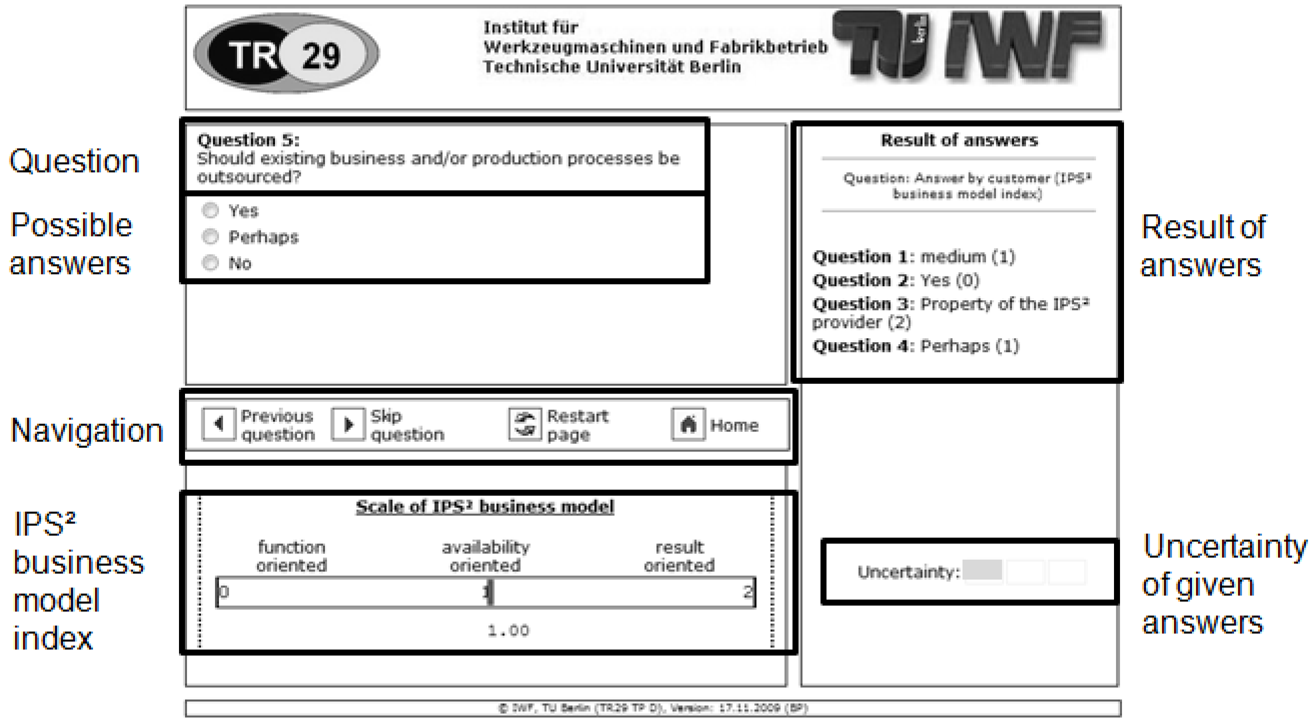

Figure 2: Graphical User Interface of the Business Model Identification Tool

can be answered by the customer. By the chosen scaling of the answers an equipartition is achieved.

For the first five questions three possible answers are given (Figure 2) and especially related to an IPS² business model. The last two questions are used to stabilize the IPS² business model index in the way the customer has answered the previous five questions (see also Figure 1).

A toolbar for the navigation is implemented (Figure 2). The user of this tool can navigate between the different pages by using the *previous question* or *skip question* button. By skipping the question it is not used for the prognosis of the IPS² business model. The tool user has the possibility at any time of tool use to answer these skipped questions, as well as to change given answers. The *restart question* will clear all data and start the tool with question 1. With the *home* button the tool user reaches the first webpage, where links to other tools are presented.

To identify the initial IPS² business model a scale is designed. The general scale range from

0 Function oriented IPS² business model,

1 Availability oriented IPS² business model to

2 Result oriented IPS² business model (see also Figure 1).

This scale is used to codify the given answers and to calculate the resulting IPS² business model index.

As an overview of answering status and to see e.g. skipped questions, a table of answers is presented.

Three questions have the possible answer "perhaps", so that this can be identified as an uncertainty of the customer. This uncertainty of the given answers is shown by a little view box (Figure 2).

5.3 Questions and Functionality

As mentioned above the questions can be answered by IPS² provider or directly by customer.

The seven questions were developed in a special workshop of the research project TR 29 concerning different influences of the IPS² business model (see 3.2). Result of the workshop was a list of 38 attributes with different characteristics for the three IPS² business models. This information was used to create the seven questions.

The stabilization of the IPS² business model index by the last two questions was done by a rule-based operation for the answer possibility *No*. The IPS² business model index of the previous five answers is used as algorithm input. If the IPS² business model index of the first five answers is related to a function oriented IPS² business model, a non existing network of supplier (question six) do not lead to a full loading of the question. Typically a non existing network of supplier characterizes the result oriented IPS² business model. Summarized, the index for this answer possibility is set dynamically concerning the result of the previous answers.

By answering with a *Perhaps* an uncertainty index is set (Figure 2), so that the IPS² provider can react to dispel the uncertainty.

The questions can be summarized with the following attributes:

- First question (I): Customer skills,
- Second question (II): Customer will to buildup skills,
- Third question (III): Property rights at the IPS²,
- Fourth question (IV): Human resources for the IPS²,
- Fifth question (V): Outsourcing of production and/or business processes,
- Sixth question (VI): Existing network of suppliers and
- Seventh question (VII): Process monitoring.

The answers have different importance on the IPS² business model and can be related to the three elements of the IPS² business model (see 3.2):

- Value Configuration: (I), (II), (IV), (V), (VII);
- Value Proposition: (I), (II), (III), (VI), (VII) and
- Revenue model: (III).

This leads to the possibility to match the answers with the IPS² business model.

To get some information about relevant service shares some answer possibilities are linked with suitable services. The services, which are automatically chosen by this relation, are summarized on the result page of this tool (Figure 3).

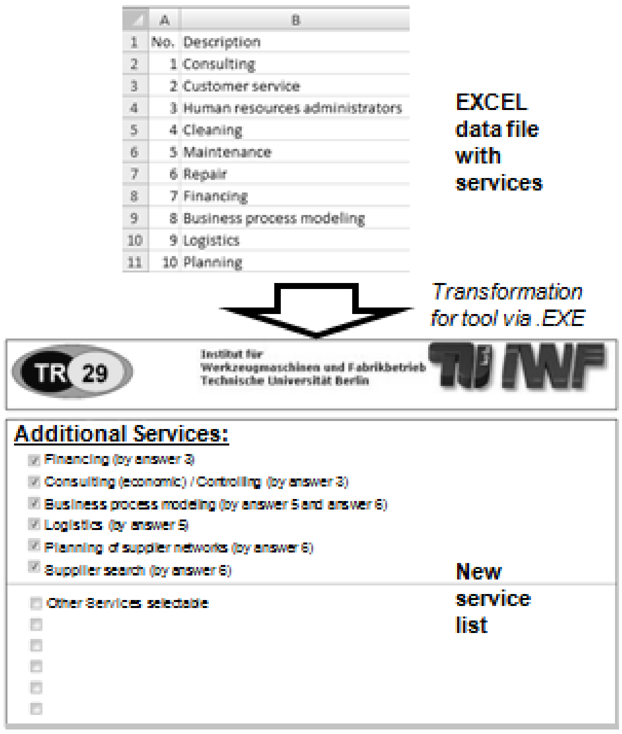

Figure 3: Update of Service Data

As a result of the tool the customer related IPS² business model index for the answers and the result of the questions is presented after the tool use. The resulting IPS² business model is specified.

The research project SFB/TR 29 has developed different tools, which can use the results of the tool. The tool in turn is now implemented in a support system for the IPS² creation called assistance system [17].

The determined information is prepared as an input for two IPS² relevant methods in the IPS² planning phase:

- Layer Method [18] and
- IPS² Compass [19].

The Layer Method purpose is to support the planning and development of IPS². It can help to clarify the design task and to derive requirements for IPS² development.

The IPS² Compass describes the influence of collected customer needs for the decision between make or buy and manual or automated. The IPS² Compass points in the direction of this decision (e.g. automated). The IPS² Compass can be used to characterize the resulting revenue model.

For the IPS² Compass the answers are also related with the answer possibilities. The attributes, which have to be linked to the answer possibilities, are:

- Make,
- Buy,
- Manual and
- Automated.

Because of these specific requirements of the IPS² compass not all answer possibilities have an influence on the customized IPS² Compass.

5.4 Service Data Update

With the result of a survey suggested services are listed. A manual selection of the automatically chosen services can be done by the user (Figure 3).

To implement existing, external lists of services a special update function is programmed for the tool. An excel file with services' descriptions can be used as an input for the tool (Figure 3). The transformation to an html page is done by an executable file. An easy and dynamical update of new service lists is thereby possible.

With the requirement that the tool has to run as a local application, a server language, like php, isn't appropriate, because for these languages the local data access is forbidden. Therefore the update of the service list is done via a separate application, which is programmed in C++. The application creates a source code by the new service data list. Also the additional services are selectable (Figure 3).

A comparison of services automatically derived by the answers and additional services is done. That procedure eliminates doublings of displayed service.

6 SUMMARY

Industrial Product-Service Systems are a customized solution for the industrial sector. The characteristics of an IPS² can be linked to these requirements and have to be taken into account by identifying the IPS² business model.

Coming from the definitions of PSS this paper presents the characteristics of an IPS² and their resulting IPS² business model definition.

Three exemplary IPS² business models were named and can be used in the IPS² lifecycle. The identification which IPS² business model fits best with the customer needs is an important task for the IPS² provider. Therefore a tool with specific questions is programmed to identify an initial IPS² business model in the early stage of development by the answers of the customer.

The answers are classified to the given IPS² business model elements to point out the influences of the answers on the IPS² business model elements *Value Configuration*, *Value Proposition* and *Revenue model.*

The procedure for the analysis of the answers and the results are shown. An IPS² business model index represents the IPS² business model.

With the tool the IPS² provider can be supported to optimize the customized IPS² creation and thereby use the innovative potentials of the integrated product and service Creation and use for the market of machine tool manufacturer.

In the future the evaluation of the tool by industrial partners is planned.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Kuhlmann, A., Sauter, W., 2009, Allgemeine Betriebswirtschaftslehre, TEIA Lehrbuch Verlag, Berlin.

[2] Rösner, J., 1998, Service: ein strategischer Erfolgsfaktor von Industrieunternehmen?, Steuer- und Wirtschaftsverlag Hamburg, Hamburg.

[3] Corsten, H., 2001, Dienstleistungsmanagement, Lehr- und Handbücher der Betriebswirtschaftslehre, 4. Auflage, R. Oldenbourg Verlag, München.

[4] Uhlmann, E., Meier, H., Stelzer, C., Geisert, C. Völker, O., Krug, C., 2009, Dynamic IPS² Networks and Operation Based on Software Agents, CIRP IPS² Conference (CIRP Industrial Product-Service Systems), 1-2 April 2009, p. 305-310, Cranfield, UK, ISBN 978-0-9557436-5-8.

[5] Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J. R., Angus, J. P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I. M., Wilson, H., 2007, State-of-the-art in product-service systems, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, Professional Engineering Publishing, Volume 221, Number 10 / 2007, p. 1543-1552, ISSN 0954-4054.

[6] Benkenstein, M., Güthoff, J., 1996, Typologisierung von Dienstleistungen. Zeitschrift für Betriebswirtschaft, 66, p. 1493-1510.

[7] Engelhardt, W., Kleinaltenkamp, M., Reckenfelderbäumer, M., 1993, Leistungsbündel als Absatzobjekt – Ein Ansatz zur Überwindung der Dichotomie von Sach- und Dienstleistungen, Zeitschrift für betriebswirtschaftliche Forschung, 45. Jahrgang 1993 – Heft 12, ZfbF, Lengerich/Westf..

[8] Downar, Peter, 2003, Vermarktung industrieller Dienstleistungen – Strategien, Prozesse, Strukturen, Deutscher Universitäts-Verlag/GWV Fachverlage GmbH, Wiesbaden.

[9] Hilke, W., 1989, Grundprobleme und Entwicklungstendenzen des Dienstleistungsmarketing, In: W. Hilke (Eds.), Dienstleistungsmarketing, Gabler Verlag, Wiesbaden.

[10] vom Brocke, J., 2007, Serviceorientierte Architekturen: SOA – Management und Controlling von Geschäftsprozessen, Verlag Vahlen, München.

[11] Müller, P., Stelzer, C., Geisert, C., Uhlmann, E, Knothe, T., 2008, Kernprozesse hybrider Leistungsbündel, wt Werkstattstechnik online, 7-8/2008, p. 581-586, Springer, ISSN 1436-4980.

[12] Timmers, P., 1998, Business Models for Electronic Markets, Journal on Electronic Markets, 8(2), p. 3-8.

[13] Osterwalder, A., 2004, The business model ontology – A proposition in a design science approach, doctoral thesis, l'Université de Lausanne.

[14] Tukker, A., Tischner, U., 2004, New business for old Europe product-service development as a means to enhance competitiveness and eco-efficiency, final report of suspronet (Sustainable Product-Service co-design Network).

[15] Stähler, P., 2001, Geschäftsmodelle in der digitalen Ökonomie, 2. Auflage, EUL Verlag, Lohmar.

[16] Guideline VDI 3423, 2002, Technical availability of machines and production lines Terms, definitions, determination of time periods and calculation, Beuth Verlag, Berlin.

[17] Uhlmann, E., Bochnig, H., 2009, Computer Aided IPS² Development, Second International Seminar on IPS², p. 31-36, Berlin, Shaker, ISBN 978-3-8322-8473-2.

[18] Müller, P., Kebir, N., Stark, R., Blessing, L., 2009, PSS Layer Method – Application to microenergy systems, In: Sakao, T.; Lindahl, M. (Eds.), Introduction to Product/Service-System Design, p. 3-30, ISBN 978-1-84882-908-4.

[19] Rese, M.; Karger, M.; Strotmann, W.-C., 2007, Welche hybriden Leistungsbündel für welche Kunden, wt Werkstattstechnik online, 7-8/2007, p. 533-537, Springer, ISSN

Design of PSS Revenue Models

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Abstract

Often practitioners react deprecatingly to PSS and point out risks in financing and investing. This deviates greatly from the academic perception of PSS. This paper aims at assessing PSS revenue model design to contribute to close this gap. It starts with discussing common PSS that can be found in industrial application. Considering PAT, a PSS revenue model proposed by Kim et al. [4] is used to identify fundamental mechanisms to coordinate the behaviour of PSS-supplier and PSS-customer. Generally applicable findings will be compared to another PSS revenue model which is used in industrial application, namely outsourcing.

Keywords

Revenue model, performance measure, PSS, outsourcing

1 INTRODUCTION

1.1 Motivation

In scientific publications on the issue of bundling technical products and services, the fact that value creation can be increased through new business models is frequently discussed [1, 2]. The combination of products and services reaches from product after sales services (e.g. maintenance) up to Product Service Systems (PSS). PSS are characterized by an integrated and mutually determined process of planning, developing, delivering and using of products and services containing immanent software components.

In doing so, added value of PSS for PSS-supplier and PSS-customer is based on new revenue models. These serve substantially for dividing costs of delivery and revenue of use between PSS-supplier and PSS-customer and therefore steer the behaviour of the contracting parties. Thus, the strategic design of revenue models gains in importance [3]. With the aim of increasing total value creation by means of PSS, innovative revenue models are discussed especially in academic publications. With that, providing value instead of technical products or service processes as a basis for PSS pricing is often discussed.

People from industry frequently react sceptically with regard to these revenue models being innovative. They argue that PSS is not a new approach to increase value in general. They refer PSS to be a novel marketing strategy to increase sales of service and to hide weaknesses of technical products. Moreover, they frequently refer to outsourcing or to performance-based contracting which are “PSS in industrial application” for many years.

In particular with regard to the design of revenue models, optimistic academics and sceptical practitioners collide. Among others, the differing appraisement of PSS revenue models can be a result of an insufficient knowledge transfer between theory and practice. Thus, there is a lack of information on both sides which needs to be eliminated.

1.2 Scope

It is the aim of this article to contribute to the examination of PSS revenue model design. Focussing on business models which target increasing customer value is a first step towards eliminating the mentioned information deficit between academics and practitioners. In order to achieve the stipulated aim, this article is divided into the following sections:

Based on the introduction, section 2 presents the basic understanding of PSS in academia. Additionally, section 2 introduces two PSS, namely “outsourcing” and “performance-based contracting”, to link PSS to its common industrial applications.

Section 3 includes the theoretical contemplation of PSS revenue model design. This section starts with a brief explanation of the underlying understanding of “PSS revenue models”. This is taken as a basis for the following discussions. The analysis of the PSS revenue model proposed by Kim et al. [4] which focuses on performance based contracting in after-sales service supply chains forms the basis for a theoretical discussion of PSS revenue model’s architecture. As the design of PSS revenue models is closely linked to the design of incentives for contractual parties, the analysis is carried out by taking the Principal Agency Theory [5] into account.

A PSS which is commonly used in practice, namely outsourcing of production processes, serves as an example to be assessed in section 4. Particular focus is placed on analysing the revenue model’s architecture of a real example which has been abstracted for data protection reasons. The objective is to reveal the effect of the PSS revenue model design on decision making and risk sharing between PSS-supplier and PSS-customer.

The article concludes in section 5.

2 PSS

Already since the beginning of the 1990s, the combination of products and services is marketed as PSS in scientific literature [6]. Especially at the beginning the focus has been placed on endeavouring to comprehend technical products and attending services as integral problem solutions. Thus, products and services are no longer regarded as separate sales objects but as a bundle (PSS) which can be offered to the customer. PSS can be differentiated, inter alia, subject to the sales market (B2B or B2C) that is targeted.

2.1 Outsourcing (OS) und Performance Based Contracting (PBC)

In industry, the existing manifold combinations of products and services are, however, less known as PSS but rather under terms like outsourcing (OS) [7], performance-based contracting (PBC) [8], etc..

The bundling of products and services to PSS is reflected, in particular, in the widely spread principle of **OS**. Legally binding cooperation agreements between OS-supplier and OS-customer are used to regulate the outsourcing of processes which are initially performed by the OS-customer himself. Shifting processes from one company to another frequently also includes shifting its required resources. These comprise both technical products and the staff. Through the strategic OS of production processes the extent of the economic value chain of the outsourcing company can be reduced. The motivation for OS can be manifold and reaches from focussing on core competences up to reducing investment risks and capital lockup. Moreover, the principle of OS usually promises more flexibility due to the scalability of the outsourced production processes. In OS, various revenue models have been established. For example "pay on demand" or "pay per use".

PBC does exist in manifold forms. Despite the customization of PBC solutions, similarities can be detected. In general, PBC solutions are based on products, machines, equipment or entire systems which are no longer sold to the customer, but which are made available to him. With that, the compensation of the PBC-supplier is typically based on a performance-related user fee. Thus, the PBC-customer pays a fee which is primarily charged according to the utility provided by the PBC-supplier. Thus, no service no cash. Analogously to the basic understanding of PSS, products and services are only offered as bundles. As with OC, PBS also results in the responsibility to maintain the functionality of an infrastructure being shifted from the customer to a PBC-supplier. As the underlying revenue model refers either to "pay-per-performance" or "pay on production", the PBC-supplier bears the financial risk and therefore the costs for a system failure or inadequate production quality.

OS and PBC are dominated by the shift of ownership of tangible and intangible assets from one party to another. The result is a reallocation of risks between supplier and customer. But, reallocating risks creates incentives and has got an immanent influence on human behaviour. As a major consequence, this needs to be taken into account for designing PSS revenue models.

2.2 PSS in industrial application

A well-established PSS can be found in the field of hard-copy document management [9, 10]. As Xerox and Océ are manufacturers of photocopying machines and, hence have best knowledge about their technical products, they have specialized in providing integral printing and document management solutions to companies, public authorities and universities. The PSS approach consists of transferring the operation of photocopying machines and printers to the manufacturer. Providing a high degree of process flexibility as well as ensuring a certain level of quality and availability are integral aspects of their offer. Thus, the corresponding revenue model is based on the output quantity of the copying machines and the flexibility to adapt to increasing or decreasing quantities of copies or prints.

Another example for PSS originates from the field of aviation and is offered by Rolls Royce, namely "Power By The Hour" and "Rolls Royce Total Care" [11]. Here, the jet engine manufacturer no longer only sells jet engines including after-sales services. Instead, he offers jet engine's availability. The remuneration of the PSS-supplier is based on actual flight hours which are done by an aircraft containing the available jet engine power.

Both examples, outsourcing of document management on the one hand and performance based contracting of jet engines on the other hand, have at least one thing in common. A PSS-customer's decision has shifted from MAKE to BUY. This basically results from coordination of external markets being more efficient than the internal coordination within the company. Especially taking into account the shift from make to buy can have a big influence on PSS revenue model design, as it will be shown in the following section.

3 THEORETICAL CONTRIBUTIONS TO PSS REVENUE MODEL DESIGN

3.1 Revenue model – definition and classification

The application of PSS in industry is based on contracts which generally contain three aspects. According to Burianek et al. [3], a contract defines i) the distribution of generated value among the contractual parties, ii) the allocation of rights for decision-making and iii) risk allocation. The distribution of generated value is determined by selection and design of a revenue model. Based on the preliminary work of Hünerberg and Hüttmann [12], the term "revenue model" can thus be defined as follows:

"A revenue model is defined as a heuristic model which addresses the measurable performance parameters for pricing and is therefore decisive for pricing. According to the basic understanding of revenue, there is a mutual dependency between price and quantity."

In the relevant literature on PSS, various approaches to classify revenue models can be found. Tucker and Tischner [13] identify three types of revenue models. The authors differentiate between i) functional, ii) usage-based and iii) performance-based revenue models. Burianek et al. [3] present an extended classification which uses the measurable output of a value-adding process (e.g. costs, frequency of utilization or availability) as a classification criterion.

3.2 PAT and PSS revenue model design

The design of PSS revenue models is based on designing incentive mechanisms. Taking into account a fundamental theory of economics, namely the principal agency theory (PAT) [5], effects of incentives on human or organisational behaviour can be modelled and assessed. In PAT a principal commissions one or more agents to carry out an activity, whereby it is assumed that the principal and the agent have various pieces of information, for example about the system or the system's environment. Both influence their actions and behaviour respectively. As gathering information causes costs, the principal is not able neither to observe all actions of the agent nor the current state of system's environment. Thus, he can often only observe the result of the agent's actions. Therefore, it is the principal's aim to abolish the information dissymmetry between him and the agent. For this purpose, the principal offers a certain remuneration to compensate the effort of the agent. Basically, this can be regarded as a revenue model, whereby the remuneration shall, on the one hand, offer an incentive to the agent to use his information advantage and, on the other hand, contribute towards reducing or abolishing any dysfunctional behaviour of the agent.

3.3 PSS revenue model design according to Kim et al.

One article dealing with the design of PSS revenue models and taking PAT into account has been published by Kim et al. in 2007 [4]. The PSS regarded by Kim et al. refers to the performance based contracting in after-sales service supply chains for jet engines.

Underlying PSS

In the example used by Kim et al. [4], the owner of an aircraft is regarded as the principal. The technical system "aircraft" consists, inter alia, of the subsystem "jet engine" which is produced and serviced by a specific supplier (agent). In contrary to a classic jet engine sale and the conclusion of an after-sales service agreement with the agent, Kim et al. now contemplate a PSS. With this the agent remains owner of the jet engine. Thus, the agent does no longer sell a technical product to the owner of the aircraft (principal) but instead the functionality of the subsystem jet engine. Accordingly, the technical availability of the engine becomes a scarce, tradable commodity.

Kim et al. focus in particular on the technical availability of the PSS and define an appropriate performance measure to model the technical availability, whereby they do not directly refer to successfully completed flight hours but define an indirect measure to quantify jet engine's availability. This indirect measure is referred to as "backorder" and describes the number of malfunctions in which an engine cannot be immediately substituted by a functioning replacement system (also see figure 1).

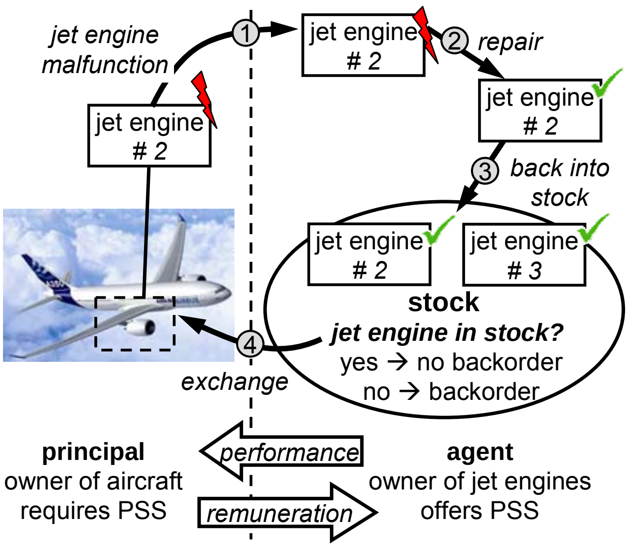

Figure 1: Interrelationship between principal and agent

On the one hand, the availability of the PSS is determined by the statistical failure probability of the technical product itself. On the other hand, the agent's decision regarding the stock quantity of replacement jet engines has just as much influence on the availability of the PSS.

The stipulated performance measure, namely the backorder, serves as an incentive for the agent to keep a sufficient quantity of replacement jet engines in stock. A large stock on the one hand lowers the risk of a backorder, but on the other hand does cause costs. Hence, the agent can spend additional effort for cost reduction. This is possible, if he changes the design of the technical product to make it more robust. Thus, the availability of the PSS from the agent's point of view is determined by two adverse parameters, namely stock quantity and cost reduction.

Discussion of the PSS revenue model

The analysis of PSS revenue model design proposed by Kim et al. [4] results in the fact that a revenue model for an availability-oriented PSS is, in principle, composed of the following three revenue components (see figure 2)

PSS revenue model:

$$R(C,P) = \underbrace{f}_{\text{fixed remuneration}} + \overbrace{\underbrace{\alpha C}_{\text{cost-oriented share}} \pm \underbrace{\beta P}_{\text{performance-oriented share}}}^{\text{variable remuneration}}$$

Figure 2: revenue model according to Kim et al. 2007 [4]

Besides a component for fixed remuneration (f), the variable remuneration is devided into a cost-oriented share (C) and a performance-oriented share (P). The variable remuneration components are integrated into the PSS revenue model with specific weighting factors. The cost-related weighting factor ($0 \leq \alpha \leq 1$) serves for dividing resulting costs for keeping a certain stock quantity between the principal and the agent. In contrast, the penalty for not delivering an available jet engine is included by the last term summand. Here the number of backorders is multiplied by a performance-related weighting factor ($0 \leq \beta \leq 1$). As the performance is indirectly measured in the example described by Kim et al., in this case the third term leads to the agent's remuneration being decreased ($-\beta P$). Determining f, α and β is part of the negotiation between PSS-supplier and PSS-customer and will end up in the PSS contract.

The analysis of the PSS revenue model proposed by Kim et al. leads to the following four findings regarding PSS revenue model design:

- A **pure fixed-price revenue model** (α=0 and β=0), transfers the entire risk of costs from the PSS-customer (principal) to the PSS-supplier (agent). This results in a great incentive for the agent to reduce costs. Cost reduction can be achieved by optimizing the technical product or by improving service processes. All this is steered by setting the agent's work input to decrease costs.
- A **pure cost-plus revenue model** (α=1 and β=0) serves for transferring the entire risk of costs to provide the PSS from the PSS-supplier (agent) to the PSS-customer (principal). This results from the fact that the principal is contractually forced to compensate any arising expenses of the agent. Thus, there is no incentive for the agent to reduce costs by optimizing the system. Additionally, the agent will only put in minor efforts to strive to increase PSS's availability.
- Fixed-price and Cost-plus revenue models normally do not provide any incentives for the PSS-supplier (agent) to improve the availability of the PSS. Both revenue models do only serve to shift all risks either to the PSS-customer or to the PSS-supplier.
- A **complete PSS revenue model** taking all three summands ($f \neq 0$, $\alpha \neq 0$ and $\beta \neq 0$) into account can, however, contribute towards efficiently dividing the costs for ensuring the availability, the risk of failure and the financial benefits resulting from PSS availability between the PSS-supplier (agent) and the PSS-customer (principal). In particular, the third summand generates incentives for the agent to behave in the interest of the principal.

Intermediate conclusion

In summary, a combined remuneration consisting of a fixed-price, cost-plus and performance-oriented share constitutes the basis for an availability-oriented PSS. Taking all three summands into account can lead to a win-win situation for the PSS-supplier and PSS-customer. This is based on sharing costs and financial benefits of availability of a PSS between both of them. Thus, the combined PSS revenue model constitutes, at least from a theoretical point of view, an effective alternative to a classic input/cost-oriented remuneration of the agent. An important issue is always the stipulation of an adequate performance measure to align PSS-suppliers and PSS-customers objectives.

4 REVENUE MODEL ANALYSIS OF AN AVAILABILITY-ORIENTED PSS FOR PROCESS OUTSOURCING

The outsourcing of a process which can be regarded as a PSS (see section 2.2) serves as a basis to assess a PSS in industrial application. In order to maintain secrecy the following case study has been constructed to represent all relevant aspects of the availability-oriented PSS.

4.1 Underlying case study

As shown in figure 3, in the initial situation a **company (C)** offers a product on a B2B sales market consisting of individualised and non-individualised components.

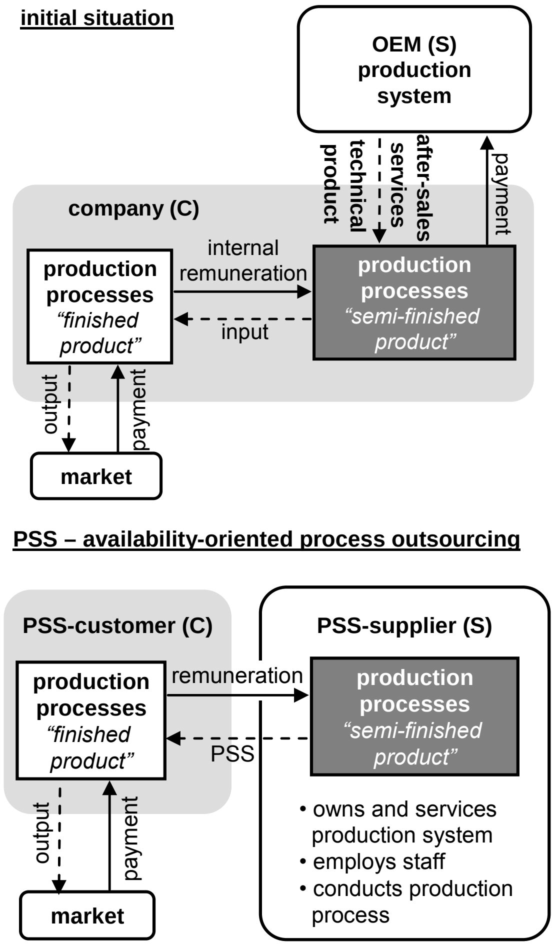

Figure 3: Underlying case study – initial situation and PSS

While the non-individualised components can be purchased on an external market, the production of individualised components requires company-internal resources. In the initial situation all necessary production facilities are property of C and are operated by employees of C. The raw materials required for producing the semi-finished product are available on the market. As not all of the processes required for producing the final product are core competencies of C, C has the possibility of outsourcing certain processes. An **OEM (S)** which has so far only delivered the production system and after-sales services to produce the semi-finished product to C, now offers C to take over the entire process up to the production of semi-finished products. By means of an adequate PSS, S now integrates itself into the production process of C. As shown in figure 3 the production of the semi-finished product is now provided by S to C.

For the official definition and specification of the PSS a contract is concluded between the **PSS-supplier (S)** and the **PSS-customer (C)**. This contract includes aspects which contribute towards the implicit or explicit determination of the revenue model. The implicit aspects include, for example, the specification of the machines to be used, the staff or the service-level agreement. In contrast, aspects such as the stipulation of production prices and the commitment of the PSS-customer to purchase certain quantities explicitly influence the design of a PSS revenue model.

4.2 Analysis – Different stages of the PSS revenue model

In the following, due to different contract variations different stages of PSS revenue models are analysed in order to reveal the influence of cost-plus, fixed-price and performance based components of remuneration.

1st stage: Mere Pay-On-Production (MPOP)

In the 1st stage of the PSS revenue model, C remunerates S based on the quantity of semi-finished products manufactured by S. C's motivation to conclude such a PSS contract based on a **Mere Pay-On-Production (MPOP)** remuneration could, for example, result from an insecure situation on the sales market. In this market the quantity of the final product demanded is fraught with risk. C therefore pursues the aim of making his production more flexible. Through concluding the contract with the PSS supplier S, C gains the possibility of transferring part of the market risk to S. At the same time, C achieves maximum cost flexibility by converting his fixed production costs into costs which are variable for him. Prerequisite for the unit-based remuneration of S is C's requirement regarding a guaranteed trouble-free operation of the PSS. In this sense, S will only receive a unit-based remuneration if the produced semi-finished products correspond to an agreed quality standard. If S does not provide sufficient capacity to produce the quantity of semi-finished product required by C, C reserves the right to procure the difference in quantity on the external market.

From PSS-supplier's point of view, this risk transfer is to be regarded differently. In particular, the calculation of the unit-based prices which have to refer to a predictable production quantity turns out to be problematic. In order to determine the underlying production quantity, S has to use an appropriate forecasting method. Under the prerequisite that the outsourcing concerns a production unit of C which already exists, S could, for example, use historical data for predicting future production quantities. Alternatively, the result of surveying the PSS-customer could be used as an input parameter for S's price calculation. But it has to be taken into account that C who is acting rationally and opportunistically will always indicate production quantities which are too high to realize unit-based prices which are as low as possible (Remark: this is only valid for the 1st stage of the PSS revenue model).

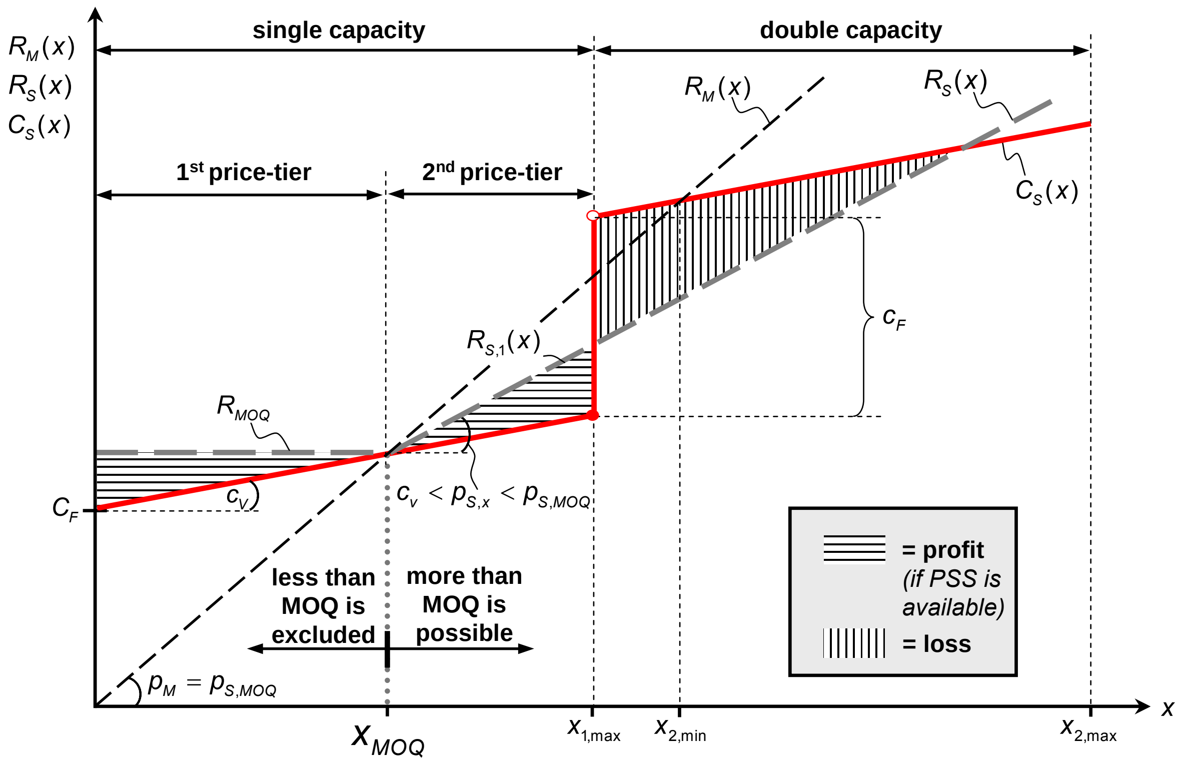

Figure 4: 1st stage (MPOP) and 2nd stage (BOQ) of the PSS revenue model

As the market risk is almost entirely transferred from C to S by applying the 1st stage of the PSS revenue model, the revenue situation is dissatisfactory for S. To generate a distribution of risks between S and C which is more advantageous, this revenue model needs to be adjusted. With this it also has to be taken into account that S can so far only react to quantity changes in the production of C. This needs to be regarded all the more critically as there are no incentives for C to forfeit his information advantage regarding a certain production quantity predicted by him.

2nd stage: Minimum Ordered Quantity (MOQ)

In order to reduce the risk to be born by S resulting from the uncertain estimation of a **production quantity which is not capable to cover his expenses**, the 1st stage of the PSS revenue model is extended by introducing a **Minimum Ordered Quantity (MOQ).** Due to this, C assures to remunerate S for delivering a certain production quantity x_{MOQ}. This is stipulated in a contract, whereby S is not only remunerated for MOQ, but is still remunerated depending on the quantity of semi-finished products x exceeding MOQ. A visualisation of this revenue model including MOQ is presented in figure 4.

The revenue function $R_M(x)$ depicted in figure 4 reflects the maximum revenue which can be achieved with the PSS. This is based on the market price p_M and on a given production quantity x. This basically corresponds to the 1st stage of the PSS revenue model and coincides with the assumption that process outsourcing provided by S can be traded on an external market. In this sense, p_M can be regarded as a reference price.

Moreover, the cost function of S, namely $C_S(x)$, has been depicted in figure 4 depending on the production quantity of the semi-finished product. $C_S(x)$ contains fixed costs C_F, step costs c_F and variable costs $c_V \cdot x$. Step costs c_F take into account that endless resource capacity cannot be assumed in general so that an increase of the production capacity is linked with a volatile increase of costs. In order to make this coherence clear by means of an example, double capacity represented by double manufacturing facility and associated staff, is depicted in figure 4.

The extension of the 1st stage of the PSS revenue model essentially consists of the introduction of a two-tiered price system. Whereas the price calculation of the first tier is based on the committed MOQ x_{MOQ}. The price for MOQ is determined by the market price p_M. Taking the PSS-supplier's perspective into account, first of all C_F is to be covered by the commitment. Besides the fixed costs, the additionally incurring variable costs are included to determine the price of the second tier. As fixed costs are already covered by MOQ, **the price in the second tier is always lower than that of the first tier.**

For using only single capacity, the revenue model's two-tier price system is reflected in the revenue function of S. Here, a differentiation is made between two levels of remuneration depending on the committed MOQ and the maximum production output $x_{1,max}$ which can be achieved by means of only one machine and associated staff. Resulting revenues to remunerate MOQ on the one hand and additional production quantity on the other hand are represented by R_{MOQ} and $R_{S,1}(x)$. The fixed remuneration R_{MOQ} of S is always carried out subject to the committed quantity, whereas the production output exceeding x_{MOQ} is remunerated on a variable basis.

Assuming both that S is initially seeking cost coverage of C_F plus $c_V \cdot x_{MOQ}$ and the intended price $p_{S,MOQ}$ is determined by the market price p_M ($p_{S,MOQ} = p_M$), S stipulates the production quantity x_{MOQ} as shown in figure

4. Based on this, S chooses a price $p_{S,x}$ in the interval $[c_V ; p_{S,MOQ} = p_M]$ for the second price-tier which targets variable remuneration. The lower interval limit of this price, namely c_V, results from the coverage of the additional variable costs $c_V \cdot (x - x_{MOQ})$, whereby the upper limit is given through the market price. By stipulating the price $p_{S,x} < p_{S,MOQ}$ for the variable remuneration, S generates an incentive for C to increase his production quantity.

A particularity of this two-tier price system is that the PSS supplier is only able to realize a profit if the actual production quantity x deviates from MOQ . This applies both for a positive and a negative deviation in quantity. It must, however, be taken into account that for a positive deviation the production quantity $x_{1,\max}$ may not be exceeded, as otherwise additional resources are required. In turn, this generates step costs.

If, however, C and S do not commit to MOQ but to the maximum quantity $x_{1,\max}$ which is producible with single capacity, S can contractually stipulate the maximum revenue. This results from choosing market price for the entire production quantity to be delivered by S. But only a minimal exceedance of $x_{1,\max}$ already requires additional capacity and additional step cost, thus S will suffer a loss. As $p_{S,x} \leq p_M$ always applies, the maximum loss resulting from exceeding single capacity is depicted in figure 4.

If $R_M(x)$ equals $C_S(x)$ both minimum quantities for single and double capacity can be defined by S. Hence, S will choose at least a minimum quantity $x_{2,\min}$ if double capacity is needed. As presented in figure 4, $x_{2,\min}$ represents the lower production limit if double capacity is offered to C. The upper production limit is defined by additional step costs for triple capacity.

Basically, the commitment of MOQ is substantially affected by the risk preference of S and C as well as by the existing information dissymmetry. There are various approaches and academic theories to determine MOQ. But, as industry is striving for cost coverage MOQ is determined by opposing revenues, resulting from different ways of pricing, to upcoming costs. Apart from break-even analysis, contract theory including negotiations between S and C should be taken into account from an academic perspective. But as observations reveal, break-even analyses are industries pricing approach number one.

In general, it can be taken from assessing the PSS in its industrial application that S will require an excessive MOQ as soon as S is more risk avers than C. The reason for this originates from the PSS-supplier's striving to minimize risk transferred to him. At the same time, the PSS-customer strives to achieve a **maximum risk transfer** to S in order to unfold production flexibility. As this dilemma substantially is caused by the information dissymmetry between the two parties, unequal distribution of information needs to be eliminated. This, however, can only be done if C is given an incentive to forfeit his knowledge advantage towards S. Such an incentive results from the PSS revenue model and its two-tier price system. With this, S is paying C to forfeit his information advantage by reducing MOQ. Committing a lower MOQ unfolds the opportunity that C can reach the revenue model's second price tier early and thus profit from a lower price than in the first price-tier.

In summary, it can be observed that risk of costs to be borne by S due to a **production quantity which is too low** to cover his expenses is covered with the 2nd stage of the PSS revenue model including a commitment of MOQ. The risk of step costs resulting from a **production quantity which is too high** still remains and will not be covered by the 2nd stage of the PSS revenue model.

3rd stage: Assured Minimum Capability (AMC)

In order to abolish the risk of **step costs arising from a production quantity which exceeds a predetermined manufacturing capacity**, the 2nd stage of the PSS revenue model is expanded once more. This is carried out by introducing an **Assured Minimum Capability (AMC)** offered by S to C to ensure a "certain level of performance" (see figure 5). AMC can be regarded as a quantitative performance measure as well as an insurance against production downtimes. Thus, C can rely on a guaranteed capability of the PSS provided by S to produce a certain quantity of semi-finished products.

Thus, S has to compensate all incurring costs resulting from non-performance. To deliver the assured quantity of semi-finished products S has to procure them from the external market. The incurring costs are composed of the production costs of external suppliers which are at least $p_M \cdot x_{non-performance}$ plus all required transaction costs, such as extra costs for transport etc.

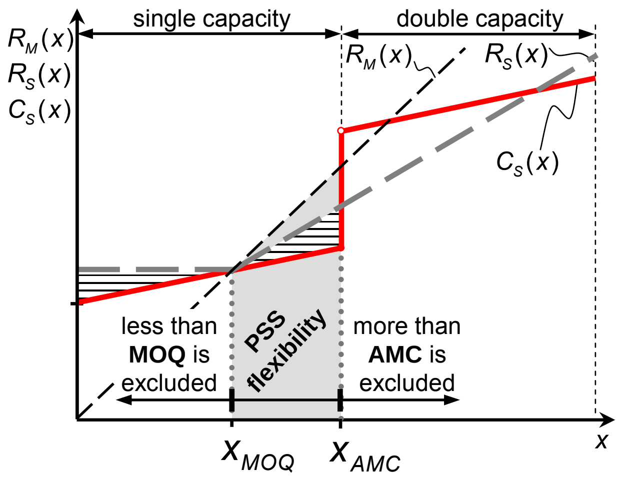

Figure 5: MOQ and AMC defining flexibility of PSS

As AMC is introduced by S to abolish the risk of uncovered step costs he defines AMC depending on the maximum quantity that can be achieved with a certain level of capacity. As depicted in figure 5, the quantity contracted in combination with AMC to ensure single production capacity equals $x_{AMC} = x_{1,\max}$. Furthermore, the maximum flexibility of a PSS is contracted. And as depicted in figure 5, it is defined by a quantity ranging from x_{MOQ} to x_{AMC}.

The benefit for S resulting from the introduction of AMC depends on the elimination of information advantages of C regarding his forecasted production quantity. This advantage will be opened up, if C discloses his maximum production quantity in order to be ensured by stipulating AMC. As PSS-customers are not just anonymous companies but human beings who decide to or decide not to reveal their intension smart wording can be extremely helpful to implicate a certain intension. In case of real world process outsourcing, especially the smart wording of "Assured Minimum Capability" generates a positive notion. But apart from a nice marketing phrase it implies that the outsourced production flexibility of C is substantially restricted by means of its underlying implication. This, however, entails a loss of flexibility for C, because S simply contracts to be able to generate the defined quantity. Anything else is just obliging.

By extending the PSS revenue model to the 3rd stage, a quantitative corridor is defined by MOQ and AMC (see figure 5). Basically, this corridor serves for covering fixed and variable costs of S and enables S to exclude or at least reduce the risk of unforeseeable step costs. Thus, the negotiation regarding the stipulation of this corridor should be substantially steered by S as S obtains an information advantage with regard to the capacity of his production system, staff and production processes.

4.3 Concluding Remarks

It could have been shown that an unequal risk distribution between PSS-supplier and PSS-customer can, in particular, result from inefficient PSS revenue model design. In this case, risks originating from outsourcing of production processes can, however, be limited by stipulating a Minimum Ordered Quantity (MOQ) and an Assured Minimum Capability (AMC).

The necessity of limiting risks shows that mere remuneration based on production quantity combined with maximum production flexibility is probably suitable for the PSS-customer, but doesn't generate a win-win-situation for both parties. In order to realize the basic idea of PSS which can be ascribed as generating a win-win situation by integrating product and service an elimination of information dissymmetry is needed.

The comparison of findings of section 3 and the analysis of the case study of section 4 leads to the following conclusions:

- Both PSS revenue models are composed of remuneration mechanisms which comprise fixed-price, cost-plus and performance-orientieted components.
- Regarding this case study a **fixed-price-oriented remuneration** does exist if S and C do commit to a certain Minimum Ordered Quantity (x_{MOQ}) and if x_{MOQ} won't be exceeded.
- A **cost-plus-oriented remuneration** is, however, effected for a production quantity of semi-finished products which exceeds the committed Minimum Ordered Quantity ($x > x_{MOQ}$).
- A **performance-oriented component** for remuneration is achieved with the introduction of an Assured Minimum Capability. It is integrated into the PSS revenue model through the stipulation of the maximum production quantity $x_{1,\max}$ that can be ensured with single production capacity. (**Remark:** The choice of a performance measure substantially depends on the PSS characteristics. In this case study, the availability of a certain production quantity has been chosen to be the performance measure. This was necessary as there is no discrete subsystem, as with the jet engine example, but a continuous production quantity).
- Applying these remuneration mechanisms separately may lead to a one-sided distribution of risks, but combining all three of these mechanisms can end up in an equitable sharing of risks between both partners.

5 SUMMARY

A substantial effect on the exploitation of PSS potentials is determined by the design of PSS revenue models. The aim of this article was to analyse PSS revenue models with regard to their components and effects.

On the basis of the clarification of vital aspects underlying this article (e.g. revenue model, PAT etc.), the fact that PSS are in principle relevant in practice could initially be demonstrated by means of characterising "outsourcing" and "performance-based contracting". The discussion of the PSS revenue model proposed by Kim et al. [4] has led to the conclusion that a combined remuneration, consisting of fixed-price, cost-plus and a performance-oriented proportion, must always be sought for availability-oriented PSS. Only the combination of all of these components of remuneration can lead to a win-win situation for both the PSS-supplier and the PSS-customer. These findings have been confronted with a PSS revenue model which is widely used in practice, namely the outsourcing of production processes. Among others, it has been shown that this revenue model also consist of different revenue components. Here, a win-win situation for the PSS-supplier and the PSS-customer has been generated by committing a certain Minimum Ordered Quantity and an Assured Minimum Capability.

Besides, it has been discussed that PSS revenue model design should not only focus on functionality of incentive mechanisms for risk allocation and cost reduction but sometimes should also take clever wording into account.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Vargo, S.L.; Lusch, R.F.: Evolving to a new dominant logic for marketing. In: Journal of Marketing, Vol. 68, 2004.

[2] Oliva, R.; Kallenberg, R.: Managing the transition from products to services. In: International Journal of Service Industry Management. 2003.

[3] Burianek, Ferdinand; Reichwald, Ralf: Contractual Implications of Solution Selling. Proceedings of INFORMS 2009, International Conference on Service Science, Hong Kong. (2009).

[4] Kim, S.-H.; Cohen, M. A.; Netessine, S.: Performance Contracting in After-Sales Service Supply Chains. In: Management Science, Vol. 53. 2007.

[5] Bamberg, Günter; Spremann, Klaus: Agency Theory, Information, and Incentives. 2. Berlin : Springer, 1989.

[6] Belz, Ch.; Büsser, M.; Bircher, B.: Erfolgreiche Leistungssysteme. Anleitungen und Beispiele. Schäffer-Poeschel Verlag. 1991.

[7] Douglas Brown; Scott Wilson: The Black Book of Outsourcing: How to Manage the Changes, Challenges and Opportunities. John Wiley & Sons Inc. 2005.

[8] Kleikamp, C.: Performance Contracting auf Industriegütermärkten: Eine Analyse der Eintrittsentscheidung und des Vermarktungsprozesses. Dissertation. Josef Eul Verlag, Lohmar-Köln. 2002.

[9] www.consulting.xerox.com/index/ (2009.11.15)

[10] www.oce.com/de/services/ (2009.11.15)

[11] www.rolls-royce.com/civil/services/ (2009.11.15)

[12] Hünerberg, R.; Hüttmann, A.: Performance as a basis for price-setting in the capital goods industry: concepts and empirical evidence. In: European Management Journal, Vol. 21. 2003.

[13] Tucker, A.; Tischner, U.: New Business for old europe – Product-Service Development,

Competiveness and Sustainability. Greenleaf Publication, Sheffield, UK, 2005.

Early Stage Assessment of Service-based Business Concepts

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Abstract

In literature the positive economic effects for suppliers and customers of Industrial Product-Service Systems (IPS^2) have often been described. However, provider companies often struggle when it comes to realize win-win potentials. Therefore, an early stage assessment is needed to allow companies to forecast benefits, risks, costs and profits of the new business model in early stages of IPS^2 planning.

It will be shown how business plans can be used to describe and assess the process, requirements and pitfalls in creating added value via IPS^2. The results of two case studies of machine tool manufacturers turning into solution providers are reported.

Keywords

Service-based business concepts, Business planning, Case studies

1 INTRODUCTION

Developing innovative products proved to be a risky business: the overall success rates are low [1] and it appears to require 3,000 ideas to develop and introduce one substantially new offer into markets [2].

Research analyzing 'how to increase success rates in innovation' has highlighted the importance of the 'front-end' stages of innovation processes [3, 4]. The greatest opportunities for improving the overall innovation process seem to lie in the very early phases of new product development [5]. At this early stage, the effort to optimize is low and effects on the whole innovation process are high [6, 7].

Successfully developing innovative products emphasizes during the front-end phase both the market and technical assessments before the projects move into the development phase [8]. Further, successful business emphasizes the voice of the customer and the strong market orientation, especially in the early stages. A crucial task in front-end innovation processes is to reduce uncertainties [9]. Recent studies [10, 11] clearly indicate that successful innovators are distinct from less successful ones by their enlarged and more systematic front-end activities.

Developing new business concepts comprising a new value proposition, a new revenue model and a new value chain architecture [12] seems to be a much more radical innovation compared to the development of 'merely' innovative products. Hence innovation processes targeted towards business concept innovation should highlight the front-end phase even more due to the increased capacities involved in such processes.

Against this background, the following paper proposes a concept for organizing front-end activities in business concept developing, including the business model approach. It is organized into the following sections: after introducing 'business planning' as a means for early stage assessment (section 2), a specific business planning model for service-based business concepts is described (section 3). In section 4, two case studies will clarify how to utilize this specific concept in industry. Section 5 summarizes the results and explains the need for further research.

2 BUSINESS PLANNING AS A MEANS FOR EARLY STAGE ASSESSMENT

Business planning is a means to systematically assess the potential of success for new businesses. Mostly business planning is seen as an activity strictly reserved for start-up firms. However, a business plan is an equally important instrument also for entrepreneurial analysis of new ventures.

The influence of business planning on venture success is discussed in a contradictory manner in the literature, as studies provide empirical data advocating the positive and also neutral affects on an organization's performance exist. Researchers promoting the positive influence of writing a business plan argue that planning activities lead to a more efficient use of resources [13] and reduce the likelihood of termination [14]. Other researchers raise doubts about the value of business planning, arguing that the time invested in planning would be invested more productively in the acquisition of resources and emphasize that planning could lead to organizational inertia [15]. Actually, both schools are right. Formal planning, mainly in the entrepreneurial context where a business infrastructure already exists, might reduce firms' ability to adapt to changes in their environment as multiple organizational hierarchies are involved in the decision process which significantly expands the time and money invested [16]. Additionally, formal planning activities can give a deceitful feeling of control, suppressing the openness needed for problem solutions [17] and often channels activities along well-worn tracks. Inherent in any planning action is the risk of applying a meaningless ritual uncoupled from its objective [18].

But also the planning school advocacies have strong arguments. Planning structures your mental model and forces you to bring it to paper and make it understandable for others, mostly to financial investors, who have a very critical eye. Formal planning also improves the decision-making process by providing structures, revealing information gaps and examining subjective assumptions [19]. In addition, planning activities help to identify goals and set up specific milestones for achieving them. Especially when people have to solve problems where uncertainty is high and they cannot rely on experience or habit in this field to begin with, a structured planning process can be invaluable.

In the context of establishing new ventures or a new business area, planning gives an orientation for the timing of resource flows, of the supply and demand of resources needed [20] and allows bottlenecks in the value chain to be spotted [21]. Formal planning forces people to transform concrete ideas into an action plan and thus to draw a line between intended result and activities needing to be done. All the listed advantages contribute in terms of resources e.g. financial and timely resources, to minimize misdirected effort [22].

With respect to the argumentation from both sides, business planning is seen here according to [23] as highly beneficial for future success, provided that the involved actors see it as an adaptive approach, not limiting their point of view to the established plan. Instead they must be open to changes in requirements in a dynamic environment and in real market needs. The process-related character of business planning cannot be over estimated.

A business plan is the written output of the prior business planning activities. Though different styles of business plans exist, in the prominent literature the needed input data is widely agreed upon/consensual [24]:

- Executive summary
- Product or service description
- Market analysis
- Marketing and sales strategy
- Business model and organization
- Team
- Opportunities and risks
- Financial planning and
- Milestone schedule

Elaborating a business plan can take between three months and one year, depending on how much time is invested daily and by how many persons. Facing the fact that a brilliant business concept in mind does not imply that it works in idea has to be made in order to minimize invested time and costs which might be without success. Before setting up a detailed business plan, a general plan on a higher aggregated level should be established. Here the idea should be transformed into a basic business model. In the business model the value proposition of the good or service for the customer should be explained, a rough plan of the architecture needed to produce and deliver the good or service should be set up. Then also part of the business model is to define the revenue model. All three components need to fit together to resemble a consistent business strategy. After the business model is drawn up, a thorough market analysis has to be performed next. Personal estimations on the customer potential strengthened by enthusiasm for the own idea are illusory. Therefore an assessment of the Porter's Five Market Forces [25] will provide an answer if any more effort in planning the new venture is approved at all.

Business planning is a worthwhile instrument for both start-up firms and already existing ones that aim to start a new business field. Within the first step of formally structuring a general business plan the potential of business models can be assessed at an early stage. In doing so, a proper estimate of the probability of future success or failure of the business model is possible, with a minimum expenditure of time and resources. As mentioned before, planning is a process and therefore should be open to adjustments at all times. Even if a concrete business concept is not appropriate to actual market demand, the business model can be adapted to suit incorporating all the gathered information as it is still at an early stage.

3 BUSINESS PLANNING FOR SERVICE-BASED BUSINESS CONCEPTS

Setting up a general business plan helps manufacturing companies to objectively forecast risks and opportunities as well as the expected added value before putting any service-based business unit in place.

'The business model approach suggests a more fluid gestalt, one that is more than the sum of its parts by having mutually reinforcing virtuous circles between its elements but is simultaneously robust, self-regulation and self-adjusting.' [26]

Offering industrial service-based business models taps different aspects in turns of external market demand e.g. different customer needs and requirements. Also from an internal perspective, delivering solutions challenges the organizational structure [27] in different ways compared to the traditional product-based business. Considering this, planning to enter the service business by just expanding the already existing industrial service activities might be a false perception of the requirements in this kind of business. But as business planning is a process where constant learning and adaptations are explicitly wanted, it is an idea to start from evaluating the market potential. In a first step of the general business plan a business model for the idea has to be set up.

3.1 The business model

A business model roughly describes the business activities of a company [28]. It can be seen as how a company has to be organized to satisfy certain customer needs [29]. Scientific literature provides no clear definition of a business model. Though various definitions exist, they claim similar domains as mandatory parts of a business model. However differences can be seen in the aggregation level of dimensions. This might come from the background of the corresponding authors and the differing focus of the manifold disciplines in management research. For a detailed list, see [28].

In this paper we follow the approach of [29] and [30], later comprised by [31]. According to them, a business model contains three dimensions:

- Value Proposition which defines the value generated for the customer and other actors involved in a business transaction. And we also consider it necessary to define the value added for the own company here. Not in detail, but a rough idea of what kind of value added, e.g. information, monetary revenue etc. should be stated here.

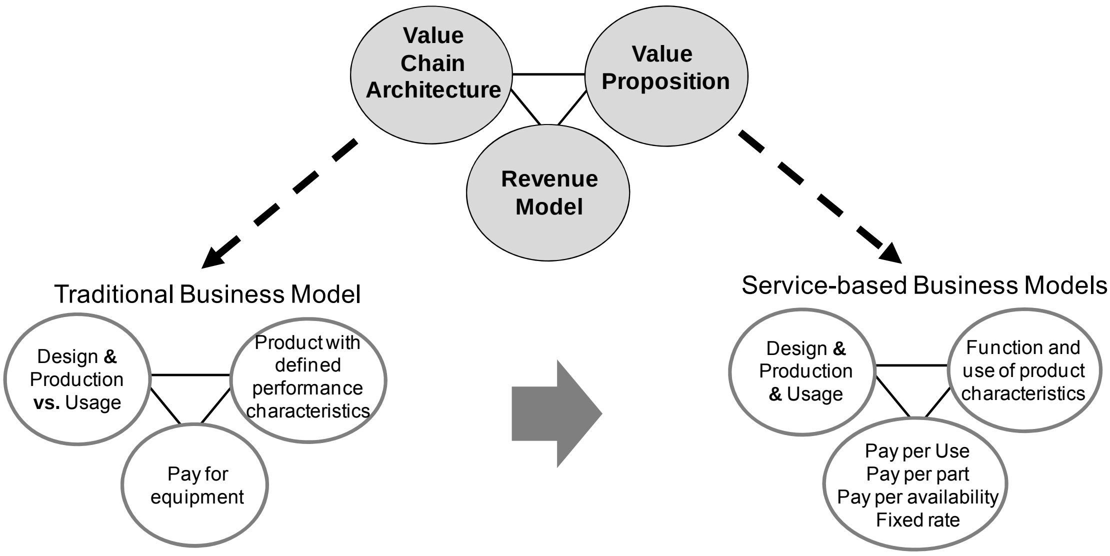

Figure 1: Business model innovation.

- Value Chain Configuration which defines the actors, their roles and their contribution involved in the value creation
- Revenue Model which defines the source and type of the payment.

3.2 The business model innovation

Offering industrial product-service systems in most cases requires a business model innovation because the way of doing business significantly differs from the traditional product-oriented model. Retaining the above presented approach according to [12], a business model innovation applies when at least two out of the three dimensions are modified. The need to establish a new business model for service-based offerings comes mainly from the strengthened importance of service for the value creation. In Figure 1, this shift from the traditional business model–designing and producing high quality products which are sold by the customer in a single business transaction–towards industrial product-service systems embedded in innovative business models is illustrated.

Especially business models selling the use or the result of capital goods (cp. Figure 2) entail a shift of risk from the customer to the provider. This innovative value proposition involves a rearrangement of the value chain architecture. Service characteristics, though their degree varies, like intangibility and the interaction with the customer in the value creation process, requires restructuring of former transaction oriented structures [32]. Furthermore, the renunciation of the product price is necessary as the revenue model requires reinvention of pricing mechanisms [33]. The complexity of establishing and coordinating these structures e.g. establishing new organizational principles and routines, often in addition to the traditional model, is a major management challenge. But it is the complexity that, handled successfully, builds the basis for a sustainable competitive advantage as it is difficult to imitate [34]. How to initiate a structured development of business models for industrial product-service systems already in an early stage in the three dimensions of the business model and key questions to be answered for each of them are outlined in more detail.

3.3 Value Proposition

In a first step, the value proposition of the new service-based business concept has to be described. It must answer the question what kind of customer need–already existing or unnoticed–is fulfilled [16]. The evaluation of the customer need has to be done from the customer's perspective. Splitting up the customer value according to the dimensions of time, quality and costs helps to systematically derive the key factors of value creation [11].

On the other hand, the added value for the own company has to be captured. The pursuit of generating value is inherent to every economic, but value does not automatically equal generating ample profits. Although high margins are often entrenched with being active in the industrial service market, also indirect monetary revenues can lead to a win-win situation for the manufacturer. Services presuppose a co-operation of customer and provider in the transaction process; this service intrinsic characteristic could be used to actively make use of the intensified customer provider relationship (for the sake of both parties). Gaining access to information about the

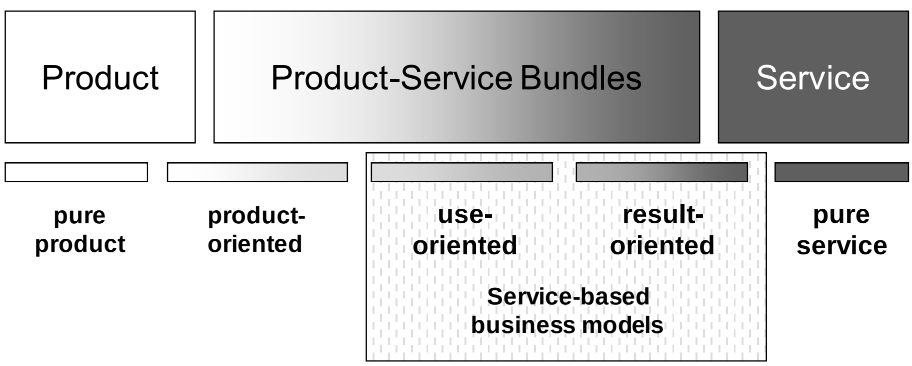

Figure 2: Service-based business models in a product-service continuum [adapted from 35].

customer production process and the usage of the product can be one source of value for the manufacturer. The formerly restricted information on customer behavior and actual problems is now open and a source of future product as well as future service innovation. Another purpose of offering service-based business models is to retain or expand the already existing customer basis. Especially when services in the manufacturing sector are offered as re-action to customer pressure, a clear and straightforward formulation of the value proposition supports further planning and analyzes the chances by accepting the deal which for example reveals synergies by clustering other customers through the market analysis. It helps also to weigh the risks and losses of accepting an offer prompted by customer pressure and also the risk of losing this customer before signing the contract.

So the next step for an early assessment would be to analyze the market and the target customers–also part of the detailed business plan. First the targeted market as a whole has to be described. Statistics that can easily be gathered for this purpose are the sales volume and growth margins of the total market–for service-based business concepts, for example, the existing customer basis could be targeted by offering availability guarantees. Hereby conflicts with the prevailing business model might arise. The offer of service-based business models might disrupt the traditional way of doing business in one sector. Therefore, this issue should be carefully dealt with and implications for the future strategy of the company have to be reflected.

Then the macro environment should be scanned, analyzing technological, legislative, economic, social and ecological influences. Especially ecological and legal regulations are gaining more importance in the manufacturing sector. The ability to anticipate future regulations concerning environmental policies might be a promoter of or barrier to the success of the business model. The advantage of already existing companies is that a systematic analysis of the business environment in an entrepreneurial context could be conducted with less effort than in start-ups. The needed knowledge is often already present in the firm through sectoral newsletters and the membership of sectoral associations. However, again it must be emphasized that although there is already expertise concerning the manufacturing sector in the company, formal planning methods benefit information gathering as they could be used as means to test the subjective assumptions by juxtaposing outside and also an objective perspective. Then the specific market or market niche has to be assessed. This question though of major importance is often carelessly dealt with. Therefore, characteristics of customer companies for which the new business model offers value added have to be identified, e.g. companies of a certain size, certain volume of demand, local restrictions. Results from that analysis should be discussed with employees from the design department, service department and marketing and sales [24]. Also customers with whom a relationship of mutual trust exists should be consulted if the value proposition really fits their needs. Take again the availability example: if you want to offer your customers a service to guarantee 95% availability, you need to assess what percentage they already realize. Furthermore, an internet search for competitive offers sheds light on the actual market demand. If no offer like this exists, it might be a disruptive business idea or it might be an idea that does not fit the market demand.

Although it is extremely difficult to precisely assess the customer potential at an early stage, the aim is here to get a feeling for the dimension, whether 5%, 20% or 50% of customers of the manufacturing sector are potential customers. The formulation of the value proposition also influences the design of the service and machine. The features of the product-service system have to be derived by the value proposition and have to be clearly documented [31]. In addition, the value for partners by participating in the business has to be clearly outlined.

If the assessment of the market conditions, the aspired market potential or the expected customer group and needed partners do not give sound proof of a future business opportunity, further efforts on realizing this value proposition should be terminated.

- Step one: Reveal win-win potential.

3.4 Value Chain Architecture

Changes in the value chain architecture of a product-oriented company are inevitable for delivering service-based business models. Despite the heated debate on the importance of organizational challenges in scientific literature, the changes to be carried out in the value chain are often neglected. [32]. [37] describe it as ‘They sometimes underestimate the operations challenge that is required to transform a good to value package, and effectively manage the service component. Operations processes, resource characteristics and structure may have to be changed.’

Of course, at that early stage a detailed organizational planning can neither be done nor should be done. Here it helps to bear in mind the following effects of service-based business models to the organization. First of all, is the physical product applicable to service-based business concepts or are any adaptations necessary? Then, inherent to the sale of use or of the result in service-based business models is the shift of risk from the customer to the provider. Accordingly, the value chain has to be prepared to cope with that risk. For example, selling use in form of ensuring a certain kind of availability guarantee requires from the provider to be able to solve any malfunction within a limited time span, no matter at what time and in what geographical region. On a sub-level, this demands a high level of flexibility of internal processes and also of the employees. Subsequently, the need for any external cooperation has to be assessed. Another service characteristic playing a major role in these business models is the integration of the customer in the value creation process, so-called value co-creation [38]. In this it has to be taken into consideration which channels are available to a provider to control the action of the customer as this party as well influences the quality of the service. Implications of the required higher level of customer interactions and interfaces need to be anticipated. It has to be kept in mind that being a service provider disrupts the self-image of a manufacturing company and also of its employees. It must be conceived as a hurdle otherwise it cannot be surmounted. Re-establishing the value chain architecture for delivering service-based business models requires the aspects in which the service-based model diverges most from traditional manufacturing to be identified.

- Step two: Mind-Set.

3.5 Revenue Model

Both sources and purpose of the gained return are defined within the revenue model [30]. Manufacturing companies often have a long tradition in delivering industrial services, e.g. spare parts, customer training. But few of them have priced their customers for that. Services have been given away as promotion to sell the product. Now as the firm is turning into a solution provider by bundling products and services, the contribution of the service activity to cover the costs has to be re-assessed.

At this stage of business model planning it needs to be defined on what basics the customer should be priced, is it the availability level that is kept, is it the time span of service delivery, is it the flexibility of outsourcing peak production capacities or is it the cost reduction that could be achieved through the know-how of the provider?

There is no clear scheme serving as an orientation for providers as service-based business contracts are often marked by a high level of individuality. It has to be reasonably assessed where the win potential for the customer comes from (see Value Proposition) and what costs have to be covered for the provider.

- Stage three: Assure Financial Benefits.

In Figure 3, the three-step-approach outlined above is summarized.

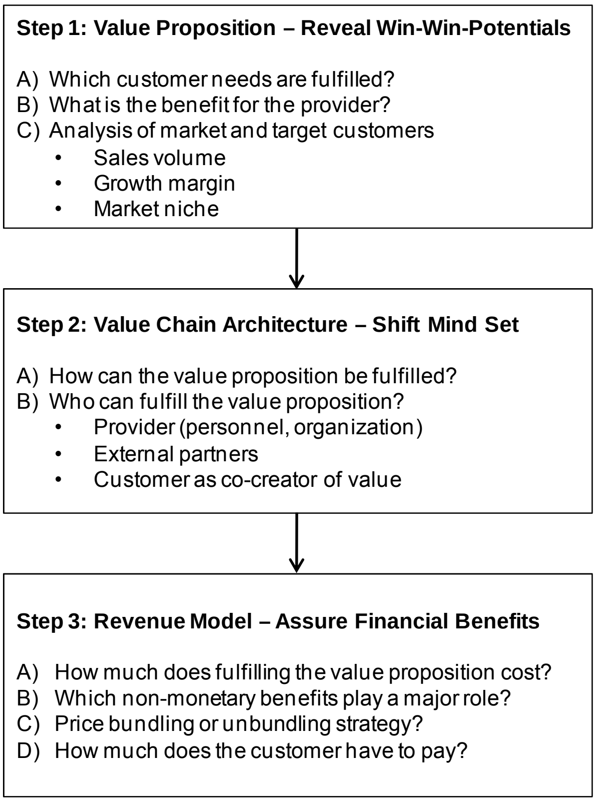

Figure 3: Three steps to business planning.

4 CASE STUDIES

The business planning approach aiming to support servitization decisions and implementation in the early stages, which was described above, was tested with two machine tool manufacturing companies. In doing so, the three step analysis depicted in Figure 3 was conducted and first a basic value proposition was identified and described on the basis of their customers' requirements. Subsequently, analyses of both customer and competitor market were conducted. In several customer case studies, i.e. interviews with actual and potential customers and complementary document analyses, the customers' attitude towards the new offering should be understood. The aim of the competitor analyses was to identify potential market competition. Afterwards, the impact of offering product-service systems to customers in the organization of the machine tool manufacturers was forecast on hierarchical and process level. The calculation of the revenue model was done by using a life-cycle software taking into consideration a variety of scenarios that could emerge and the risks associated with the implementation of the industrial product-service system.

4.1 Case study 1: Machine tool manufacturer providing an availability guarantee

The case study company is a large enterprise operating worldwide as one of the international market leaders in designing, producing, maintaining and supplying equipment and components for the railway and aerospace industry. They currently offer value-adding solutions in niche markets, i.e. customized equipment and basic services. The main revenue in this business model comes from payment for the manufactured machines and from corrective maintenance performed during the machine's life cycle.
On that basis, the case study company considers promoting and fostering additional services and service-based business concepts. In particular, the case study company takes into account offering an availability guarantee to a subset of customers.

Step 1: Value Proposition

When analyzing the company's customer sectors, the aeronautic sector turned out to be the most promising sector in which the business model could be implemented.

Results of a market analysis, i.e. four interviews with representatives of potential customers from the aeronautic sector, revealed that these are currently not familiar with service-based business concepts, but perceive the potential of their implementation. Furthermore, two of the four interviewed companies had already had good experiences with availability guarantees and were inclined and open for this offer. The main goals of the customer companies were found to be improving the financial performance as well as process quality and gains in productivity and availability.

The study of potential competitors was done on a trans-sector level as the examined companies were not only targeting the aeronautic sector. It revealed that large supplier companies had already started to introduce a more or less comprehensive range of additional service offerings into their portfolio. Maintenance, engineering and consulting as well as supplying spare parts turned out to be services commonly offered by machine builders in all sectors. Yet, availability guarantee contracts, defining a guaranteed level of functioning time without failures for equipment, supported by a pre-defined benefits and penalties system were not found.

Hence, the case study company identified an unfilled need in one of its customer sectors which was not served by its competitors.

Step 2: Value Chain Architecture

From an organizational point of view, the provision of an availability guarantee to the customers from the aeronautic sector requires several changes in the current organizational processes and structure of the case study company.

Especially planning of the preventive maintenance activities, like working out checklists and setting up databases etc., will require a temporary team of specialists from service, design, production and research and development. This team will be responsible for setting up draft service contracts and also elaborating time and task lists for the newly arising work packages.

Furthermore, the general structure of the service team was also revisited. Up to now, it is split into three main business units and hence maintains three service units, one for each business division. An analysis of the requirements that an availability guarantee implies resulted in the recommendation to merge the three service units into one service team, consequently realizing synergies in warehouse management, capacity utilization and spare part procurement.

Step 3: Revenue model

From the economic point of view, based to the hypothesized costs and profitability of the case study company a life cycle software tool was used to comparatively calculate the life cycle costs of the traditional business model–selling the machine and providing basic maintenance–to the provision of an availability guarantee. The calculations revealed that providing and using an availability guarantee respectively would result in a moderate increase in life cycle costs for both provider and customer but that the net present value for the case study company would almost triple while the net present value of the business model for the customer would remain as is. However, for the customer, also non-monetary benefits need to be taken into consideration, i.e. guarantee equipment availability which allows to better plan production and consequently consumption of resources. A risk analysis was carried out to provide a solid base for the final decision in favor or against an availability guarantee offer. A best and worst case scenario were assessed by changing the standard conditions. The net present value was forecast to be positive in both situations, with a 20.5% increase in the best case and a 38.5% decrease in the worst case compared to the standard scenario.

The case study company is going take these figures into account before making its decision on the new business concept in addition to the non-monetary benefits arising from this product-service system: the increase of the overall company competitiveness and performance and the chance of acquiring new customers and entering new markets.

4.2 Case study 2: Machine tool manufacturer providing a renting service

The case study company is a small enterprise specialized in electrical discharge machines, like sinking machines, wire electrical discharge machines and filtration units. Currently, the case study company provides its customers not only with equipment, but also with consumables and services like preventive maintenance, customer trainings, technical assistance and constant back-ups. Traditionally, the machines are either sold directly to the customers, i.e. the end users, or to distributors who later resells the machines to the end customers.

The main reason why the case study company considers going into a new service-based business model can be seen in the global economic crisis which leads to a worldwide economic slump. In this tough environment, the traditional value proposition–high quality equipment–is not sufficient any longer to keep sales growing and hence new services can be one way of making business with potential customers. Many EDM users are afraid of purchasing new equipment as they in the current situation do not have enough orders to justify this decision. Furthermore, customers who however are willing to buy new machinery might not be able to pay for it due to lacking funds or refused requests for bank loans. In addition, some of the main competitors of the case study company have already started to offer alternative types of financial services to their customers. Hence, it is vital for the case study company to take a new business model into consideration to improve its condition as some of its customers have already demanded financial services from them.

A renting service is a business agreement in which a payment is made for the temporary use of a good owned by someone else. The renter of the equipment is not interested in the ownership of the good but in its functionality. Though renting does not necessarily involve a financial institution, due to reasons of risk management, the case study company is interested in having a financial partner to avoid the risk of not getting paid by the renting company. So, the business transaction of the renting concept will be the following. If a customer is interested in renting a machine, a financial institution buys the equipment and rents it to the customer company. During the contract period, the case study company maintains the machine along with any other service agreed upon in a contract and the renter pays the case study company for the services and the renting feeds to the financial institution. If at the point of contract expiration the contract is not renewed, the financial entity re-sells the equipment to the case study company which will try to find a new renter for the machinery. In case the contract is renewed, the financing institution remains the owner of the equipment.

Step 1: Value Proposition

To understand the full potential for the proposed renting service and to identify the appropriate advertising strategy, five potential customers were interviewed. The interviews revealed that in 80% of the business transactions, the equipment was obtained with leasing contracts with banks while the remaining 20% of business transactions were done via direct payment using cash. None of the interviewed companies had received a proposal of direct financing or renting by their machine suppliers, hence they appeared to be interested in the renting concept. One of the main barriers identified during the interviews was the fact that the ownership of the equipment would not be transferred to the customer unless the supplier after contract expiration agreed to sell it.

From the competitor side, the interviews revealed that no other company in the EDM market offered renting services to their customers.

The case study company preliminarily forecast that 15% of their customers were going to use the renting concept and that the share of companies taking advantage of this service was going to increase gradually by 10% per year once the service would have become better known in the market.

Step 2: Value Chain Architecture

From an organizational point of view, the introduction of the renting service implies new tasks for marketing, sales and maintenance department of the case study company. Tasks like rating the customer's creditworthiness, setting up the contracts and dealing with missing payments were outsourced to the financial entity. The case study company provides its expertise in producing EDM machines and in maintaining the equipment during the renting period to keep up the functionality.

The existing hierarchical structure of the case study company is not going to be affected by the offer of a renting service and the preliminarily estimated number of customers will not demand for an increase in staff.

Step 3: Revenue Model

From the economic point of view, based to the hypothesized costs and profitability of the case study company a life cycle software tool was used to comparatively calculate the life cycle costs and net present value for both, customer and case study company, in the traditional and the new business model. Thereby, three different scenarios after contract expiration need to be taken into consideration. The customer can decide to rent the machine for another five years. Supposedly, 50% of the customer will go for this option. The customer decides to no longer rent the equipment and the case study company takes it back and re-rents it to another customer after refurbishment. Probably, in 25% of the business transaction this will be the case. In the remaining 25% of business transactions, the customer decides to no longer rent the equipment but the case study company fails in finding a new renter for the machinery after taking it back.

Calculating these scenarios resulted in a positive net present value for the case study company. Yet, not surprisingly, it was shown that renewing the contract with the same customer resulted in the highest net present value and this consequently would be the best option for the case study company, mainly because costs like transportation and installation do only occur once. On the other side, the worst case would be that the case study company will not find a new renter after taking back the equipment which results in a net present value of -58% compared to the best case.

This calculation allows the case study company to understand and asses the impact of offering this renting service to the customer and to realize how the business transaction conditions change when compared to their traditional business model.

5 CONCLUSIONS AND NEED FOR FURTHER RESEARCH

In this paper, an approach was presented to assess the risks and benefits of service-based business concepts in early stages of their development. The tools and instruments used in business planning for start-up companies but also for intrapreneurial activities were connected to the three dimensions of new business concepts–value proposition, value chain architecture and revenue model. In a first stage of assessment, it is important for servitizing manufacturers to define value proposition, value chain architecture and also revenue model.

When doing the same considerations like entrepreneurs and intrapreneurs, it should become clear to a servitizing manufacturer what the win-win potential of the service-based business concept is going to be, how the mind-set in the providing but also in the customer company and in third parties needs to change and how financial benefits of a product-service system can be assured.

In two case studies it could be shown how the three steps interact and how win-win potentials can be revealed. Interviewing actual and potential customers and studying the offers of potential competitors, defining competences and tasks and the use of a life cycle costing software proved to be of great use for the two case study companies to establish a basis for a decision in favor or against offering a service-based business concept.

As discussed in section 2 of this paper, companies compiling business plans benefit from these, but also need to invest time and human resources in them. A business plan for a business model centering an industrial product-service system resembles a feasibility study for this offer and gives hints on potentials and pitfalls in early stages of business model implementation. Especially in service-based business models with a high level of customer integration and hence result variation and unpredictability, proper projecting of value, value delivery and value capture is needed. Resources that need to be invested in the compilation of a business plan are the other side of the coin.

Consequently, in future research, guidelines for companies need to be elaborated which support them in working out their business plans for industrial product-service systems, showing them how to use the business planning instruments. Furthermore, these first consideration need to be connected to the topics of detailed business plans which allow companies willing to innovate their business model to in-depth analyze the consequences of change.

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7 REFERENCES

[1] Cooper, R. G., Kleinschmidt, E. J., 2000, New Product Performance: What Distinguishes the Star Products, Australian Journal of Management, 25 (1): 17-45.

[2] Stevens, G. A., Burley, J., 1997, 3,000 Raw Ideas = 1 Commercial Success!, Research Technology Management, 40 (3): 16-27.

[3] Shenhar, A.J., Tishler, A., Dvir, D., Lipovetzsky, S., Lechler, T., 2002, Refining the search for project success factors: A multivariate, typological approach, R&D Management, 32 (2): 111–126.

[4] Verworn, B., Herstatt, C., Nagahira, A., 2008, The fuzzy front end of Japanese new product development projects: impact on success and differences between incremental and radical projects, R&D Management, 38:1-19.

[5] Backman, M., Börjesson, S., Setterberg, S., 2007, Working with concepts in the fuzzy front end: exploring the context for innovation for different types of concepts at Volvo Cars, R&D Management 38 (1): 17–28.

[6] Smith, P.G., Reinertsen, D.G., 1991, Developing products in half the time, Van Nostrand Reinhold, New York.

[7] Verganti, R., 1999, Planned flexibility: linking anticipation and reaction in product development projects, Journal of Product Innovation Management, 16 (4): 363–376.

[8] Cooper, R. G., 1997, Fixing the Fuzzy Front End of the New Product Process. Building the Business Case, CMA Magazine, 71 (8): 21 –23.

[9] Kim, J., Wilemon, D., 2002, Focusing the fuzzy front-end in new product development, R&D Management, 32 (4): 269-279.

[10] Ernst, H., 2002, Success factors of new product development: A review of the empirical literature, International Journal of Management reviews, 4 (1): 1-40.

[11] Salomo, S., Talke, K., Strecker, N., 2008, Innovation field orientation and its effect on innovativeness and firm performance, Journal of Product Innovation Management, 25 (6): 560-576.

[12] Ahlert, D.; Backhaus, K.; Meffert, H., 2001, Geschäftsmodelle im E-Business–Modethema oder

mehr?, Absatzwirtschaft, Sondernummer zum Deutschen Marketing-Tag 2001, Oktober: 32-44.

[13] Delmar, F., Shane, S., 2003, Does business planning facilitate the development of new ventures?, Strategic Management Journal, 24: 1165-1185.

[14] Shane, S., Delmar, F., 2004, Planning for the market: business planning before marketing and the continuation of organizing efforts, Journal of Business Venturing, 19: 767-785.

[15] Bhide, A.V., 2000, The Origin and Evolution of New Businesses, Oxford University Press, New York, NY.

[16] Camillus, J., 1975, Evaluating the benefits of formal planning systems, Long Range Planning, 8 (3): 33-40.

[17] Mintzberg, H., 1994, The Rise and Fall of Strategic Planning, The Free Press, New York, NY.

[18] Langeley, A., 1988, The roles of formal strategic planning, Long Range Planning 21 (3): 40-50.

[19] Boyd, B.K., 1991, Strategic planning and financial performance: a meta-analytic review. Journal of Management Studies, 28: 353-374.

[20] Armstrong, J., 1982, The value of formal planning for strategic decisions: review of empirical research, Strategic Management Journal, 3: 197-211.

[21] Bracker, J.S., Keats, B.W., Pearson, J.N., 1988, Planning and financial performance among small firms in a growth industry, Strategic Management Journal, 9: 591-603.

[22] Campbell, D., 1998, Task complexity: a review and analysis, Academic Management Review, 13 (1): 40-52.

[23] Gruber, M., 2007, Uncovering the value of planning in new venture creation: A process and contingency perspective, Journal of Business Venturing, 22: 782-807.

[24] Landwehr, S., 2005, Know-how-Management bei der Gründung innovativer Unternehmen, Deutscher Universitäts-Verlag/GWV Fachverlage, Wiesbaden.

[25] Porter, M. E., 1998, Competitive Advantage. Creating and Sustaining Superior Performance, Fre Press, New York.

[26] Spring, M., Araujo, L., Service, services and products: rethinking operations strategy, International Journal of Operations and Production Management, 29: 444-47.

[27] Galbraith, J.R., 2002, Organizing to deliver solutions, Organizational Dynamics, 31 (2): 194-207.

[28] Morris, M., Schindehutte, M., Allen, J., 2005, The entrepreneur's business model: toward a unified perspective, Journal of Business Research, 58: 726-735.

[29] Timmers, P., 1998, Business Models for Electronic Markets, Electronic Markets, 8 (2): 3-8.

[30] Stähler, P., 2002, Geschäftsmodelle in der digitalen Ökonomie: Merkmale, Strategien und Auswirkungen, Josef Eul Verlag, Lohmar/Köln.

[31] Rentmeister, J., Klein, S., 2003, Geschäftsmodelle ein Modebegriff auf der Waagschale, Zeitschrift für Betriebswirtschaftslehre (ZfB), Ergänzungsheft 1: 17-30.

[32] Backhaus, K., Voeth, M., 2004, Besonderheiten des Industriegütermarketing, Backhaus, K.; Voeth, M. (eds.): Handbuch Industriegütermarketing: Strategien–Instrumente–Anwendungen, Wiesbaden, 2004: 4-21.

[33] Malleret, V., 2006, Value creation through service offers, European Management Journal, 24 (1): 106-116.

[34] Teece, D.J., 2010, Business models, business strategy and innovation, Long Range Planning, Article in press.

[35] Tukker, A., 2004, Eight types of product-service system: eight way to sustainabiltiy? Experiences from SusProNet, Business Strategy and the Environment, 13: 246-260.

[36] Windahl, C., Andersson, P., Berggren, C., Nehler, C., 2004, Manufacturing firms and integrated solutions: characteristics and implications, European Journal of Innovation Management, 7 (3): 218-228.

[37] Correa, H.L, Ellram, L.M., Scavarda, A.J., Cooper, M.C., An operations management view of the services and goods offering mix, International Journal of Operations and Production Management, 27 (5): 444-463.

[38] Vargo, S.L., Lusch, R.F., 2008, From goods to service(s): divergences and convergences of logics, Industrial Marketing Management, 37 (3): 254-259

PSS for Product Life Extension through Remanufacturing

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Abstract

Remanufacturing is defined as a process by which an end of life product is returned to an as-new condition with an equivalent warranty. It is seen as an effective method for extending the life of product leading to an overall reduction in our environmental burden. Issues associated with remanufacturing include customer perception over reduced quality and limited access to end of life product. The implementation of product service systems is feasible way to mitigate these issues, delivering environmental benefits whilst ensuring that the user receives the services provided by the product. We will present examples including a refrigerated display cabinet remanufacturer, games console manufacturer, a vacuum pump manufacturer and an earth moving equipment manufacturer to highlight service providers using remanufacturing and remanufacturers offering services to increase their remanufacturing turnover. We will outline our activities to increase the level of remanufacturing in the UK, focusing on standards development, design initiatives and sector level engagement.

Keywords

remanufacturing, reuse, end of life, environment, service led sales, refrigerated display cabinets, vacuum pumps, earth moving equipment, games consoles

1 INTRODUCTION

Remanufacturing is defined as returning a used product, via a manufacturing-type process, to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product. [1-5] A remanufactured product should be practically indistinguishable from a new product from the purchasers' point of view. The process of remanufacturing involves disassembling a product, inspecting and replacing worn parts and consumables, applying a surface finish, reassembling the product and thoroughly testing it to ensure that the product complies with original performance specifications. Remanufacturing is an important, but under-exploited, method of reducing our environmental burden, and is estimated to be worth at least £5bn to the UK economy. [1]

It is important to state that there is a common misconception that remanufacturing and recycling are synonymous. Recycling is a process for reusing materials: During recycling the function or physical form of the recycled product and its components is lost through physical or chemical destruction. Remanufacturing is a process for reusing products, where the form and function of a device or its sub-components are retained to the fullest extent.

Remanufacturing a product removes the need to use virgin materials and consume energy in its manufacture. Broadly speaking, the remanufacture of a product produces fewer carbon dioxide emissions than manufacturing from new [7]. Also, because the embodied energy in the construction of the product is retained, remanufacturing involves a lower carbon footprint than scrapping and recycling materials and – all other factors being equal – is a preferential option to recycling. [8-12]

The exception to this occurs most often where the product consumes energy in its operation and where energy efficiency improvements in new product design have reduced the overall energy consumption of a device whilst in use. [13-16] Under such circumstances, savings made through delivering a remanufactured product may be lost through the inefficiencies of persisting with the use of an older design. This issue can be eliminated if a remanufactured unit can be upgraded to attain the energy efficiency standards of a new unit. [17]

Remanufacturing is an important and integral aspect of numerous UK sectors. Its prevalence and application are dictated by several factors including cost of original product, speed of technological advance and the ease with which a product can be disassembled and remanufactured. Industries such as aerospace [18] and automotive [19-21] are exemplars, in which remanufacturing is built into the business models of all component manufacturers and is seen as an essential way to reduce costs. The aerospace example also counteracts concerns that the remanufactured product will not perform as well as a new item. The wide-spread use of remanufactured parts in a heavily regulated and safety-conscious industry demonstrates that a remanufactured product can achieve as good as new performance and perform in a strictly delineated manner.

There have been several studies showing both the environmental and business benefits of remanufacturing. [22-24] In addition to the reduction in greenhouse gas emissions and material use delivered by remanufacturing, and the cost benefits realised by both remanufacturer and purchaser, there are several less measureable benefits from remanufacturing. These include: [17]

Enhanced skills and employment

Anecdotally, the skills level and pay of the staff involved in remanufacturing are higher than counterparts who are involved in recycling. The main reason for this is that the operations within a remanufacturing factory are more complex and the remanufactured product is significantly more valuable than equivalent recycled material.

A higher workforce skills rate has positive implications for the wider economy. A more skilled workforce is required to compete with our main international rivals: the higher skills set and higher pay also result in a net increase in gross value-added per employee, which is a key indicator of economic success

Enriched customer relations

There are opportunities for remanufacturers to develop closer ties with customers. Where service-type agreements are developed, or where an organisation remanufactures products to order, there is greater contact between client and provider. Such activities lead to the development of good business relationships, which can lead to further business or the resolution of other areas of business where there have been problems. This is discussed further below.

Improved product failure knowledge

A key problem for OEMs is in obtaining statistical data on modes of failure of their products outside of warranty. Such data could be used to improve the reliability of their product. It will also highlight less critical failures such as unusual wear patterns or long-term unexpected behaviour of the product. Third party remanufacturers can use this to their advantage to design out any defects present in the original product, which can then be used as a selling point.

1.2 Remanufacturing industry profile

In general there are three classes of remanufacturer: The OEM, the contracted "official" agent, and the independent operator. In the first two cases, OEMs retain at least some control over both the rewards and the quality of the remanufactured product. [6] Relationships between contractors and OEMs can involve mutually beneficial information flows regarding both original design specifications and product failure modes and frequencies; these can be used to enhance product design, design for remanufacture and even upgrade paths for old generation products. Independent operators usually provide a service in segments where the OEM is not deeply involved in direct customer support (such as out-of-warranty automotive), or simply concentrates on new sales. OEMs may re-enter remanufacture where they recognise that their strong brand name is being parasitized, and technological advances offer strong upgrade potential. This has happened in the machine tool area, where computer control technologies may be retrofitted to high-longevity basic equipment. [25]

Remanufacturing shares many features of normal manufacturing, particularly in relation to the aspects of output quality control, materials flow handling, and other principles of lean manufacturing. [6] Significant differences do arise from the fact that the raw materials – core – at the input to the process is of unknown quality. This has implications for evaluation of suitability for remanufacture, and the processes of testing, verifying or remediation at the component level. A more serious challenge exists for independent remanufacturers. Access to product engineering data can be seriously restricted; in response leading remanufacturers have built reverse engineering capabilities that attempt to determine product specifications by deconstruction of original equipment items. [26] These issues can be seen as barriers to remanufacture or as points of attack by OEMs. However, the most advanced OEMs do not perceive remanufacturing to be – in principle – any different to new manufacture, and can run both operations in parallel at the front end, and sharing parts management, assembly and processes logistics at the back end. [27, 28]

1.3 PSS and remanufacturing

To derive maximum benefit, remanufacturing depends on the customer recognising the value of his end-of-life asset, and the manufacturer creating products that have the required durability in critical components. Both these motives can be enhanced if the goods can be seen less as products and more as a service. [21] Profit margins can be sustained or even improved over new sales, particularly if performance upgrades can be included in the remanufacturing activity. Customers can then stay up to date with respect to energy consumption, emissions controls or safety systems. In other cases "servicisation" offers remanufacturers an alternative way to compete with lower-priced products. [29]

To date, this has largely been a feature of business to business services, where – in general – there is a greater awareness of financial implications of purchasing decisions. Even here, however, there are plenty of opportunities for more informed purchasing based on life-cycle costing rather than "least cost, now". From the manufacturer's perspective, remanufacturing can provide a route to addressing Producer Responsibility demands. The necessary recovery systems are accountable and demonstrably more resource efficient when integrated with the management accounting of manufacturing processes. [30, 31]

This paper presents a series of case studies of remanufacturers that incorporate aspects of PSS into their business models. The provision of such offering has enabled them to establish this resource efficient activity as a profitable enterprise.

The case studies presented here were collected over a number of years through face-to-face and over the phone ad-hoc and formal interviews with key members of senior management and production staff at the various companies. Our remit, as a governmental funded delivery body, is to promote the benefits of remanufacture and reuse to business and government. The aim of these case studies is to provide insight

2 CASE STUDIES

2.1 Sony Computer Entertainment Europe and the Playstation

Sony Computer Entertainment Europe (SCEE) is responsible for sales, marketing, distribution and software development for the PlayStation® 2, PSP & PS3 Video game & Multimedia consoles. SCEE has offices around Europe, the Middle East, Australia and New Zealand responsible for the sales and marketing of these computer entertainment systems and associated software to a total of 94 territories. SCEE import units from its parent in Japan and in turn supply these units to SCE UK, who then sell them to retail outlets. Warranty returns are also the responsibility of SCEE.

The move to remanufacture

SCEE has always used a remanufacturing model to enhance its customer service offering. At the launch of the original PlayStation®, SCEE considered the idea to service warranty returns using a traditional repair model, where by returns would be dealt with locally at small Sony approved retailers. The problem would be fixed on site, and parts would have been ordered on an individual basis, with no thought given to recovery of defective parts by the individual repairers, either for reuse or recycling.

This model allowed for little or no quality control, economy of scale, or recovery of potentially valuable parts. It also meant that the repairs would be expensive, with this potential cost being incurred by SCEE. Customers whose unit failed out of warranty would face a bill for labour and parts, as well as a long wait for parts to arrive. This would have put many people off repair, and these units would have been discarded by the consumer. The business model for games console manufacturers and suppliers relies on a large installed hardware base to enable the sale of games. The manufacturer charges licensing fees to third party games makers, the larger the installed base, the higher the revenue the console maker can make from the license. It is therefore in the console manufacturers' interest to ensure that as large as possible user base exists to attract games developers. Broken and faulty games consoles clearly reduce this revenue.

To maintain the large installed user base, SCEE opted to establish three large European refurbishment centres and two in Australia & New Zealand. This was a conscious effort by SCEE to cut the cost of its service operation and improve customer service, in a market where customer loyalty was vital to the success of the product.

In practice, a defective unit is reported to SCEE and a pickup time is arranged for the unit. At the point of receipt, a remanufactured unit is offered to the customer. A modest (less than £50) cost is charged for this service.

What are the benefits to the end user?

- Service replacement scheme means they are without a console for the minimum amount of time. (typically only 24 – 48 hours in the UK)
- The console is collected from their home, or other choice of address and a new one delivered. There is no need to take the unit to a shop.
- Using economies of scale and the use of reclaimed parts, SCEE have been able to reduce the price for out of warranty repairs to an absolute minimum.
- Customers know that their remanufactured console will have been through a thorough and consistent process, ensuring the highest standards of quality.
- Although the console they receive from SCEE is not the same as the one they send for repair, the remanufactured working model does enable them to use a console as fast as possible.

Reuse of Parts

SCEE identified that faulty modules removed from returned units have value and were stored for later use and analysis. They quickly began to utilise this stockpile of parts by cannibalising units to reduce spare part costs. SCEE then introduced reclamation and reuse to one of its service centres as a test case in 2000. The process was then gradually rolled out over a number of years and by 2004, all service centres were actively involved in reclaiming usable parts.

Benefits

The reuse of components from faulty units has clear benefits in terms of production, transportation and resource depletion. Although the volume of components reused is impressive at 6.8 million, many of these are very small items, so whilst they are important, the most important environmental benefit lies elsewhere.

The cost for repair of out of warranty units has been made affordable through SCEE's remanufacturing operation. A higher cost would force many users to purchase a new console, particularly as a model reaches the end of its life cycle.

SCEE estimates that around 40% of returns towards the end of a product lifecycle can be attributed to out of warranty units. If they did not offer an affordable option to customers, these units would likely end up as landfill and be replaced with new. Over the period 2004 to 2006, this would have prevented 3,000 tonnes of CO2 entering the atmosphere due to UK operations or 13,000 tonnes over the rest of Europe[2].

Further gains are made by the centralised collection of damaged units. The service centres can amass large enough quantities of Polycarbonate case components to sell as a feedstock for recycling. This is mixed with virgin polymer and used in mid grade polycarbonate components, such as internal components for photocopiers, pens or even plastic chairs.

2.2 Remanufacture at caterpillar

Caterpillar is the world's largest maker of construction and mining equipment, diesel and natural gas engines and industrial gas turbines. Sales outside the US accounted for 53% of CAT's $36 billion turnover. Its products include track-type tractors, hydraulic excavators, backhoe loaders, motor graders, off-highway trucks, wheel loaders, diesel and natural gas engines and gas turbines.

In 2005 CAT's global remanufacturing operation reused 43 million tons of core material. This means that by remanufacturing rather than recycling, CAT has prevented 52 million tonnes of CO2E entering the atmosphere. It also means that other associated waste due to raw material extraction has been substantially reduced.

Every remanufactured product that leaves the factory has been through a stringent quality test procedure, often having been passed along the same production line as a new product. This is backed up by a full warranty, the same as is issued with a new product.

Keeping Hold of core

When a customer purchases a remanufactured part from CAT it is delivered to them in a reusable container, for which they pay a deposit. When returning a worn part (core), customers are expected to use this container. Their site in Shrewsbury, UK, which is their European centre of excellence for Europe, Africa and the Middle East, site has reduced its wooden packaging waste by 70% using this system, reducing cost and making sure core arrives undamaged. The customer also pays a "core deposit" which is refunded upon receipt of their worn part (provided it is complete and has no unexpected damage). The worn parts are then sorted at Shrewsbury and given a basic visual inspection. Some parts will be remanufactured on site and others will be shipped to facilities elsewhere.

Process Simplification

The remanufacturing process at Shrewsbury uses patented processes, procedures and tools to dismantle, modify, and reassemble the products. This allows the plant to be flexible in the type of components it can remanufacture. With a skilled workforce, a wide variety of engines can be remanufactured on site without the need for expensive dedicated lines. Remanufactured products often leave the plant in "better than new" condition, as every part is modified to include the latest design features available at the time for the original specifications to which the product is remanufactured.

Overcoming challenges

Table 1 shows the key challenges that Caterpillar have been confronted with and how they have overcome these.

[2] These figures have been calculated assuming 40% of all consoles returned were out of warranty. The mix of "PS2" to "PS2 Slimline" was 1:1. The associated embodied CO2 for each device has been estimated from data produced by Best Foot Forward for a range of similar devices. The figures in that report have been benchmarked against other computing equipment. [An ecological footprint and carbon audit of digital radio A1 – DAB Acme Digital, Best Foot Forward, 2006]

Key challenges	Caterpillar Solutions
Making sure that core is returned to CAT rather than rebuilt by 3rd parties, who will not have access to the full technical data and test procedures.	The core deposit is set above the market price for the used part so that the customer has an incentive to return the core to CAT. Only CAT remanufactured parts will carry a full warranty and give the customer guaranteed reliability and performance.
How to gather together sufficient core when a new product is introduced?	CAT will offer customers new equipment at remanufactured process in exchange for used core.
How to persuade customers that a remanufactured product is as good as new?	The 'as new' warranty reassures customers that they will be buying a quality product with excellent after sales support should they need it. Strict quality procedures ensure that the customers experience is trouble free, building trust and confidence in remanufactured products.
How to find new ways of salvaging more components?	CAT is constantly developing new technology and methods of materials recovery and will continue to do so.

Table 1: Key challenges and solutions for Caterpillar remanufacturing operation in Shrewsbury.

2.3 Edwards Vacuum and low pressure vacuum pumps

Edwards is one of the leading organisations in the world specialising in the design and manufacture of vacuum and exhaust management products for both general vacuum and semiconductor applications. Edwards employs around 3,500 people globally, in the design, manufacture and support of high technology vacuum equipment. Its turnover in 2006 was over US$1bn. The company is a leading global supplier of equipment and services to the world's most advanced industries including semiconductor, flat panel display, chemical, metallurgical, analytical instrumentation and R&D. It is also a world leader in vacuum technology for industrial, scientific, process, and R&D applications including:

- Flat Panel Display
- Analytical Instrumentation
- Industrial Vacuum
- Process Vacuum
- Research and Development
- Thin Film Coating
- Semiconductor
- Renewable Energy

Edwards Vacuum supplies blue chip customers in Asia, Europe and the Americas through a worldwide manufacturing and sales network. Edwards was acquired by CCMP Capital, a premier global private equity firm, becoming an independent private company, in June 2007.

The Edwards Offering

Edwards' activities have led it to follow the operations of global industrial players, locating its own remanufacturing and support facilities near to its larger customers. The scale of the semiconductor industry in particular, where a large fabrication plant may contain over 600 vacuum pumps, clearly justifies this approach. In the largest of plants, where even a small downtime due to loss of pumping capacity can far outweigh the cost of repairing or replacing a pump, the fabricator may opt for an on-site service team.

Capabilities are not sold simply on the basis of repair and maintenance. Other major service attributes include:

- The ability to responsibly handle contaminated equipment: Fabrication applications in particular deal in potent toxic and corrosive brews which leave reagent and corrosion by-products within the casings. Decommissioning, removal, transport, disassembly and cleaning present significant health, environmental and even fire risks. The provision of a robust service that minimises these risks to the customer therefore attracts a premium. Edwards offers such services, which can be further mitigated by use of its associated emissions abatement units during normal operation.
- Lean manufacturing: Edwards seeks to minimise its own operating costs and improve product reliability with commensurate benefits to its customers. Lean manufacturing has been applied to the support operations to standardise techniques using on-line manuals, replacement parts and kits, and to track serialised items.
- Diversified repair, refurbishment and remanufacturing options: A significant change over the past twenty years – following the rising complexity and cost of products – is the recognition that customers need a range of options for buying and supporting equipment. Of particular significance is the adoption of a fully qualified remanufacturing programme offering as-new or better products (through upgrades to the latest build standard).

Evolution of Remanufacturing

The problem of out-of-service downtime was addressed by the concept of Service Exchange: Edwards would still sell a new pump, but on failure it would be replaced by another unit – a remanufactured unit that met the latest build specifications. The recovered units would be remediated and form an inventory for field replacements. Levels of work committed to the remanufacture entailed a higher cost for these items compared to repair, but offered significant warranty and – more importantly – up-time benefits.

Over the last decade the concept of selling remanufactured pumps alongside the new alternatives has become established. These pumps offer cost advantages for the purchaser and are additionally supported by the sale of fitting kits which simplify installation. Thus the customer is fully "bought in" to the remanufacturing programme.

The complexity of this scheme is higher than the service exchange programme because of the logistics, on-going support and need to maintain sufficient inventories, which does incur cost.

Environmental Benefits

The exemplar is a mid-range drypump undergoing an "average" remediation cycle. Remanufacture of this product involves the reuse of over 90% by weight of its components – with a corresponding saving in raw materials and their embodied carbon dioxide.

The once-through benefits of remanufacturing are amplified many times when we consider the life-cycle of a pump. As an extreme case, a device on a fab-plant duty may be overhauled every three months and see an installed service life of 10 years. Typically, the pump would then be exchanged or upgraded, but would undergo a complete overhaul for another 5-10 year cycle. Remanufacturing turnovers of 20-40 are therefore not unheard of in this environment, but more commonly are in the range 4-10 for less severe duties.

Key Competences

Edwards views its products as being differentiated on quality and performance.

These technically complex products have increasingly demanded sophisticated support options. This is one identifiable capability of the new Edwards Vacuum company; a suite of manufacturing, sales and support operations that meet the diverse financial and operational needs of the customers. These options require careful management in order that options are appropriately costed and controlled:

- Attention to quality in design and manufacture. Standardisation of procedures and parts kits using on-line service support guides has enabled rationalisation of components per service location, and consequently costs.
- Ability to handle entire life-cycle of product including decommissioning.
- Ability to track all registered components using centralised systems and to identify costs of replacement.
- A system whereby failures in service are captured, diagnosed and used to modify or upgrade current models or new evolutions. This capability has evolved over the last decade or so and has led to increasing integration of the front end design – design for disassembly.

2.4 Refrigerated display cabinet remanufacture by the Bond Group

What is an RDC?

A Refrigerated Display Cabinet, RDCs are devices that enable the sale and storage of chilled and frozen food and beverage products in a retail environment. They are common to all supermarkets and convenience stores selling chilled food. They serve two purposes: to ensure that the produce sold is fresh and to enable the customer to view produce prior to selection and purchasing.

The design, shape and size of RDCs can vary greatly depending on their specific use, but are a largely cosmetic feature of the overall functionality of a unit. RDCs operate in an identical manner to domestic fridges: A compressed refrigerant gas, cooled to below ambient temperature by rapid expansion, chills the air in the RDC via a cooling coil. The gas is then compressed, away from the cool zone, and the resultant waste heat is radiated (remotely in the case of a domestic fridge).

Remanufacturing RDCs

TBG is one of the largest RDC remanufacturers in the UK. Based in Sheerness on the Isle of Sheppey, Kent, TBG employs around 210 staff. TBG operate a product-oriented service business model: They do not own any RDCs but support RDCs already in the field (for extending life or upgrading) by remanufacturing on the retailer's behalf. In general, the old, remanufacturable cabinets are stored in TBG's warehouse. When TBG receives an order to refit a store, the number and type of RDC required is determined. The stored cabinets at TBG are remanufactured and the old in-store stock is replaced with the remanufactured units. Any salvageable cabinets from the in-store stock are placed in storage ready for remanufacturing, with the remainder being sent for disposal.

This system requires the retailer to have a surplus stock of RDCs, but allows the old stock to continue operating whilst TBG remanufactures the stockpiled cabinets. An advantage to this system is that the lead time between placing an order and installing the remanufactured cabinets is significantly shorter than buying new: The whole process takes between two and four weeks.

There are several other advantages to remanufacturing RDCs. For example, the ability to mix and match old functional store cases with remanufactured cases when performing a partial refit enables the store to keep RDCs looking aesthetically similar. The purchaser saves twice: Once from the reduced cost of the remanufactured product and again from reusing serviceable RDCs within the refit.

By holding older units in stock, TBG also has the facility to trade RDCs between retail companies to fill a large or unusual order. To service and repair such a wide selection, TBG has had to develop an extensive knowledge base, encompassing detailed technical drawings of hundreds of RDC models.

The remanufacturing process performed at TBG has been developed to ensure that the RDC reaches the retailer in the expected specified condition.

3 SUMMARY

Here we present a series of case studies of successful businesses employing remanufacturing in different service based systems. Event though the industry sectors are diverse, the over reasons for using remanufacturing were to save customers money and provide a service that added value to their sales proposition. There were also positive and measureable environmental benefits from remanufacturing. Clearly as both political and business agendas focus on improving resource efficiency, remanufacturing will be seen as a means to achieve this goal. As part of this solution though, product service systems will need to be employed to overcome inherent barriers (for example core collection or consumer perceptions) associated with such offerings.

4 ABOUT THE CRR

The CRR has been formed to promote, where appropriate, the activities of remanufacturing and reuse. Our work is largely funded by Defra (the UK environmental ministry) but we work with a range of regional agencies to reach our targets. We will work directly with companies, although individual support does require paid-for contribution. Work that assists sectors or helps not-for-profit and third sector organisations is free, as is our advice to the ordinary consumer.

We believe that remanufacturing and reuse (r&r) are underused means of conserving resources; significant extra savings in materials and energy use are possible whilst boosting skills, employment and economic activity. To this end, the Centre is developing an evidence base which will enable Government and industry to take actions to boost remanufacturing and reuse.

Core to our purpose is the implementation of actions that will boost - in particular - remanufacturing. These policies and strategies are designed to help businesses (both consumers of remanufactured goods and remanufacturers), governmental policy makers, OEMs and trade bodies to deliver more remanufactured goods and thus reduce our impact on the environment, and at a profit. We generate the supporting information that the remanufacturing industry needs to make its case and raise its profile.

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] BS8887:2009

[2] Lund, R., 1983, Remanufacturing: United States Experience and Implications of Developing Nations. The World Bank: Washington DC.

[3] Sarkis, J, 1995, Manufacturing strategy and environment conciousness, Technovation, 15(2), pp.79-97.

[4] Ijomah W, 1998, Remanufacturing: Evidence of environmentally conscious business practice in the UK, 2nd Int. Working Seminar on Re-use. March 1-3, TU Eindhoven, 1998

[5] Ijomah W, 2002, A model-based definition of the generic remanufacturing business process, Doctoral thesis, University of Plymouth, UK

[6] Parker D, 2004, Remanufacturing in the UK. Oakdene Hollins Ltd: Aylesbury.

[7] Parker D and Butler P, 2007, An Introduction to Remanufacturing. Oakdene Hollins Ltd: Aylesbury.

[8] Kara H, 2008, Carbon Impact Studies: Toner Cartridges, The Centre for Remanufacturing and Reuse.

[9] Kara H, 2008, Carbon Impact Studies: Tyres, The Centre for Remanufacturing and Reuse.

[10] Kara H, 2009, Carbon Impact Studies: Photovoltaics, The Centre for Remanufacturing and Reuse.

[11] Kara H, 2009, Carbon Impact Studies: Gearboxes, The Centre for Remanufacturing and Reuse.

[12] Kara H, 2009, Carbon Impact Studies: Cutting Tools, The Centre for Remanufacturing and Reuse.

[13] Tsurusaki T, 2006, Actual energy consumption of toprunner refrigerators in Japan, EEDAL06 Conference proceedings

[14] Stamminger R, 2006, Old washing machines wash less efficiently and consume more resources, EEDAL06 Conference proceedings

[15] Rüdenauer I, 2006, Accelerated replacement of refrigerators and freezers – does it make sense?, EEDAL06 Conference proceedings

[16] Pautzke G, 2006, Promote the early replacement of old, energy-inefficient household appliances EEDAL06 Conference proceedings

[17] Walsh B, 2009, Report on the remanufacturing of refrigerated display cabinets, The Centre for Remanufacturing and Reuse.

[18] Gray C and Charter M, 2006, Remanufacturing and Product Design: Designing for the 7th Generation The Centre for Sustainable Design and SEEDA

[19] Kumar S and Putnam V, Cradle to cradle: Reverse logistics strategies and opportunities across three industry sectors, Int. J. Production Economics 115 (2008) 305–315

[20] Subramoniama R, Huisingh R, Chinnam R, 2009, Remanufacturing for the automotive aftermarket-strategic factors: literature review and future research needs, Journal of Cleaner Production, 17 (2009), 1163–1174

[21] Sundina E and Bras B, 2005, Making functional sales environmentally and economically beneficial through product remanufacturing, Journal of Cleaner Production, 13(2005), 913-925

[22] Ayers R, Ferrer G, van Leynseele T, 1997, Ecoefficiency, Asset Recovery and Remanufacturing, European Management Journal, 15(5), pp.557-574.

[23] Sundin E and Bras B, 2005, Making funcational sales environmentally and economically beneficial through product remanufacturing, Journal of Cleaner Production, 13, pp.913-925.

[24] See also for example www.remanufacturing.org.uk

[25] Butler P, 2006, Product Group Report: Machine tools: A report on the remanufacture of manual and CNC tooling machinery in the UK, The Centre for Remanufacturing and Reuse

[26] Walsh B, 2005, A Study of Remanufacturing in the UK, Envirowise-MTP joint report, 2005.

[27] Sutherland J, Adler D, Haapalaa K, Kumar V, 2008, A comparison of manufacturing and remanufacturing energy intensities with application to diesel engine production CIRP Annals - Manufacturing Technology, Volume 57, Issue 1, 2008, Pages 5-8

[28] Colin Hutchinson, 1996, Integrating environment policy with business strategy, Long Range Planning, Volume 29, Issue 1, February 1996, Pages 11-23

[29] Heese H, Ferrer G, Gill, W, Roth A, 2005, Competitive advantage through take-back of used products, European Journal of Operational Research, 164(2005), 143–157

[30] Maxwell D, Vorst R, 2003, Developing sustainable products and services, Journal of Cleaner Production, 11(2003), 883–895

[31] Michaelis L, 2003, The role of business in sustainable consumption, Journal of Cleaner Production, 11(2003), 915–921

Session 4A:
Design Methods

Matching Product Flexibility on the Integrated Portfolio of a Product-Service-System

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Abstract

This paper deals with the question, how a product-service-systems portfolio could look like and which approaches in product flexibility are already existing that can fulfil the requirements of such a tool for the early planning. The reoccurring possibility of changed circumstances, known as cycles during the innovation process, are translated into criteria, with which the suitability of the flexibility approaches can be checked. The worked out recommendations are combined to a holistic entity for structuring the various granularities of a PSS referring to the Munich Model of Product Concretization. Thus, this paper sets up a basis for facing the challenge of product flexibility already in the early stages of systematically planned product service systems. This supports a higher degree of flexibility for the stakeholders throughout the lifecycle and thus also allows faster responses to market needs.

Keywords

PSS-portfolio, Product Flexibility, Innovation Process, Integrated Product Development

1 INTRODUCTION

1.1 Motivation

Today's products and corresponding innovations processes are characterised by an increasing level of complexity. The same applies for combinations of products and services and even more for integrated product-service-systems. Proper handling of the design process gets more ambitious with every PSS generation. Further, companies face the challenge to be able to quickly respond to altered market conditions in a fast changing environment. Hence, the new and modified requirements created out of it, have to be adopted in amended product-service-systems. Equally, throughout the same market developments, the planning horizon of a PSS-strategy is shorter and more intricate than several years ago. The amount of different varieties in a company offered to market is increasing exponentially due to diversified market needs and stronger competition. On the one side, customers have the ambition to satisfy their special needs with individual solutions. Beyond, a globally acting company faces the needs of very heterogeneous customer groups. On the other side, stronger competition in a globalized economy pushes companies into market niches in order to reach the broadest diversification for higher turnover.

Hence, the companies have to deal with higher developing costs in order to get these varieties to market. The expenses depend on developing the option itself, the fixed capital deriving from reserved resources i.e. the production tools or service personal and the variety management which has to deal with many different products. Therefore, a key issue of the persons involved in the planning phase is to decrease these costs to preserve the financial flexibility of a company. As new variants costs money in the whole process from a first idea over development, production, utilization to even recycling, it is essential to discover the right choice of products and services which are provided to the customer. Following the creation and concretization of PSS-ideas, the question arises how to deal with them.

1.2 The PSS-portfolio as a solution to changed circumstances

Mass Customization [1, 2, 3] is a well documented approach on this problem. The area of conflict exists in the coordination of mass production efficiency with individualized products. Product flexibility guarantees decreasing the influence of this conflict by analysing i.e. functions or modules, separating and comparing them. Therefore, they provide a method to handle variants regarding commutability, changeability and interconnection.

A difficult contribution to the increasing complexity of products mentioned above is an aspect of the product itself. Products are widely acknowledged as final outcomes of material. This is not sufficient enough anymore. The near past has shown a movement in companies to provide packages including products and services. These so called product-service-systems (PSS) mean new requirements to companies. The point of view got more unclear to the development department. As there was always the distinct imagination of something palpable, now the connections between products and services are abstract.

The idea of a portfolio addresses the need of a representation of the image of all the provided product-service-systems by a company. It must be capable to handle new variants and be able to point out common parts as well as connections between them. As for the early planning, products and services have to be distinguished in their degree of maturity as changes during the development process may occur in different phases. That poses the question how such a portfolio can be structured in order to handle these requirements. A reasonable way doing so can be derived from the well-described approaches for product flexibility which deal with similar requirements. Though, the initial position is a different one. PSS-projects demand different output than provided by most of the methods for product flexibility. This work examines the requirements of PSS represented by the chosen criteria being fulfilled by the examined methods.

Specifying, the approaches to product flexibility need an analysis if the service component fits into the changed requirements of a company as the requirements to product flexibility changed itself. The product spectrum [4, 5] describes an image of the products, which are established in an enterprise. This means the sum of products in market, product concepts in development and the product ideas a company is able to bring to market. With this potent method, there is a way to illustrate the different product varieties with the focus on the product structure and the differentiation within. The considered characteristics reflect several specifications and are shortly outlined in Figure 1 and with an example (car) for better understanding in the following. There are the compulsive parts (chassis), the mandatory choice of parts (engine), optional parts (parking assistant), etc. In other words, a product spectrum is a reflection of the potential of a company.

The posed challenge is to include services as a fully integrated product specification unlike an additional option which can be chosen or not. This poses as well challenges on a product spectrum with which it cannot handle. Therefore, a PSS-portfolio is suggested that can provide information in the early phases of development. As service development differs from that of a product, the innovation processes of product and service must be aligned. The second aspect of the PSS-development which has to be satisfied is the consideration of interconnections between steps within the integrated life cycle. I.e. the answer to the question has to be given which cyclic change in the use behaviour – so the utilisation phase of the customers can be anticipated and therefore included already in the early planning and therefore in the appearance of the suggested PSS-portfolio. Because of the absence of an integrated PSS life cycle, there is used a detailed product life cycle [6] which fits the requirements sufficiently. This work is motivated by the participation in the collaborative research centre 'Sonderforschungsbereich (SFB) 768 – Managing cycles in innovation processes – Integrated development of product-service-systems based on technical products'.

The goal is to develop a method that is able to deal with an integrated approach on product-service-systems and to handle changed circumstances in strategic alignments of a company regarding the satisfaction of market needs. The idea is to combine approaches on product flexibility with the product spectrum in order to achieve a method that can master the new complexity of challenges in the early phase of developing product-service-systems including cycles in regard of the SFB.

2 FLEXIBILITY IN THE INNOVATION PROCESS

2.1 Methods of product flexibility in literature

The fundamentals for product flexibility throughout the innovation process should already be stressed in the early phase of strategic product planning. In the past, various approaches in respect to product flexibility have been researched and published. In particular product families, product platforms, and approaches concerning mass-customization and strategies for individualizing products have been analysed in detail and can be found in sufficiently high numbers in literature [7, 8, 9 ,10, 11].

Mass Customization has been a massively developed area in product development since two decades. The advantages of the combination of mass production and individual products are obvious. Diverse approaches concerning product flexibility have been discussed in the industrial and academic world. Product platforms [12] compose the basis for competitive shares of product portfolios. The multiple applications of the same parts allow higher outcome numbers in production. Product families [13] offer the possibility to diversify a certain product in order to satisfy special customer needs without developing completely new products. Modular assembly systems [14] provide specific interfaces between modules. These modules themselves are able to have variants within.

As a general overview, Figure 2 shows an abstract of analysed methods and their time reference. The lines represent the development of a method. The regarded publication is marked with a small box. Boxes without a specific name indicate publications with only small reference or small further development to the methods taken into consideration.

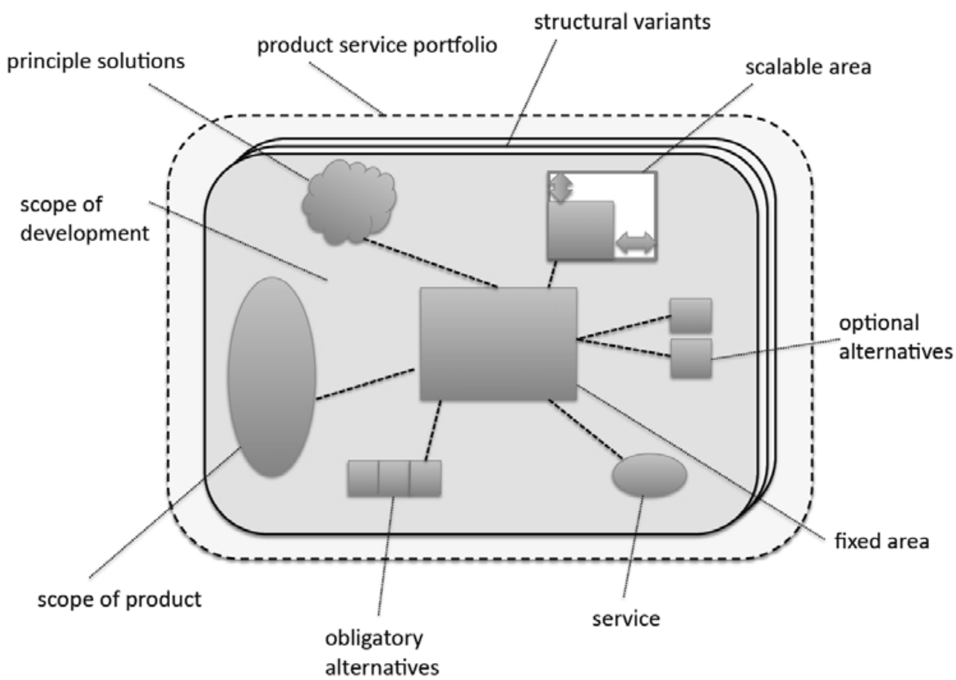

Figure 1: The product spectrum with its dimensions [5]

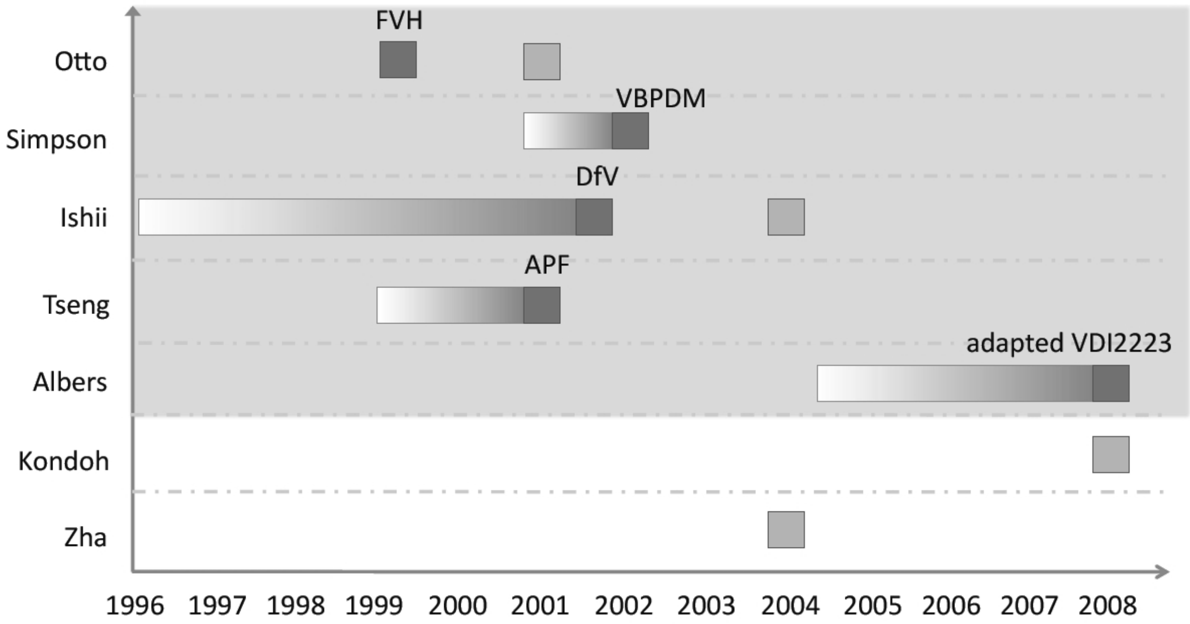

Figure 2: A chronology of product flexibility

The four methods which are taken into account in this paper give an overview regarding the steps of planning of a product. These five examples which only represent a small part of the published work in this research domain represent work which has its foci in different phases of the innovation process. From the requirements level through the function and behaviour level to the structure level in the Munich Model of Product Concretization model [15], each method represents a concretion level.

Focusing on the function level, Zamirowski and Otto [16] are introducing the function variety heuristics method (FVH) dealing with functions and possible modularization of them. Combining costumer needs with product function architecture, the authors propose to develop monolithic product architectures. With the overview of all functions, one can identify product modules which are separated from the product platform.

Martin and Ishii [17] introduce a method for standardizing and modularizing product platform architectures. Existing products are analysed and improved with a focus on the design for variety (DfV). The detailed work presents two indices with which it is possible to identify decoupled architectures with lesser design effort for new generation products. The generational variety index is a measure for the effort which is needed to develop new generations of products. The coupling index is a factor for the interactions of the individual components of a product.

With the described interest in early planning methods, the work of Albers et al. [18] gives an interesting approach on modularization adapting the German guideline VDI 2223 [19]. The interactions between the components are analysed and clustered. The clusters feature a small number of intercluster connections and a high number of intracluster connections.

Du et al. [20] provide a conceptual approach on architectures of product families (APF). The described characteristics and procedures supply designers with a tool for the improved design of product families. The proposed Generic Product Structure is explained as a platform for adjusting products to individual customer needs. The well-elaborated state of the art review provides the reader with an interesting overview of research work done in the last years in this field.

3 EVALUATION OF APPROACHES ON PRODUCT FLEXIBILITY REGARDING THE IMPLEMENTATION IN A PSS-PORTFOLIO

3.1 Approach

In order to extract a sophisticated method to analyse given models of innovation processes, there has been developed a selection of specific criteria, which help to appraise in which way and to which extent the analysed model can be helpful in solving the problem discussed before. The paper compares and opposes in how far the existing approaches are suitable for consideration in the context of early planning of integrated product-service-systems. Thereby, it is focused on if these methods are suitable to represent integrated product service systems, i.e. if the existing methods on product flexibility are capable of representing both products and corresponding services. Further, it is analysed how different aspects from the various lifecycle phases of a product service system can be considered within the respective approaches. For example, it is of interest to which extent the they are able to take various specifications concerning the development, production, distribution, utilisation, maintenance, modernisation, recycling and disposal of the product service system into account. Thereby, it is also analysed in how far cycles (i.e. recurring processes and artefacts) within the lifecycle phases can be represented within the different methods concerning product flexibility. Besides the consideration of cycles within the lifecycle phases, the comparison of existing methods is also directed on the cyclic behaviour in dealing with the process steps within the methods itself. Thereby, it is of interest how often and to which extent representation models of the respective approaches have to be adapted due to new and changing market needs and corresponding product potentials and product ideas. It implies the answer to the question, to which level and to which frequency, the connection between strategy phase, planning phase and design phase has to be considered in the innovation process.

3.2 Introducing criteria for the PSS-portfolio

For evaluation of the regarded methods, there were gathered 45 criteria, which represented the characteristics of a suitable approach for a PSS-portfolio. These criteria strongly correlate with the requirements of a robust product service portfolio as introduced before. After identifying and weighing these criteria, they were combined into six clusters, which shall be presented as follows:

1 The initial criterion 'Categories' is meant to structure the methods according to their focus and their aim. The main question to be answered here is: Why and what for is the method being used?

2 The 'Point of View and Time' covers the different perspectives of the method. Namely ranging from the level of abstraction the level of detail, the development stage to the consideration of cost, this cluster combines all these in order to help to classify the methods even when using several different and independent methods.

3 The 'Input and Origin' cluster regards the question, where the information which is required by the method is coming from and how concrete it is. On the one side, information as input of a method is considered and checked. On the other side, the origin of a new planning process is taken into account.

4 The section 'Implementation' deals with the integration of the method especially with the procedure and the flexibility of the method.

5 The cluster 'Flexibility' only regards the category which deals with the product design. It does not cover the flexibility of the method since that is part of the implementation process. Here, adapting and adding functions are specified since they can measure the flexibility of the product design.

6 The final category 'result oriented" rounds up the list of criteria to evaluate the methods. It deals with the effort of the documentation process and the results of the methods in general.

3.3 Matched correlations of method for product flexibility and PSS-portfolio

The evaluation of the considered methods shows a shared optimum between the four concepts. Hence, there is no method which meets the requirements of the chosen criteria in all categories. The four most interesting methods shall be displayed regarding their performance in each of the clusters.

1 Almost all methods can deal with the product, service and both at the same time. The adapted VDI 2223 is the only one that cannot deal with the service due to the mathematical approach for the generation of a product service portfolio or due to a too low level of abstraction.

2 As expected, all methods can easily handle the requirements as a level of abstraction. The requirement level is mentioned in every single method. Almost the same status can be found for the functional level. All methods can perfectly handle the functional level of abstraction. This trend continues for the behavior and the structure.

3 For most methods, it is difficult to deal with or aim for undefined customer wishes. However, the method FVH is using market research and surveying techniques. This shows the intended importance of identified costumer needs. Therefore, FVH awaits an input on the highest level of abstraction. DfV is also able to handle soft and unsharpened customer wishes with which the development team has to deal further. Undefined wishes can be translated to formulate statements that are necessary for the further development. In comparison to the rest, the adapted VDI 2223 has the lowest possible input compared to all other methods. It is waiting for a specific behavior, given parts or a sub-assembly. Hence, the input for the method already is already a basic solution.

4 The category implementation focuses on the procedure and aspects of the method itself rather than the PSS-portfolio. Thus, the procedure of the method as well as its flexibility and adaptability are covered here. The first two attributes cover the polarity of simplicity and complexity. The APF, DfV and adapted VDI 2223 are well explained, deal with known information only and have no or not much internal dynamics. The FVH is a more abstract method that processes everything on a higher level. In order to stay on track, it is important to follow the steps accurately. Therefore, this method is a slightly complex one.

5 A central point for the PSS-portfolio is the adaption of functions which has to be possible in order to handle a progress through time and changed requirements. DfV and the adapted VDI 2223 only need a decent amount of work load to change the functions of an existing structure. The influence of parts and functions from or on other parts cannot be proven in the APF and the FVH. DfV is the most prominent example for this attribute using the so called coupling index between the parts and functions. The adapted VDI 2223 knows what functions or parts affect each other due to the use of a design structure matrix for displaying dependencies.

6 The FVH and adapted VDI 2223 are the only ones that need to be interpreted. For FVH the result is complex, thus, not visible straight away. Albers et al. show a matrix combined with a graph, that needs interpretation and verification before the development of the product can start due to a possible misleading of the modularization process. On the other hand, the generic product structure discussed in Du et al. gives all information in a compact figure. DfV does not miss to give the developer the results of the generational variety index but suggests concrete options of how to continue. It is positive to see, that all authors reflect on the method and highlight this by a perspicuous example. However, plausibility checks with the results are missing. Not every method guarantees a continuous work with its result. The DfV method leaves the user with several options that are not part of the method anymore but have to be performed in order to continue the development process.

The question about the possibility to add functions to the product service portfolio plays an important role for its success. However, it is the most difficult question to answer as many papers don't mention a lot about it. Initially known functions can be added fairly easy to the product service portfolio as they have been kept in mind and considered all along the product planning and product development and design process. The amount of effort is higher than the effort to adapt a function, but it is still manageable. However, if functions are initially unknown, it is impossible for any of the five methods to add a new one without having to rerun the method. In this case a new product service portfolio has to be generated and the entire process starts over again.

3.4 Combining the analyzed methods to a heuristic approach

As the results have shown, a single product flexibility approach appears not to be sufficient to meet the demands of a PSS-portfolio. It is shown, that different methods comprise different foci during product planning and are therefore not redundant or superior to one another but rather ancillary. Taking the phases of product planning into account like they are introduced by Ponn and Lindemann in the Munich Model of Product Concretization with its generic classification of different levels of abstraction during the planning of product-service-systems, each of the analyzed methods arranges itself differently in the levels function, behavior and structure.

The method of function variety heuristics meets the requirements of the abstract level of the planning process. The functions are still neutral and can be filled unrestrictedly with various technical and service solutions. As functions are the direct interpretations out of the requirements level, handling them suits better to the FVH than to the other analyzed methods and are therefore chosen as the beginning method for the classification of a PSS-portfolio. Regarding the requirements of a PSS-portfolio, the stage of a structured portfolio during the early planning phase of a function structure is given by the FVH.

As for the behavior level, the Design for Variety method is chosen. The focus of this method is the handling of technical and service solutions. With the various indices that describe the interconnections between components and the behavior of single components, the DfV is a powerful tool, to build an image of the existing PSS-portfolio at this level of abstraction. Again, regarding the requirements of a PSS-portfolio during the planning phase, in which the behavior structure is compiled, the DfV acquires an entire image of the technical or service solutions available.

The adapted guideline VDI 2223 by Albers deals with the structuring of the very specific properties of a PSS. As the method is very potent in characterizing different variants regarding i.e. the package size or the performance value, the usability is restricted to the product side of a PSS. The service side is hard to divide in numbers or values and is therefore, mostly, not suitable for a modularization of service parts of the PSS. Nevertheless, there can be entire PSS-concepts with reasonable need for the adapted VDI 2223.

4 SUMMARY

4.1 Conclusion

Connecting three methods together to get an integrated and continuous portfolio, there has to be a tool, with which the parts can be aligned. During research, the analysis has shown, that the also examined method of architecture of product families has the characteristics of a meta method. It provides the language for the other three methods to define incoming and outgoing information and therefore joining them into a whole consistent method. Figure 3 outlines the arrangement of the analyzed methods. As the characteristics used by APF, the other three methods have to be adapted in order to meet these requirements. This will be part of future work. The common language is necessary to develop analysis and controlling tools within the portfolio as same as between various portfolios.

Configurating an image of the aligned balance of the potential of a company and the needs of the customer, the portfolio describes an important instance during the PSS-planning process. With it, it is possible to estimate the effort which is required to change an existing potential of a company in bringing a PSS to market and the work that has to be done in order to fill the white gaps, which are not covered by resources, knowledge or capacities in the company.

Along, the impact of specific changes coming from cyclic interconnections can be damped, because it is more obvious to the planning team where this impact takes place. Even more, anticipated changes will be already included in a continuously updated PSS-portfolio. The result is the reduction of time pressure in the development process, because expansive iterations will be avoided and further, aberrations of PSS are minimized.

4.2 Future Work

As mentioned before, the four identified methods are building a base for the structure of a PSS-portfolio. Though, it is necessary to define exactly the information which is handled between the three stages of function, behavior and structure and shall be part of future work including an example from an analyzed portfolio in the industry.

Further research will take the results in this paper into

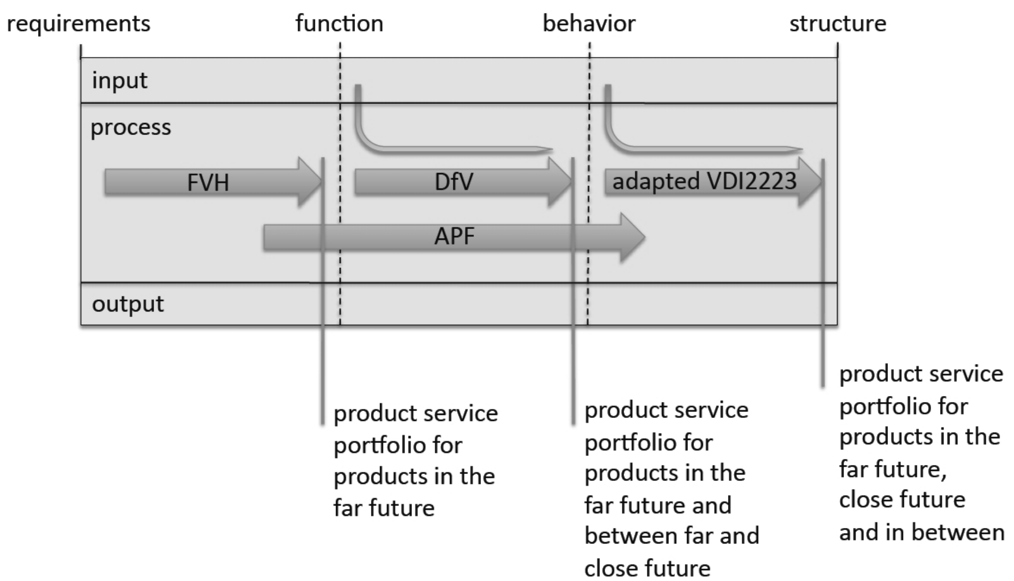

Figure 3: Adapted approaches on product flexibility

account and develop special indices, out of which it will be possible to guide an innovation process. It is planned to monitor the process at every desired time and give a respond on the extent of flexibility in every step of the design process. Therefore, it will be feasible to estimate the degree to which a project is suited for further changes along the early stages of the product life cycle. With changed market conditions in a running design process, the indices shall be capable of providing definite directives to confront fulgurous market events. A possible enhancement of the PSS-portfolio could be the inclusion of manufacturing requirements and the interconnection of PSS and production.

The structure of a PSS-portfolio is developing over time. Today's portfolio is displaying the resources and potential of a company. Including methods of early planning, there is the opportunity to develop future portfolios regarding middle-and long-term targets which are influenced by the strategic orientation of the management of a company. It will be possible to analyse the costs and therefore the effort needed for the changes regarding meeting the strategic goals. By tools coming from systems engineering [21, 22], the structures can be analysed and decisions can be made. I.e. the future work in this topic will focus on minimizing the change of structure. The middle-term structure of the PSS-portfolio shall be aligned to long-term goals in order to avoid unnecessary efforts which are not helpful in the long-term perspective.

5 ACKNOWLEDGEMENT

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6 REFERENCES

[1] Pine, P. J., 1993, Mass Customization The New Frontier in Business Competition, Harvard Business School Press, Bosten

[2] Gräßler, I., 2004, Kundenindividuelle Massenproduktion. Springer Verlag, Berlin

[3] Piller, F., 2001, Mass Customization, DUV, Wiesbaden

[4] Baumberger, G., 2007, Methoden zur kundenspezifischen Produktdefinition bei individualisierten Produkten, Technical University Munich: Dr. Hut, PhD thesis

[5] Lindemann U., Reichwald, R., Zäh, M. F., 2006, Individualisierte Produkte – Komplexität beherrschen in Entwicklung und Produktion, Springer, Berlin

[6] Hepperle, C., Thanner, S., Mörtl, M., Lindemann, U., 2009, An integrated product lifecycle model and interrelations in-between the lifecycle phases, 6th International Conference on Product Lifecycle Management.

[7] Nayak, R., Chen, W., Simpson, T., 2002, A variation-based method for product family design, Engineering Optimization 34: 65-81.

[8] Robertson, D., Ulrich, K., 1998, Planning for Product Platforms, Sloan Management Review, Vol. 39, No. 4: 19-31.

[9] Zha, X., Sriram, R., Lu, W., 2004, Evaluation and selection in product design for mass customization: A knowledge decision support approach, Special Issue: Platform product development for mass customization Cambridge: Cambridge University Press: 87-109.

[10] Kondoh, S., Masui, K., Hattori, M., Mishima, N., Matsumoto, M., 2008, Total performance analysis of product life cycle considering the deterioration and obsolescence of product value, International Journal of Product Development 6 3-4: 334-352.

[11] Tseng, M., Jiao, J., 2001, Mass customization, Handbook of Industrial Engineering. Edition 3,. New York: chapter 25

[12] Meyer, M. H., Utterback, J. M., 1993, The Product Family and the Dynamics of Core Capability, Sloan Management Review, Vol. 34: 29-47.

[13] Erens, F. Verhulst, K., 1997, Architecture for product families, Computers in Industry 33: 165-178.

[14] Meyer, M., Lenhard, A., 1997, The power of product platform: building value and cost leadership, New York: Free Press

[15] Ponn, J., Lindemann, U., 2008, Konzeptentwicklung und Gestaltung technischer Produkte, Berlin

[16] Zamirowski, E., Otto, K., 1999, Identifying product portfolio architecture modularity using function and variety heuristics, Proceedings of the 11th International Conference on Design Theory and Methodology, ASME Design Engineering Technical Conferences.

[17] Martin, M., Ishii, K., 2002, Design for variety: developing standardized and modularized product platform architectures, Research in Engineering Design, Vol. 13: 213-235.

[18] Albers, A., Burkardt, N., Sauter, C., 2008, A modularization method in the early phase of product development, International Design Conference – Design 2008: 253-260.

[19] German Industry Guideline, 1999, VDI-Richtlinie 2223: Methodisches Entwerfen technischer Produkte, March

[20] Du, X., Jiao, J., Tseng, M., 2001, Architecture of product family: fundamentals and methodology, Concurrent Engineering: Research and Application 9, No. 4: pp. 309-325.

[21] Browning, T.R., 2002, Applying the Design Structure Matrix to System Decomposition and Integration Problems – A Review and New Directions, IEEE Transactions on Engineering Management 48: 292-306.

[22] Lindemann, U., Maurer, M., Kreimeyer, M., 2004, Intelligent strategies for structuring products, Knowledge based intelligent information and engineering system, International Conference: 1157-1163

A Product-Service Systems Design Method Integrating Service Function and Service Activity and Case Studies

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Abstract

This paper proposes a design framework of Product-Service Systems (PSS) using both functional modelling and service activities. In the functional modelling of PSS, the function decomposition approach is used with specification of service providers and service receivers. The overall function of PSS is decomposed into various sub-functions and service providers/receivers are also decomposed into sub-providers/receivers, which are later appropriately assigned to sub-functions. Each sub-function is linked with the service activities based on the information on its service providers and receivers. The linkage between sub-functions and service activities is represented in the modified service blueprint through the introduction of the function layer. The pairs of sub-functions and service activities are mapped to product and service elements to produce PSS concepts. Case studies are conducted to confirm the applicability of the proposed methodology for effective PSS design.

Keywords

Product-Service Systems (PSS), Functional Modelling, Service Blueprint, Service Function, Service Activity

1 INTRODUCTION

A number of researches on a novel and innovative value proposition through the integration of products and services – product-service systems (PSS) – have been conducted over the last decade. The concept of PSS has been firstly introduced by Goedkoop et al. in 1999 to deal with the environmental and economical challenges, and it was defined as a marketable set of products and services, jointly capable of fulfilling a client's need [1]. In their research work, the advantages of PSS were also discussed such as creating value of clients with quality and comfort, customizing offers or delivery of the offer to clients, decreasing the cost of initial investment by sharing, leasing and hiring, decreasing environmental load, and so on. Mont also defined PSS as a system of products, services, supporting networks and infrastructure that is designed to satisfy customer needs and have a lower environmental impact than traditional business models [2, 3]. In addition, a theoretical framework for PSS reflecting societal infrastructure, human structures and organizational layouts was proposed to enhance environmental values.

The research on the methodological framework to design PSS from the views of designers was conducted by Morelli [4]. The case study for the development of PSS – an urban telecenter – was carried out. In the case study, the major functions and requirements for the PSS were extracted, and they were then mapped to the elements of products and services. Aurich et al. researched the life-cycle oriented design processes of products and services [5]. They proposed the systematic design process of technical services associated with products, which would be later integrated with the product design process. They also introduced the concept of process modularization for integrating of product and service design processes by selecting, combining and adapting appropriate process modules [6]. Matzen and McAloone proposed a tool for conceptualizing the development of PSS by introducing the activity modelling cycle (AMC) model to address many issues identified as central for PSS development [7]. They investigated the effectiveness of the AMC model by conducting case study on service delivery in the container ship industry. In their more recent work, they structured modelling scheme to differentiate and categorize different development tasks towards product/service oriented business with the case study of maritime equipment [8].

Shimomura et al. have conducted substantial research on service engineering [9-13]. They introduced the service model, including several sub-models such as flow model, scope model, view model and scenario model, and receiver state parameters (RSPs) representing value and cost to be implemented into the service design process. They also developed the prototype system as the computer-aided design tool for service design, which was called Service Explorer. Their concept was borrowed by Maussang et al. to develop the model for designing PSS [14]. They modified engineering product design process into PSS design process by introducing the service model of Shimomura's group. In their case study, the feasibility of the proposed method based on functional analysis and agent-based value design was examined by considering the bike rental system – Velo'v. In more recent work, Maussang et al. proposed the modified PSS design method incorporating users' activity and operation sequence [15]. They also studied the evaluation of PSS concepts in the early design phase.

Although considerable researches for the effective design of PSS have been conducted, none of the above research works have presented any systematic approach to address functions of PSS. Functions could be regarded as the neutral term to realize the values to satisfy the customer needs, which could be of much significance to effectively realize PSS. In the product design domain, the considerable research works have been conducted to address functional modelling and analysis. The verb-noun pair expression of functions was firstly proposed by Miles [16] and Rodnacker [17]. They considered the product functionality to develop the functional representations and models of transformations of energy, material and information flows. Koller then proposed twelve basic functions to describe the product functionality [18], and Hundal refined Koller's work to produce the set of function and flow classes [19]. To provide the universal language for the functional modelling, the research efforts to propose the standardized sets of functions and flows have been made by Szykman [20] and Stone [21]. Their works were later reconciled by Hirtz et al. to result in the Functional Basis [22]. Nagel et al. proposed the function design framework combining process and function modelling to deal with complex systems [23].

On the other hand, a number of parallel researches on the development of functional modelling techniques could be found. Umeda and Tomiyama proposed the Function-Behavior-State modelling approach to reflect the designers' intent when addressing behaviour as the realization of the function [24]. The Function-Behaviour-Structure framework was proposed by Gero to represent various steps in the design process and capture associated transformation among these three classes [25]. He also extended the above framework into the situated Function-Behaviour-Structure to reflect dynamic context related to the environment [26]. In Gero's research works, the concept of behaviour was regarded as more detailed descriptions of high-level functionality. The mappings from function to behaviour to physical structures were addressed in Gero's research.

In PSS design, due to the nature of its service elements, associated service activities should be considered as well as functions. Therefore, in this paper, a design framework of PSS including both functional modelling and service activities is proposed. In the functional modelling of PSS, new scheme to represent the function of PSS adding service provider and service receiver will be proposed. The overall function and service provider/receiver will be decomposed into sub-functions and sub-service providers/receivers, and they are appropriately associated to each other. The modified service blueprint will also be proposed by adding the layer of functions and relating them with various activities of service providers and receivers. In addition, PSS concept generation scheme will be addressed by borrowing the notion of morphological chart. In PSS concept generation template, functions, service providers/receivers, service activities and product/service elements are combined together to effectively generate the alternative PSS concepts. Finally, the case study on handcrafting PSS design is conducted to examine the applicability of the proposed methodology for effective PSS design.

2 FUNCTIONAL MODELLING OF PSS

PSS design can be different from the product design since it involves the service elements. It has been known that service greatly involves the human elements [27]. In addition, the service usually requires providers and receivers, and its quality and contents highly depend on their interactions. Therefore, it is necessary to include the information of service providers and receivers in the functional modelling of PSS. The functional language used in the PSS functional modelling was the Reconciled Functional Basis proposed by Hirtz et al., which was such an example including the standardized sets of functions and flows [22].

The representation scheme for the functional modelling of PSS is shown in Figure 1. As can be seen in Figure 1, three flow classes – energy, material and information – are still used to connect the function blocks, which is similar to the case of product design. Function classes used in this framework are also same as those in the reconciled functional basis. The service provider and service receiver are represented as folded lines in upper left corner and lower right corner of the function block, respectively.

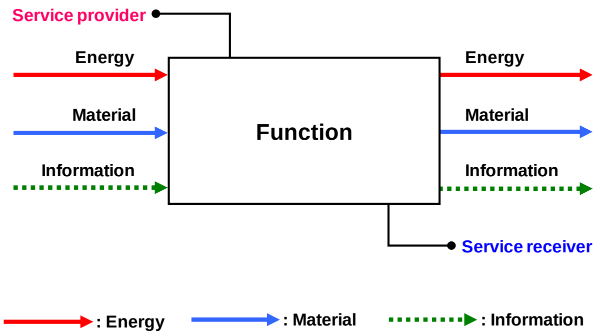


Figure 1: Schematic of Functional Modelling of PSS

Once the overall function is defined, the decomposition into the related sub-functions will be conducted, and the associated flows connect the sub-function blocks based on their causal and logical relations. These causal and logical connections among the sub-function blocks can later be used to define the PSS components or functional modules. The procedures for the PSS function decomposition are similar to those in the case of the product design. The illustrative example of the function decomposition diagram is shown in Figure 2. Several sub-function blocks can be grouped together to form a function module. As can be seen in Figure 2, the sub-function blocks are connected via three flows, and therefore, these flows could play an important role for building up the interfaces among product and service elements in the whole PSS. The functional modelling framework can facilitate the arrangement of product and service elements to produce various PSS concepts. When overall function of service is decomposed, the service providers and receivers are also decomposed. As can be seen in Figure

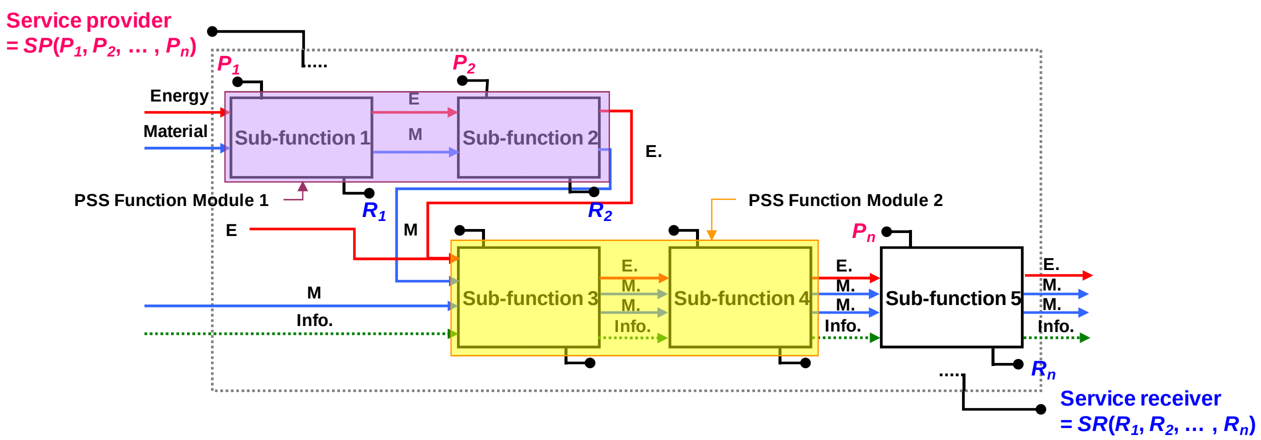


Figure 2: Function Decomposition of PSS and Functional Module Grouping

2, each block of sub-functions has its own service provider and receiver, which are elements of sets of overall service provider (SP) and service receiver (SR). They are called by sub-service providers and sub-service receivers, and appropriately assigned to sub-function block.

3 SERVICE BLUEPRINT AND SERVICE ACTIVITIES

The concept of service blueprint was originally proposed by Shostack to describe service roadmaps [28]. In the service blueprint, how and where customers (Service Receiver, SR) and employees of company (Service Provider, SP) interact is tangibly and visually documented. More specifically, the service blueprint is an information-laden document which consists of five components, and can help make customer-company relationship clear. The five components in the service blueprint are customer actions, onstage/visible contact employee actions, backstage/invisible contact employee actions, support processes and physical evidence. Those five components are arranged into the table form, which is shown in Figure 3.

Service Blueprint Components	
Physical Evidence	
Customer Actions	Line of Interaction
Onstage/ Visible Contact Employee Actions	Line of Visibility
Backstage/ Invisible Contact Employee Actions	Line of Internal Interaction
Support Processes	

Figure 3: Service Blueprint Schematic Diagram [28]

Customer actions include all of the steps that customers take as part of the service delivery process. Onstage/visible contact employee actions are the actions of frontline contact employees that occur as part of a face-to-face encounter with customers. Backstage/visible contact employee actions are non-visible interactions with customers, such as telephone calls, as well as other activities employees undertake in order to prepare to serve customers or that are part of their role responsibilities. Support processes are all activities carried out by individuals in a company who are not contact employees, but whose functions are crucial to the carrying out of services processes. Physical evidence represents all of the tangibles that customers are exposed or collect to during their contact with a company.

In the traditional service blueprint schematic diagram, the interactions between customer actions and onstage/visible employee actions are expressed as a single line. However, the connection of activities between service provider and receiver can be made more clearly by introducing functions, since they establish the relationship between service provider and receiver, which is shown in Figure 1. Therefore, in the modified service blueprint, the function layer was inserted between service provider activity and on-stage service receiver activity. In addition, the component of physical evidence was also modified into the layer of product and service elements to effectively generate PSS concepts by linking them with functions and activities. The schematic diagram of the modified service blueprint is shown in Figure 4. As can be seen in Figure 4, the interactions between SR activity and on-stage SP activity can be described by the function layer.

Modified Service Blueprint (SR: Service Receiver, SP: Service Provider)	
Product & Service Elements	
SR Activity	
Functions	Interaction Layer
Onstage SP Activity	Line of Visibility
Backstage SP Activity	Line of Internal Interaction
Support Processes	

Figure 4: Modified Service Blueprint Schematic Diagram

4 PSS CONCEPT GENERATION

In the case of PSS concept generation, function, service provider/receiver, service activities and product/service elements should be considered as a whole, which is much different from the case of product design. Therefore, the template to generate alternative PSS concepts integrating above components was proposed by borrowing the notion of morphological chart, which is shown in Figure 5. In this template, functions, service providers/receivers, service activities and possible product/service elements can be combined together to generate several alternative PSS concepts. In the column of product/service elements, the regular rectangles mean product elements, and the rounded rectangles denote the service elements.

The functions in the PSS concept generation template are identified from the functional modelling framework described in section 2. Possible service providers and receivers are assigned to the function, and the appropriate service activities are mapped to service providers and receivers, respectively. Finally, potential product and service elements are associated with the service activities to generate the PSS concepts.

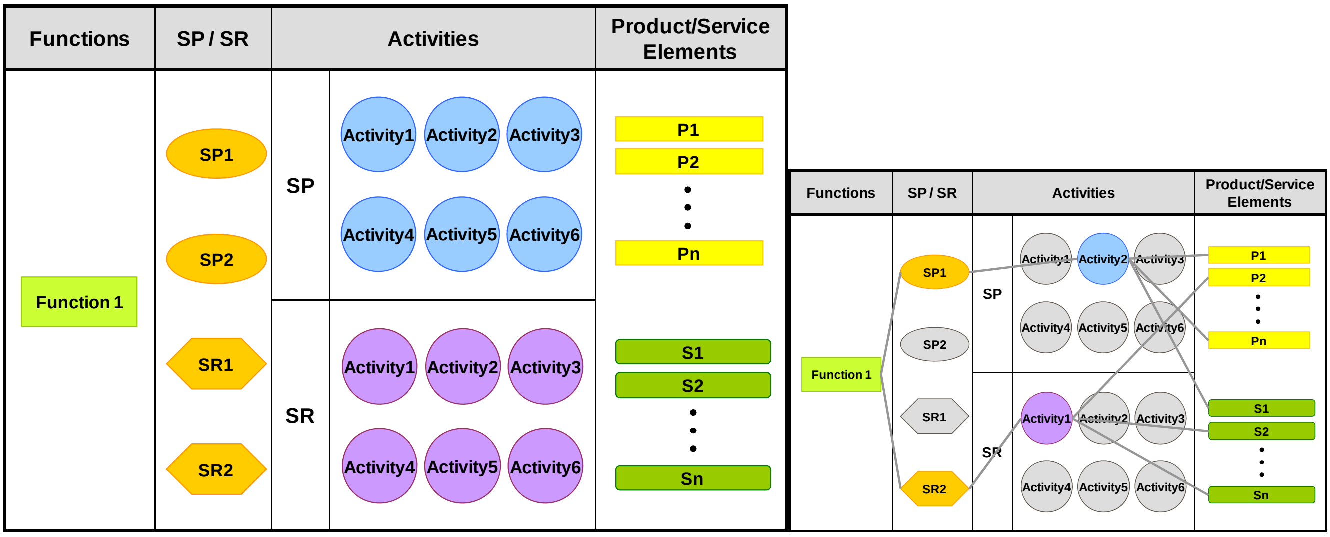


Figure 5: PSS Concept Generation Template and Mapping for PSS Concept Generation

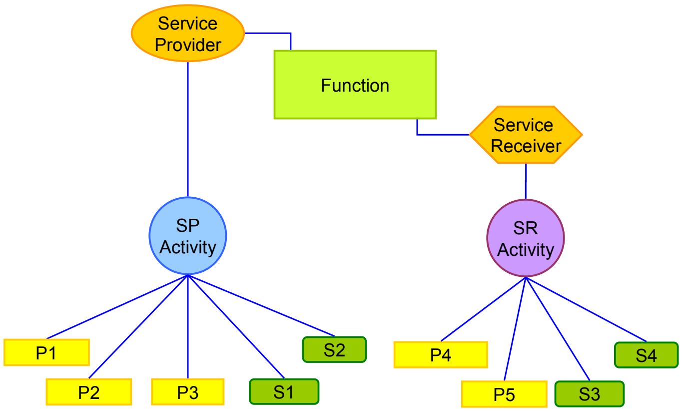


Figure 6: Schematic Representation of PSS Concept

The schematic diagram of the PSS concept was also developed to effectively represent the relationship among functions, service providers/receivers, service activities, and product/service elements, which is given in Figure 6. The schematic given in Figure 6 can systematically represent the structure of the PSS concept, and help understand the components consisting of the PSS concept and their relations.

5 CASE STUDY: HANDCRAFTING PSS

To examine the effectiveness of the proposed PSS design framework, the case study to design handcrafting PSS was conducted. In the handcrafting PSS, the customers' need to carry out handcrafting work can be satisfied in various ways

5.1 Functional Modelling

The overall function of the handcrafting PSS was defined as "provide handcrafting service", as shown in Figure 7. The input and output flows were listed according to the classes of energy, material and information. The service provider was defined as "handcrafting PSS management" and service receiver was defined as "handcrafting PSS service receiver". The function decomposition of the overall function of the handcrafting service was conducted and is shown in Fig. 8. As can be seen in Fig. 8, critical sub-functions are appropriately arranged and connected according to the logical relations of flows. In addition, the service provider and receiver were decomposed into sub-service providers and receivers and appropriately assigned to each sub-function block. For instance, when considering the function of "process handcrafting work", the service provider and receiver were handcrafting service station and customer, respectively. These sub-service provider/receiver were subset of overall service provider and service receiver. The PSS function modules could also be generated by grouping several sub-function blocks, as shown in Fig. 8. Seven (7) PSS function modules were identified such as reservation module, import module, handcrafting service provision module, export module, procurement module, cleaning module and repair module. The grouping of sub-function blocks could be conducted by considering logics of flow connections, sub-service provider/receiver, and so on.

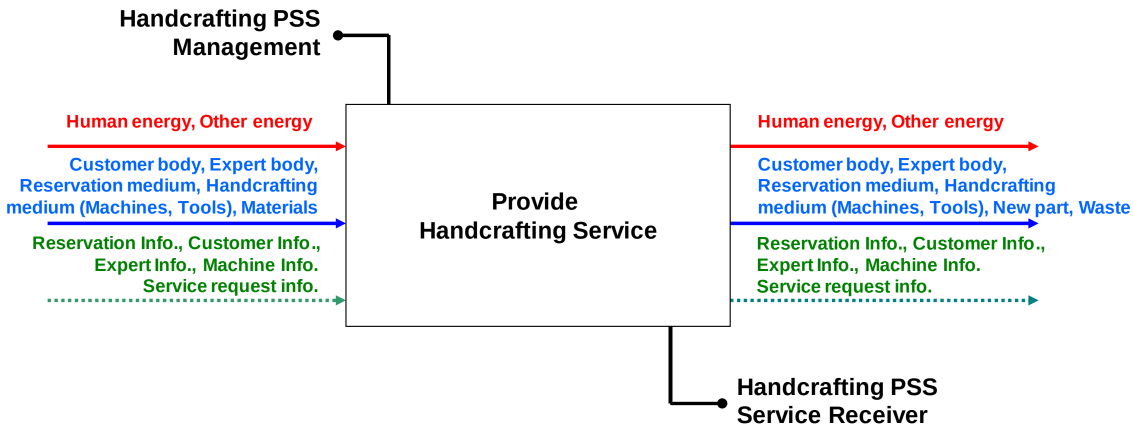


Figure 7: Overall Function and Associated Input/Output Flows of Handcrafting PSS

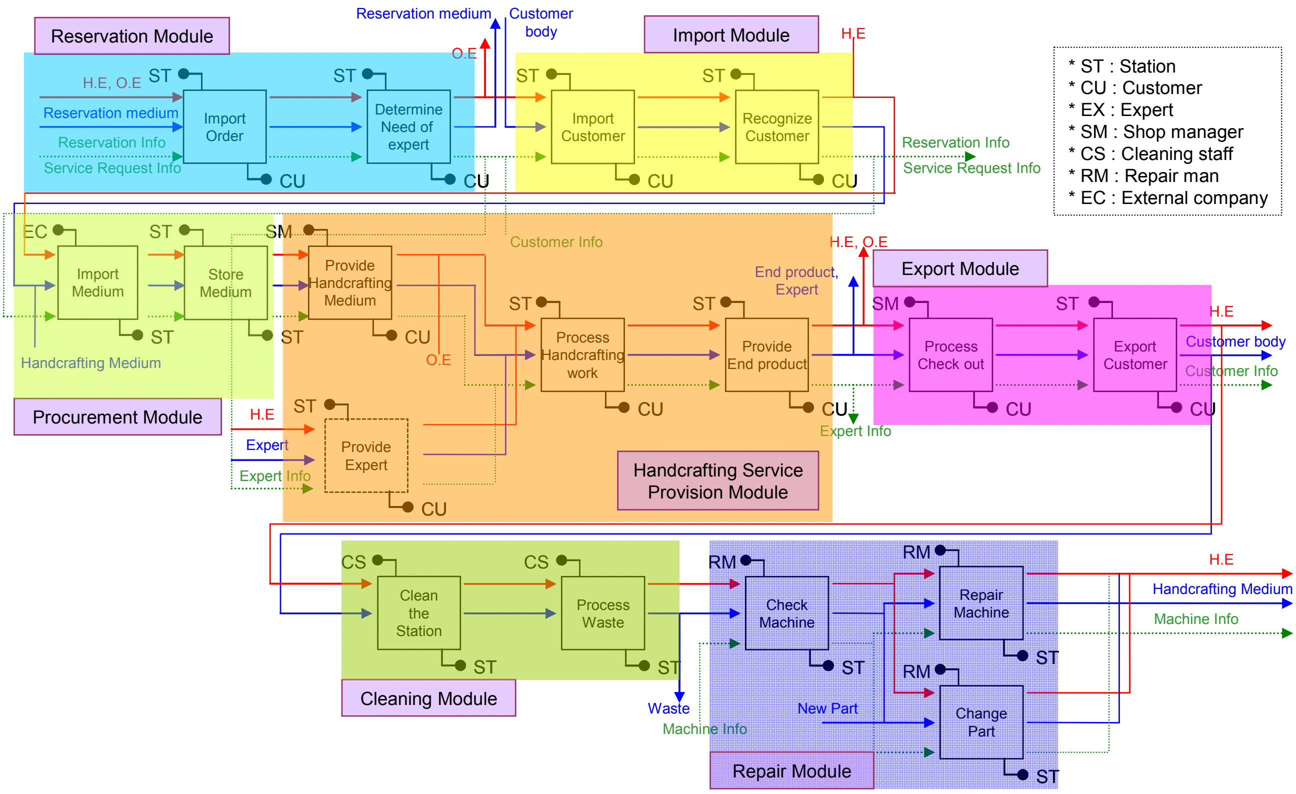


Figure 8: Function Decomposition of Handcrafting PSS and Functional Module Grouping

5.2 Service Activities and Modified Service Blueprint

Possible service activities of customer and service provider of the handcrafting PSS were listed, and they were mapped with the functions identified from the functional modelling. Figure 9 shows the modified service blueprint for the handcrafting PSS. For simplicity, the layer of product/service elements was omitted. When closely observing the modified service blueprint, the critical relationship among functions and service activities can be identified. In addition, the elements in the support process were related to the activities of service provider. For instance, the part of service blueprint corresponding to the handcrafting service provision module is given in Figure 10. As can be seen in Figure 10, four (4) sub-functions consisted of the handcrafting service provision module, and each sub-function was associated with the activities of customer and service provider, and the activities of service provider were related to the system in support process. Specifically, in Figure 10, the function of “provide expert” was linked to the customer activities of “receive expert service” and “use machine” and the service provider activities of “provide expert”, “provide professional help” and “call expert”. These service provider activities were associated with “expert provision system” in the support process. These relations can allow the designers to know which service activities should be considered to realize specific functions of PSS.

5.3 PSS Concept Generation

To generate alternative PSS concepts, the PSS concept generation template given in Figure 5 was used in the case study. In particular, the case study was focused on the generation of PSS concepts corresponding to the sub-functions of the handcrafting service provision module. The PSS concept generation template for the handcrafting services provision module is given in Figure 11. As can be seen in Figure 11 (a), in each column, functions, service providers and receivers, activities and product/service elements were located, respectively.

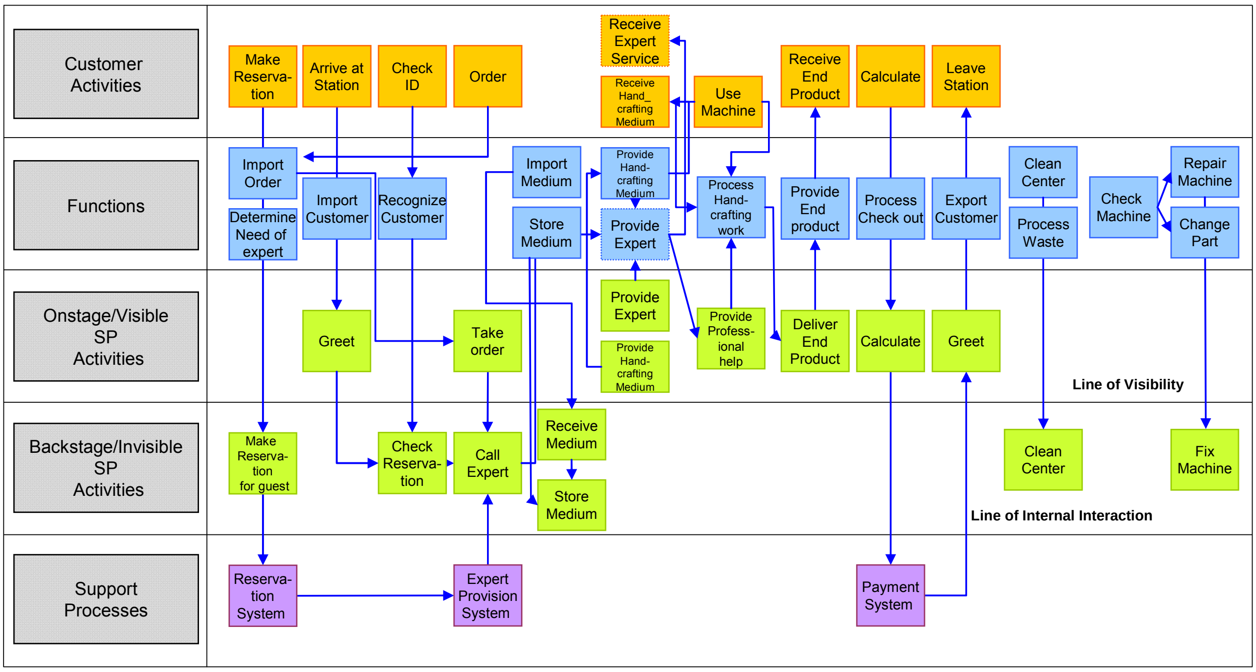


Figure 9: Modified Service Blueprint of Handcrafting PSS

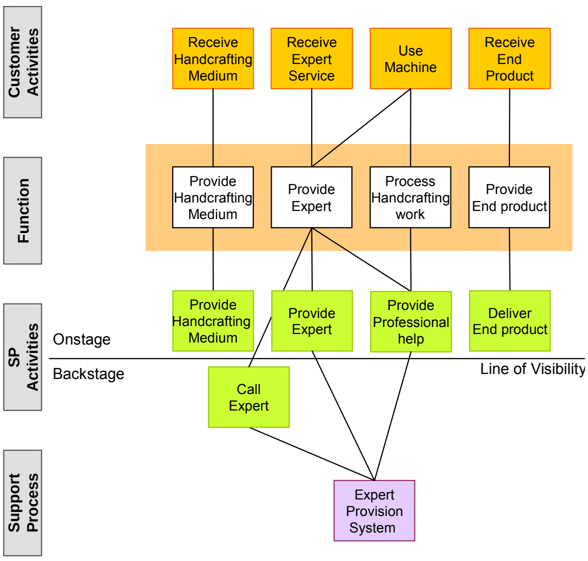


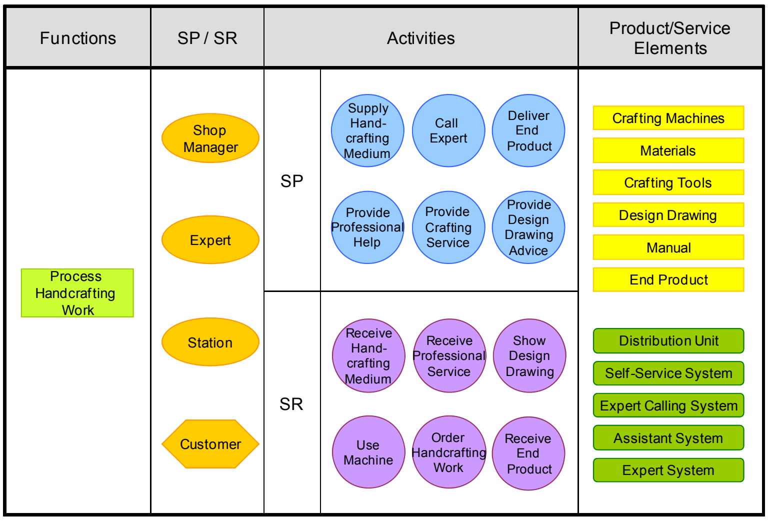
Figure 10: Part of Modified Service Blueprint: Handcrafting Service Provision Module

For each function, specific service provider and receiver would be selected from the template. Then, possible activities were assigned to service provider and receiver. Finally, the product and service elements were mapped to the activities. The various combinations of function, service provider/receiver, their activities and product/service elements would become the PSS concepts. In Figure 11 (b) and (c), the generation of two alternative PSS concepts realizing the function of "process handcrafting work" is illustrated.

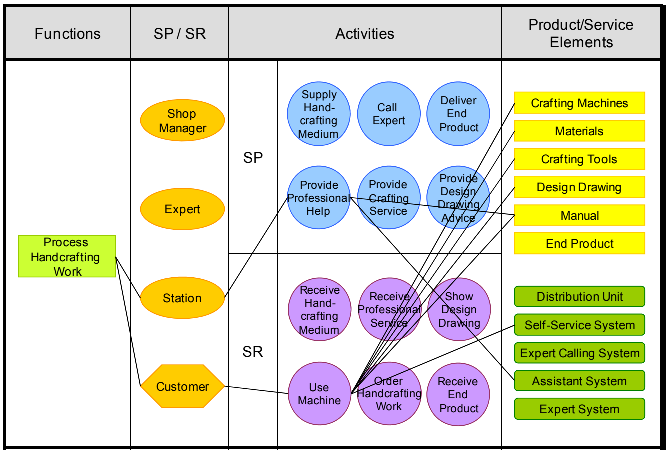
In the case of the PSS concept 1 shown in Figure 11 (b), the customer uses the crafting machine, tools and materials to conduct his/her own crafting work with the help from an assistant system of the handcrafting service station. In this concept, the activity of "provide professional help" was related to the service provider of "station", and the product element of "manual" and the service element of "assistant system" were associated with the activity. On the other hand, the activity of "use machine" was mapped to the service receiver of "customer" and was related to the product elements of "crafting machine", "crafting tools", "materials", "design drawing" and "manual" and the service element of "self-service system". The corresponding schematic representation to the PSS concept 1 is given in Figure 12 (a).

In the case of the PSS concept 2 given in Figure 11 (b), the customer asks the station fully complete crafting service to produce an end product. In this concept, the customer places an order of crafting service through expert system, and the station then conducts complete crafting work using crafting machine, crafting tools and materials based on the design drawing provided by customer. Therefore, the schematic diagram corresponding to the PSS concept 2 is given in Figure 12 (b). As can be seen in Figure 12 (b), the activity of "order handcrafting work" was mapped to customer and the product element of "design drawing" and the service element of "expert system" were assigned to that activity. In addition, the activity of "provide crafting service" was mapped to the service provider of "station" and was associated with the product elements of "crafting machine", "crafting tools", "materials", "design drawing" and "manual and the service element of "expert system".

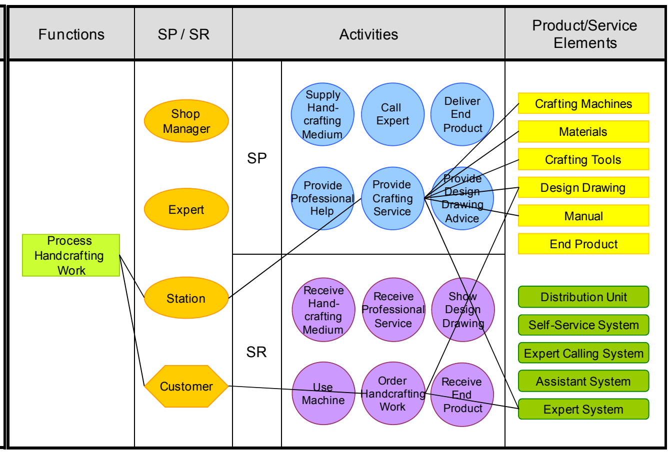
As can be seen in Figure 12 (a) and (b), the different mapping of the activities to the service provider/receiver and product/service elements to the activities makes two PSS concepts distinctive. With this kind of diverse mappings, various PSS concepts could be generated. In addition, the different service elements such should be introduced and appropriately assigned to the activities to effectively develop each concept.



(a) PSS Concept Generation Template for Handcrafting Service Provision Module

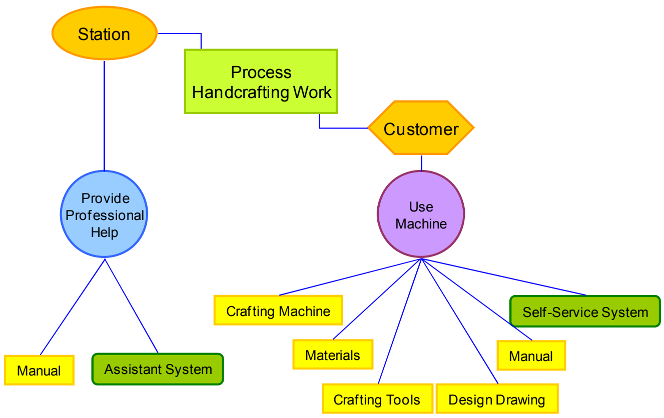


(b) Generation of PSS Concept 1

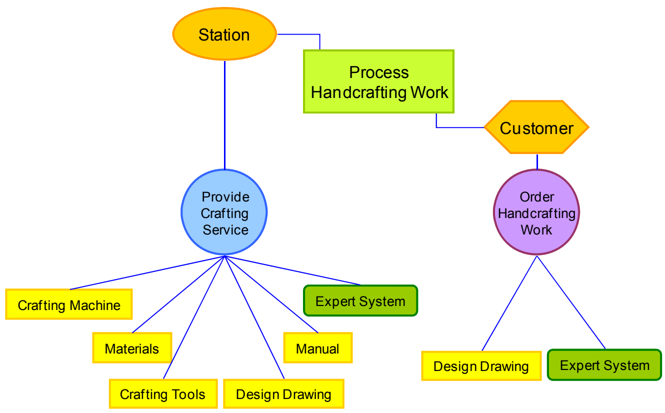


(c) Generation of PSS Concept 2

Figure 11: PSS Concept Generation Template: "Process Handcrafting Work"



(a) PSS Concept 1



(b) PSS Concept 2

Figure 12: Schematic Representations of PSS Concepts Corresponding to Function of "Process Handcrafting Work"

6 SUMMARY

This paper proposed a PSS design framework incorporating functional modelling and service activities. In addition, a novel PSS concept generation scheme combining functions, service providers/receivers, service activities and product/service elements was proposed.

In the functional modelling of PSS, a new representation scheme of function was devised by adding service provider and service receiver. The function decomposition approach was also applied to obtain critical sub-functions and sub-service providers/receivers.

While considering service activities of PSS, the layer of functions identified from the functional modelling was inserted, resulting in a modified service blueprint. The modified service blueprint could help clarify the interactions between service providers and receivers, which could be of much significance in the PSS design.

A new PSS concept generation template was also proposed. This template enabled the systematic mapping among functions, service providers/receivers, service activities and product/service elements. As a result, several alternative PSS concepts could be generated. In addition, a novel schematic diagram representing PSS concept was developed to effectively investigate the structure of PSS concepts by understanding its components and their relations.

In order to verify the applicability of the proposed PSS design framework, the case study on designing handcrafting PSS was conducted. The results from the case study confirmed the usefulness of the proposed PSS design framework.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Goedkoop, M. J., van Halen, C. J. G., te Riele, H. R. M., and Rommens, P. J. M., 1999, “Product Service Systems: Ecological and Economic Basics”, Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ).

[2] Mont, O., 2002, “Clarifying the Concept of Product-Service System”, Journal of Cleaner Production, 10: 237–245.

[3] Mont, O., 2004, “Product-Service Systems: Panacea or Myth?”, Ph.D. Dissertation, Lund University.

[4] Morelli, N., 2003, “Product-Service Systems, a Perspective Shift for Designers: A Case Study: the Design of a Telecentre”, Design Studies, 24(1): 73–99.

[5] Aurich, J. C., Fuchs, C., and Wagenknecht, C., 2006, “Life Cycle Oriented Design of Technical Product-Service Systems”, Journal of Cleaner Production, 14: 1480–1494.

[6] Aurich, J. C., Schweitzer, E., and Mannweiler, C., 2008, “Integrated Design of Industrial Product-Service Systems”, Proc. 41st CIRP Conf. on Manufacturing Systems, Tokyo.

[7] Matzen, D. and McAloone, T. C., 2006, “A Tool for Conceptualising in PSS Development”, Design for X, Beiträge zum 17. Symposium. Lehrstuhl für Konstruktionstechnik, Technische Universität Erlangen, 131–140.

[8] Matzen, D. and McAloone, T. C., 2008, “From Product to Service Orientation in the Maritime Equipment Industry – a case study”, Proc. 41st CIRP Conf. on Manufacturing Systems, Tokyo.

[9] Tomiyama, T., Shimomura, Y., and Watanabe, K., 2004, “A Note on Service Design Methodology”, Proc. ASME Int’l. Conf. of Design Theory and Methodology, Salt Lake City.

[10] Lindahl, M., Sundin, E., Sakao, T. and Shimomura, Y., 2005, “An Application of a Service Design Tool at a Global Warehouse Provider”, Proc. Int’l. Conf. on Engineering Design, Melbourne.

[11] Sakao, T., Shimomura, Y., Comstock, and M., Sundin, E., 2005, “Service Engineering for Value Customization”, Proc. 3rd Int’l. World Congress on Mass Customization and Personalization (MCPC), Hong Kong.

[12] Sakao, T., Shimomura, Y., Comstock, M., and Sundin, E., 2006, “A Method of Value Customization”, Proc. Int’l. Design Conference, Dubrovnik.

[13] Sakao, T., and Shimomura, Y., 2007, “Service Engineering: a Novel Engineering Discipline for Producers to Increase Value Combining Service and Product”, Journal of Cleaner Production, 15: 590–604.

[14] Maussang, N., Sakao, T., Zwolinski, P. and Brissaud, D., 2007, “A Model For Designing Product-Service Systems Using Functional Analysis and Agent Based Model”, Proc. Int’l. Conf. on Engineering Design, Paris.

[15] Maussang, N., Zwolinski, D. and Brissaud, D., 2009, Evaluation of “Design Loops” to Support the Design of Product Service Systems: A Case Study of a Helium Liquefier, Proc. CIRP Industrial Product-Service Systems Conference, Cranfield.

[16] Miles, L., 1961, Techniques of Value Analysis and Engineering, New York, McGraw-Hill.

[17] Rodenacker, W., 1971, Methodisches Konstruieren (Methodical Design), Berlin, Heidelberg, New York, Springer.

[18] Koller, R., 1985, Konstruktionslehre für den Maschinenbau (Mechanical Engineering Design), Berlin: Springer-Verlag.

[19] Hundal, M., 1990, “A Systematic Method for Developing Function Structures, Solutions and Concept Variants,” Mechanism and Machine Theory, 25(3): 243-256.

[20] Szykman, S., Racz, J., and Sriram, R., 1999, “The Representation of Function in Computer-Based Design,” Proceedings of the ASME Design Theory and Methodology Conference, Las Vegas, NV.

[21] Stone, R. and Wood, K., 2000, “Development of a Functional Basis for Design,” Journal of Mechanical Design, 122(4): 359-370.

[22] Hirtz, J., Stone, R., McAdams, D., and Szykman, S.W., K., 2002, “A Functional Basis for Engineering Design: Reconciling and Evolving Previous Efforts,” Research in Engineering Design, 13(2): 65- 82.

[23] Nagel, R. L., Stone, R., Hutcheson, R., McAdams, D. A. and Donndelinger, J. A., “Function Design Framework (FDF): Integrated Process and Function Modelling for Complex Systems”, Proceedings of the ASME Design Theory and Methodology Conference, Brooklyn, NY.

[24] Umeda, Y., Takeda, H., Tomiyama, T., and Yoshikawa, H., 1990, “Function, Behaviour, and Structure,” AIENG'90 Applications of AI in Engineering: 177-193.

[25] Gero, J.S., 1990, “Design Prototypes: A Knowledge Representation Schema for Design,” AI Magazine, 11(4): 26-36.

[26] Gero, J.S. and Kannengiesser, U., 2002, “The Situated Function - Behaviour – Structure Framework,” Artificial Intelligence in Design: 89- 104.

[27] Hara, T., Arai, T., and Shimomura, Y., 2008, Integrating Function Model and Activity Model for Design of Service, Proc. 41st CIRP Conf. on Manufacturing Systems, Tokyo.

[28] Shostack, G.L., 1982, “How to Design a Service,” European Journal of Marketing, 16(1): 49-63

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Design Method for Concurrent PSS Development

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Abstract

In manufacturing, Product-Service Systems (PSSs) that offer products in combination with services have attracted considerable attention. However, due to the characteristics of PSSs, its development is more complex than that of a product. This paper proposes a design method that allows PSS designers to address conflicts in the development phase. To do so, first, we adopt the approach of axiomatic design to detect and avoid the conflicts. Second, for the representation of PSS structure, the modeling methods from Service Engineering are applied. The effectiveness of the method is demonstrated by applying it to a practical case-study.

Keywords

Requirement extraction, Design support, Resource management, Axiomatic design

1 INTRODUCTION

Environmental problems have grown in importance over the last couple of decades. Consequently, society should reduce the production and consumption volumes of artifacts to an adequate, manageable size without decreasing the current quality of life. For the purpose, it would be effective to pursue qualitative satisfaction rather than quantitative sufficiency, and thus, decouple economic growth from material and energy consumption [1]. For this purpose, manufacturing companies are starting to recognize that services and knowledge provided through a product are more important than the product itself [2]. As a result, "Product-Service Systems" (PSSs) [3-5], which create value by coupling a physical product and a service, have been attracting attention.

In order to achieve a successful PSS, the stakeholders are required to extend their responsibility in the life cycle [5]. This is because, from the viewpoint of environmental issues, providers need to establish proper organization for the management of product life cycle, such as reuse, remanufacturing, and recycling. They also need to educate receivers for efficient use and proper disposal of products. With respect to the value creation process, value is always determined by receivers [2]; providers, therefore, need to construct systems for the observation of receivers' needs and to establish networks to share relevant information. To compensate these extended responsibilities, new and varying types of stakeholders must be involved [5]. However, this situation may cause incompatibilities among their objectives and tasks and will inevitably induce conflicts. Namely, tasks aiming to achieve the objectives of a particular stakeholder may preclude the achieving the objectives of the others. The execution of a PSS containing excessive conflicts results in falling performance [6].

This paper, therefore, proposes a design method that allows PSS designers to address such conflicts in the development phase. The effectiveness of this method is demonstrated by its application to the example of an e-learning service.

2 OBJECTIVES OF THIS STUDY

2.1 Scope of this study

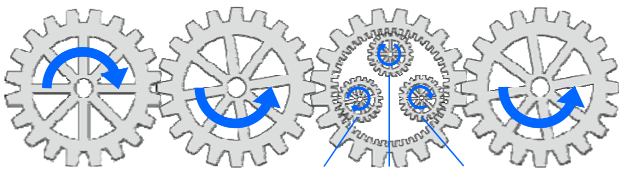

Figure 1: Life cycle of Product-Service Systems.

In this study, the life cycle of a PSS is defined as shown in Figure 1. The life cycle is comprised of four phases: value analysis, design, execution and evaluation. In the value analysis phase, the goals of a PSS, such as requirements and objectives of receivers, are first extracted, and the realization structures for the goals are then designed in the design phase. In the following phase, the designed PSS is executed; note that the execution phase is subdivided into three phases: transition, operation, and maintenance. In the transition phase, both providers and receivers make preparations for the operation phase; these preparations include not only manufacturing and installing physical products but also obtaining knowledge and skills required in the operation phase. During the operation phase, maintenance is carried out as necessary for tangible products, as well as intangible resources, such as employees. Finally, the designed and executed PSS is evaluated from the viewpoints of both providers and receivers.

2.2 Problems in the development of Product-Service Systems

According to the PSS life cycle, PSS development is carried out through the value analysis and design phases, and therefore, in these phases, designers need to consider the conflicts that may occur in the operation phase.

For the management of these conflicts, in product development, several approaches have been developed from various aspects such as requirement elicitation, process management, and so forth [7-11]. For example, in requirement engineering, various approaches have been proposed to tackle conflict management in requirement elicitation [7]. In the management field, on the other hand, critical success factors are defined for conducting collaborative product development involving several stakeholders [8]. However, few studies deal with these conflicts from the viewpoint of PSS design.

To address this issue, this paper proposes a design procedure in consideration of the life cycle of a PSS. In the procedure, a design method is introduced in order for designers to detect the conflicts and to avoid them as much as possible in the development phase.

3 APPROACH OF THIS STUDY

3.1 Overview

In this study, the conflicts are considered from the viewpoint of independence among the elements of a PSS structure. This is because if independence among the elements is guaranteed, an operation for a particular element has no influence on the others, and therefore can be executed without conflicts with them. In consideration of independence, in this study, we adopt the approach of axiomatic design [12-14]. Since it is difficult to represent the structure of a PSS systematically and concretely, there are few studies that adopt the approach of axiomatic design in the context of PSS design. In order to represent the elements of a PSS structure, therefore, the modeling methods from Service Engineering [15-18] are adopted and are arranged according to the design domains proposed in axiomatic design.

The remainder of this section introduces two disciplines: axiomatic design and Service Engineering.

3.2 Axiomatic design

Axiomatic design proposes fundamental design principles; it is a methodology about how to think and use fundamental principles during mapping process among the domains of the design world [12-14]. The principle defines the elements that have respective domains: customer needs (CNs), functional requirements (FRs), design parameters (DPs), and process variables (PVs) (see Figure 2).

In the design process, CNs in the customer domain are converted into FRs in the functional domain. FRs are a minimum set of independent requirements that completely characterize the functional needs of the design solution. FRs are embodied into DPs in the physical domain, and then, DPs determine PVs in the process domain to produce and/or control the DPs.

Suh et al. state that all designers go through the same process, although the objectives may be different among various designs [12]. Table 1 shows how all these different design tasks can be described from the viewpoint of the four design domains. For example, in organization, after requisite functions of the organization (FRs) are determined, the next task is to design business programs and organizations (DPs) to meet the functions, and then find human and other resources (PVs) to staff and operate the business.

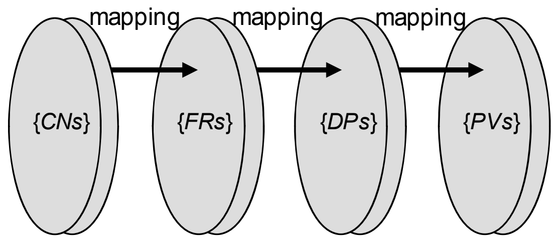

Figure 2: Four domains of the design world [12-14].

In axiomatic design, this mapping process is evaluated according to an axiom called "the Independence Axiom" [12-14], which is stated formally as:

> Maintain the independence of the functional requirements.

Under the independence axiom, the design should maintain the independence of FRs. Satisfying an FR with a DP that has effects on several FRs may cause a negative effect on the other FRs. Therefore, designers should associate FRs with DPs so that a DP has an effect on a single FR. In addition, the mapping process among the four domains can be expressed mathematically in terms of the characteristic vectors [12-14]. The set of FRs constitutes a vector {*FRs*} in the functional domain; the set of DPs in the physical domain constitutes a vector {*DPs*}. At each hierarchical level, the relationships between the {*FRs*} and the {*DPs*} can be represented with equation (1).

$$\{FRs\} = [\mathrm{DM}]\,\{DPs\} \tag{1}$$

where [DM] is called "the design matrix".

For design of processes, in the same way, the design equation can be written as:

$$\{DPs\} = [\mathrm{DM}]\,\{PVs\} \tag{2}$$

To satisfy the Independence Axiom, the matrix must be either diagonal or triangular [12-14]. When [DM] is diagonal, each of the FRs can be satisfied independently by one DP. Such a design is called an "uncoupled design" (see equation (3)). When the matrix is triangular, the independence of FRs can be guaranteed when the DPs are determined in a proper sequence. For example, in equation (4), if DP1 is firstly determined to satisfy FR1, DP1 can be considered as fixed value in satisfying the other FRs, and therefore D2 can be determined independently to satisfy FR2. Such a design is called a "decoupled design" (see equation (4)). All other designs violate the Independence Axiom and are called "coupled designs". Designers, therefore, need to develop design

Table 1: Features of the four domains of the design world for various designs [12].

Fields \ Domains	Customer domain	Functional domain	Physical domain	Process domain
Manufacturing	Attributes which customers desire	Functional requirements specified for the product	Physical variables which can satisfy the functional requirements	Process variables that can control design parameters
Materials	Desired performance	Required properties	Micro-structure	Process
Software	Attributes desired in the software	Output	Input variables and algorithms	Sub-routines
Organization	Customer satisfaction	Functions of the organization	Programs of offices	People and other resources that can support the programs
Systems	Attributes desired of overall system	Functional requirements of the system	Machines or components, sub-components	Resources (human, financial, materials, etc.)

solutions that have a diagonal or triangular design matrix.

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ 0 & X & 0 \\ 0 & 0 & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix} \quad (3)$$

$$\begin{Bmatrix} FR1 \\ FR2 \\ FR3 \end{Bmatrix} = \begin{bmatrix} X & 0 & 0 \\ X & X & 0 \\ X & X & X \end{bmatrix} \begin{Bmatrix} DP1 \\ DP2 \\ DP3 \end{Bmatrix} \quad (4)$$

3.3 Service Engineering

Service Engineering is a new engineering discipline with the objective of providing a fundamental understanding of services, as well as concrete engineering methodologies to design and evaluate services [15-18].

In Service Engineering, service is defined as an activity between a service provider and a service receiver to change the state of the receiver [15-17]. Note that the term "service" is used in a broad sense, and thus, the design target includes not only intangible human activities but also tangible products in a similar manner to that of PSSs. According to the definition, a receiver is satisfied when his/her state changes to a new desirable state. As the value of a service is determined by the receiver, service design should be based on the state change of the receiver. For design purposes, it is necessary to find a method to express the state changes of the receiver. The target receiver's state in a service design is represented as a set of parameters called receiver state parameters (RSPs) [15-17]. RSPs are changed by "service contents" and "service channels," as shown in Figure 3.

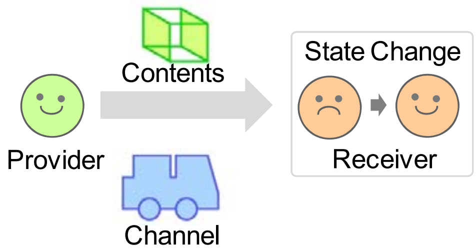

Figure 3: Definition of service [15-17].

In Service Engineering, it is assumed that service contents and service channels are comprised of various functions. In a realization structure for each RSP, function hierarchy is designed as shown in Figure 4 (a). In addition, these functions are performed by both service activities and product behaviors (Figure 4 (b)) that are actualized by attributes of entities (Figure 4 (c)). The entities represent not only physical products but also facilities, employees, and information systems. As a result, the framework representing the structure of a service can be illustrated as shown in Figure 4.

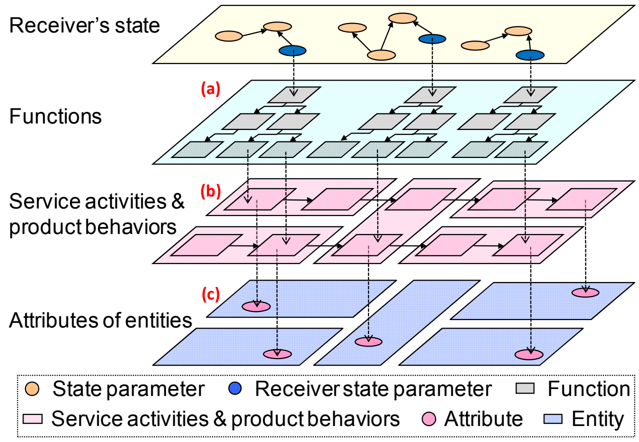

Figure 4: Framework for the representation of a service [18].

4 DESIGN METHOD FOR THE DEVELOPMENT OF PRODUCT-SERVICE SYSTEMS

4.1 Features of the four domains in PSSs

According to the models proposed in Service Engineering, in this study, features of the four domains in PSSs are defined as shown in Table 2.

In PSSs, the goal is to fulfill customer requirements. In the customer domain, therefore, customer requirements are defined as CNs and are represented as the receiver's state in the same manner as Service Engineering. The receiver's state includes not only his/her internal state but also his/her external state, such as the objectives of the organization to which the receiver belongs. With respect to the functional domain, functions realizing the state change are determined as FRs, and the service activities and product behaviors that perform the functions are then designed as DPs in the physical domain. Finally, in order to actualize the service activities and product behaviors, attributes of entities are determined as PVs in the process domain.

4.2 Design procedure

Overview

Figure 5 shows a PSS development process consisting of the value analysis and design phase in the life cycle. The process begins with the customer analysis, and the conceptual design is then carried out. In the conceptual design, designers first develop functional structure to fulfill the requirements extracted in the customer analysis. According to the functional structure, designers simultaneously determine the PSS features: service activities and product behaviors, and attributes of entities. Next, in the embodiment design, designers determine actual entities that embody the attributes determined in the conceptual design. Comparing these entities with the current one, designers specify the task in the transition phase, such as manufacturing products and preparing human resources. Finally, in the detailed design, designers develop plans to perform the tasks for the transition phase of the life cycle.

From the development process, especially, this study

Table 2: Features of the four domains in Product-Service Systems.

Domains / Fields	Customer domain	Functional domain	Physical domain	Process domain
Product-Service Systems	Receiver's state	Functions for the receiver's state	Service activities and product behaviors	Attributes of entities

proposes a design procedure that includes the customer analysis and conceptual design (see the process colored gray in Figure 5). In this procedure, the conflicts that may occur in the operation phase are detected and are avoided as much as possible, and the inevitable conflicts are finally specified.

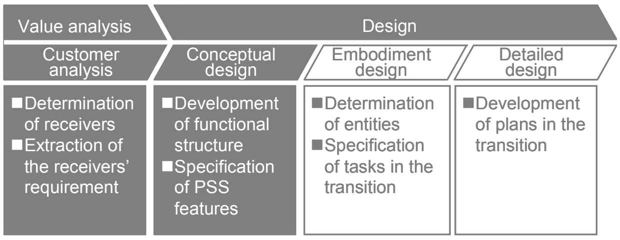

Figure 5: Development process for Product-Service Systems.

The remainder of this section introduces the design procedure in detail.

Step 1: Development of an initial flow model

In this design procedure, designers first define a chain of relevant stakeholders.

Many PSSs form complex structures consisting of many stakeholders. Between a receiver and a provider, there may be many intermediate stakeholders. As intermediate stakeholders also evaluate PSSs as service receivers, designers need to consider the requirements of the intermediate stakeholders, as well as those of an end receiver. In Service Engineering, a flow model is proposed to represent the chain of stakeholders (see Figure 6). In this step, an initial flow model is determined by defining the stakeholders and their relationships.

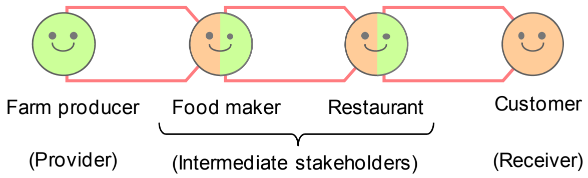

Figure 6: Flow model of a restaurant service [15-17].

Step 2: Extraction of RSPs of a receiver

In this step, in order to extract the RSPs of receivers, the designers describe the business process of the receiver. Next, from the business process, the stakeholders involved in the PSS are identified to extract their objectives, which are called practical goals [19]. Practical goals indicate objectives that should be achieved in individual tasks through the business process. For the identification of practical goals, a persona [19] is described for each stakeholder. The persona is a tool to give a simplified description of a customer and works as a compass in a design process [19]. In this procedure, the persona is described with a focus on the professional background, such as his/her daily tasks, and the designers then identify the practical goals of each stakeholder with reference to them. Based on this persona, a scenario is developed to clarify the context in which the PSS is operated. The scenario is described in the form of a state transition graph, as the purpose of receiving products and/or services in a PSS is to change the receiver's state into a more desirable one. The receiver's state is represented as a set of parameters called state parameters (SPs). From the SPs, RSPs, which correspond to target parameters in the PSS design, are extracted. Any SP can be defined as an RSP; however, for meaningful design to be realized, RSPs must be observable and related to the concrete requirements of a receiver.

Step 3: Decomposition in the four PSS domains

After the determination of RSPs, a PSS structure is designed through the decomposition of functions, service activities, and product behaviors, as well as attributes of entities.

In axiomatic design, a design method for large flexible systems is proposed [13]. Large flexible systems are defined as systems whose FRs are represented as time variant. In these systems, in particular, a subset of these FRs must be fulfilled at any given time, and the elements of this subset change as a function of time. With regard to PSSs, as receivers' requirements change depending on the phases of their scenario, PSSs can be regarded as large flexible systems. In this step, therefore, initial functions for the RSPs are determined in each phase of the scenario and are then decomposed until the design task is completed.

According to axiomatic design, the hierarchical structure of each domain is developed through zigzagging. Namely, the decomposition of these elements cannot be done by remaining in a single domain; however, it can be achieved through zigzagging between the domains [12-14] (see Figure 7). In this step, before decomposing the functions at a particular hierarchical level in the functional domain, the corresponding service activities and/or product behaviors must be designed as the elements of the same hierarchical level in the physical domain. In the same way, the designers determine attributes corresponding to the service activities and/or product behaviors through the zigzagging decomposition.

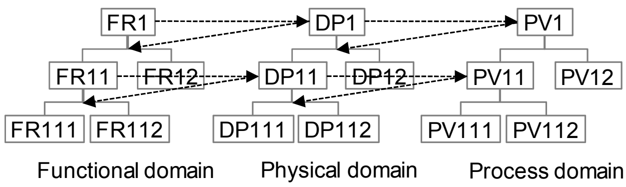

Figure 7: Zigzagging decomposition [12-14].

In this study, the conflicts existing in a PSS structure are considered from the viewpoint of independency among its elements, and therefore, at each hierarchical level, the design matrix must be diagonal or triangular to conform to the Independence Axiom. In particular, for functions at each hierarchical level, the corresponding service activities and/or product behaviors must be selected in order to guarantee the Independence Axiom; attributes must be associated with the corresponding activities and behaviors in the same manner.

Through this step, the designers can avoid conflicts by making attributes uncoupled. With regard to decoupled attributes, conflict can be avoided if the target values of the attributes are determined in a proper sequence. Finally, all of the other attributes are specified as one that contains the inevitable conflicts.

Step 4: Determination of components in a PSS

In the following process, these attributes are allocated to actual entities that may be manufactured or prepared in the transition phase. If decoupled/coupled attributes are allocated to separate entities, these entities depend on each other. Therefore, a stakeholder who takes responsibility for each entity needs to interact with the other stakeholders each time in changing the target value of the attributes. This situation complicates tasks in the transition phase and results in lower efficiency in terms of cost and time in the transition phase. Therefore, in this step, the designers determine PSS components as minimum units that are independent of each other.

PSS components consist of the modules proposed in axiomatic design. In axiomatic design, a module is defined in terms of the (FR/DP) or (DP/PV) relationship [13-14]. A module is defined as the row of the design matrix that fulfills an FR when it is provided with the input of its corresponding DP. In this study, on the other hand, a module is defined in terms of the (function/attribute) relationship. For the determination of PSS components, the designers first define modules from the (function/attribute) relationship. The relationship can be mathematically expressed as shown in equation 7.

$$\{Functions\} = [A]\ \{SAs, PBs\} \qquad (5)$$

$$\{SAs, PBs\} = [B]\ \{Attributes\} \qquad (6)$$

$$\{Functions\} = [C]\ \{Attributes\} \qquad (7)$$

Where {*Functions*}: a vector of functions
{*SAs, PBs*}: a vector of service activities and product behaviors
{*Attributes*}: a vector of attributes
[C] = [A]*[B]

As a result, in the design matrix [C], a module uncoupled from the others is defined as a single component; a minimum subset of decoupled modules is defined as a single component whose attributes need to be controlled sequentially; and a minimum subset of coupled modules is defined as a single component whose modules violate the Independence Axiom. For example, in Figure 8, module 1 is uncoupled from the other modules, and therefore, it can be defined as a single component solely. As module 3 requires the input of attribute 2, a subset of these decoupled attributes - that is, module 2 and 3 - is integrally defined as a single component. A subset of the coupled modules - that is, module 4 and 5 - is also defined as a single component.

	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5		
Function 1	X					Module 1	Component 1
Function 2		X				Module 2	Component 2
Function 3		X	X			Module 3	
Function 4				X	X	Module 4	Component 3
Function 5				X	X	Module 5	

Figure 8: Components in the design matrix.

A component of a PSS is defined as a minimum subset of modules that are independent from the other modules. The input of attributes in a particular component only influences the corresponding functions, and, therefore, has no influence on the other functions associated with the other components. Therefore, in the following process, the designers need to utilize components as the basis for the allocation of attributes to actual entities.

5 APPLICATION

In this chapter, the proposed method is applied to an e-learning service. The purpose of this application is to determine PSS components.

First, the initial flow model of the e-learning service was developed as shown in Figure 9. Next, the business process of the client company and the system vendor was described. The business process proceeded in five steps: planning the e-learning course, developing materials, preparing for the hosting of the e-learning course, holding the e-learning course, and evaluating the e-learning course. According to the process, the stakeholders involved in this PSS were identified (see Figure 9 below).

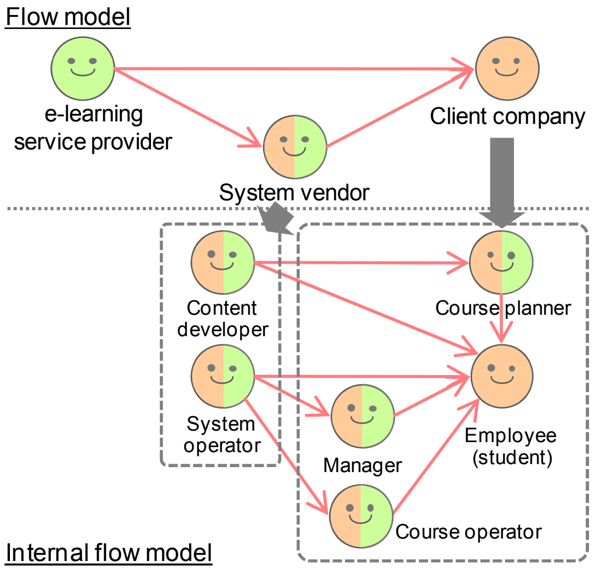

Figure 9: Flow model of the e-learning service.

In this example, the client company and the system vendor were comprised of six stakeholders: content developers, system operators, course planners, course operators, managers and employees who take the e-learning (students). For the extraction of their practical goals, a persona was subsequently described for each stakeholder. The course planners take responsibility for the planning of courses based on the program of human resource development. The contents developer provides the development environment of e-learning contents to the course planner and registers e-learning contents on the e-learning system. The system operator operates the e-learning system and manages relevant data, such as the list of students and their progress status. The manager plans the program of human resource development and manages it based on the reports of progress status provided from the e-learning system. The course operator takes responsibility for tasks relating to the conduct of courses, such as announcements, applications and student support, by using the e-learning system. Based on the personas, a scenario was described for each stakeholder, and RSPs were extracted as shown in Table 3.

Table 3: The list of Receiver State Parameters.

Phases	Receiver State Parameters
Planning the e-learning course	CN1: Feasibility of system operation CN2: Feasibility of course planning
Developing materials	CN3: Accuracy of content development CN4: Timely offerability of learning contents
Preparing for the hosting of course	CN5: Accuracy of processing CN6: Certainty of status follow-up
Holding the e-learning course	CN7: Responsiveness of student support
Evaluating the e-learning course	CN8: Accuracy of implementation report CN9: Exactness of evaluation

Table 4: Decomposition of functions, service activities/product behavior and attributes of entities.

Functions	Service activities and product behaviors	Attributes of entities
FR1: Organize a course	DP1: Course planning	PV1: Capability of planning
FR11: Draw up the proposal for a course	DP11: Education planning	PV11: Capability of education planning
FR12: Organize group training	DP12: Planning of group training	PV12: Capability of organizing group training
FR2: Design system operation	DP2: Design of system operation	PV2: Certainty of system operation
FR21: Ensure system security	DP21: System security	PV21: Certainty of Security
FR22: Support system	DP22: Support system	PV22: Certainty of Support
FR23: Determine the roles in operation	DP23: Operation design	PV23: Capability of operation design
FR3: Make up materials	DP3: Material preparation	PV3: Capability of material preparation
FR4: Develop e-learning contents	DP4: Development of e-learning contents	PV4: Quality of materials
FR41: Conduct logical design and physics design	DP41: Development of e-learning contents	PV41: Capability of contents development
FR42: Upload e-learning contents onto server	DP42: Management of e-learning contents	PV42: Capability of management
FR5: Announce a course	DP5: Course announcement	PV5: Quickness of communication
FR6: Follow up learning status	DP6: Management of learning status	PV6: Capability of information control
FR61: Manage learning status	DP61: Management of course participation	PV61: Real-time update
FR62: Report learning status	DP62：Status report	PV62: Capability of communication
FR7: Support students	DP7: Student support	PV7: Quickness of response
FR8: Conduct implementation report	DP8: Implementation report	PV8: Accuracy of implementation report
FR81: Report completion status	DP81: Management of completion status	PV81: Completeness of information
FR82: Collect the questionnaire	DP82: Questionnaire	PV82: Collection rate of questionnaire
FR9: Evaluate a course	DP9: Course evaluation	PV9: Accuracy of evaluation
FR91: Evaluate achievement of objectives	DP91: Evaluation of achievement objectives	PV91: Comprehension of objectives
FR92: Reflect user requests on a course	DP92: Reflection of user feedback	PV92: Amount of user feedback

		PV1		PV2			PV3: Capability of material preparation	PV4		PV5: Quickness of communication	PV6		PV7: Quickness of response	PV8		PV9			
		PV11: Capability of education planning	PV12: Capability of organizing group training	PV21: Certainty of security	PV22: Certainty of support	PV23: Capability of operation design		PV41: Capability of contents development	PV42: Capability of management		PV61: Real-time update	PV62: Capability of communication		PV81: Completeness of information	PV82: Collection rate of questionnaire	PV91: Comprehension of objectives	PV92: Amount of user feedback		
FR1	FR11: Draw up the proposal for a course	X																M11[*1]	C1[*2]
	FR12: Organize group training	X	X															M12	
FR2	FR21: Ensure system security			X														M21	C2
	FR22: Support system				X													M22	C3
	FR23: Determine the roles in operation					X												M23	C4
FR3: Make up materials							X											M3	C5
FR4	FR41: Conduct logical design and physics design						X	X	X									M41	
	FR42: Upload e-learning contents onto server							X	X									M42	
FR5: Announce a course										X								M5	C6
FR6	FR61: Manage learning status										X	X						M61	C7
	FR62: Report learning status										X	X						M62	
FR7: Support students													X					M7	C8
FR8	FR81: Report completion status													X				M81	C9
	FR82: Collect the questionnaire														X			M82	
FR9	FR91: Evaluate achievement of objectives													X		X		M91	
	FR92: Reflect user requests on a course														X		X	M92	

*1 M: module, *2 C: component

Figure 10: Full design matrix table of the e-learning service.

For each RSP, a realization structure was then developed. First, a function for each RSP was determined, and the zigzagging decomposition was carried out to design the corresponding service activities, product behaviors, and attributes. Table 4 shows the result of the decomposition of each domain. Simultaneously, in each hierarchical level, the design matrices were determined by developing the equation 5 and 6.

Finally, based on the design matrices, equation 7 was developed to obtain the (function/attribute) relationship, and components of the PSS were defined. Figure 10 shows the design matrix that describes the relationships between the functions and attributes. In the design matrix, uncoupled modules include M21-23, M5, and M7; decoupled modules include M11-12, M81-82, and M91-92; coupled modules include M3, M41-42, and M61-62. As a result, for example, the uncoupled modules, M21-23, M5, and M7, were determined to be a single component, respectively. With regard to decoupled modules, a subset of decoupled modules, for example the set of M11-13, was determined as a single component. In the same way, a subset of coupled modules, for example the set of M61-62, was determined as a single component (see Figure 10, right column).

6 DISCUSSION

6.1 Effectiveness of the proposed method

In this application, the proposed design procedure was applied to an e-learning service. According to the approach of axiomatic design, elements of each domain, which are functions, service activities and product behaviors, and attributes of entities, were decomposed in consideration of their independence.

As a result, the conflict could be avoided by making the following modules uncoupled: M21-23, M5, and M7. With respect to the decoupled modules, which are M11-12, M81-82, and M91-92, the conflict can be avoided if the target values of corresponding attributes can be determined in a proper sequence. In the case of M11-12, the target values of the corresponding attributes need to be determined in the following order: “Capability of education planning” and “Capability of organizing group training”. Finally, M3, M41-42, and M61-62 were identified as containing the inevitable conflicts, and therefore their attributes, for example “Capability of material preparation”, “Capability of contents development” and “Capability of management”, conflict with each other.

For a successful PSS, several stakeholders must be involved [5]. This situation may cause incompatibilities among their objectives and tasks and will inevitably induce conflicts. The design procedure proposed in this paper enables designers to detect such conflicts arising in the operation of a PSS and avoid them as much as possible in the design stage.

In addition, the nine components were determined to be minimum subsets of modules that are independent of each other. The input of attributes in a particular component only influences the corresponding functions and has no influence on the other functions associated with the other components. Therefore, if the interface among components is completely defined, tasks for each component in the transition phase can be assigned to independent stakeholders, respectively, and be executed concurrently. PSSs consist of various components, such as products, software, systems, and organization, that are assigned several stakeholders to prepare them. Since the components that are determined in the proposed method are independent of each other, stakeholders involved in the PSS are able to prepare the assigned components concurrently. Therefore, the proposed method is useful for the efficiency of tasks in the transition phase.

With regard to the representation of a PSS structure, according to the modeling method from Service Engineering functions, service activities and product behaviors, and attributes of entities are defined as the elements of the four domains of the design world. Whereas PSSs consist of various components, the modeling method can be considered as useful for describing the four domains of PSS design.

6.2 Possible improvements of the proposed method

In this application, the design procedure drew “the ideal PSS structure” that avoids conflicts as much as possible. However, in reality, in the transition phase to realizing such a structure, stakeholders need to prepare the requisite resources that include not only tangible resources, such as infrastructure, but also intangible resources, such as knowledge and skills. The preparation of these resources may be constrained by their current states; the constraints define the bounds on the acceptable design. Therefore, the extension of the proposed procedure is required to consider the constraints that arise in the transition from current structure to ideal one.

7 CONCLUSION

In this paper, a design method is proposed to address the conflicts in PSS development. In the method, the approach of axiomatic design is adopted to detect and avoid these conflicts. In addition, the modeling methods from Service Engineering are applied for the representation of PSS structure. The application reveals that the proposed procedure enables designers to detect and avoid conflict as much as possible.

Future studies will include the extension of the procedure to consider the constraints that arise in the transition phase.

8 REFERENCES

[1] Tomiyama, T., 1997, A Manufacturing Paradigm Toward the 21st Century, Integrated Computer Aided Engineering, 4: 159-178.

[2] Vargo, S.L. and Lusch, R.F., 2004, Evolving to a New Dominant Logic for Marketing, Journal of Marketing, 68/1: 1-17.

[3] Tukker, A. and Tischner, U., 2006, Product-services as a research field: past, present and future. Reflections from a decade of research, Journal of Cleaner Production, 14/17:1552-1556.

[4] Morelli, N., 2003, Product-Service Systems -a Perspective Shift for Designers-, A Case Study -The Design of a Telecentre-, Design Studies, 24:73-99.

[5] Mont, O.K., 2002, Clarifying the concept of product–service system, Journal of Cleaner Production, 10: 237–245.

[6] Duarte, M. and Davies, G., 2003, Testing the conflict–performance assumption in business-to-business relationships, Industrial Marketing Management, 32: 91– 99.

[7] Lamsweerde, A.V., Darimont, R. and Letier, E. 1998, Managing Conflicts in Goal-Driven Requirements Engineering, IEEE Transactions on Software Engineering.

[8] Lam, P.K. and Chin, K.S., 2005, Identifying and prioritizing critical success factors for conflict management in collaborative new product development, Industrial Marketing Management, 34: 761– 772.

[9] Kim, M., Park, S., Sugumaran, V. and Yang, H., 2007, Managing requirements conflicts in software

product lines: A goal and scenario based approach, Data & Knowledge Engineering 61: 417–432.

[10] Shaw, V., Shaw, C.T and Enke, M., 2003, Conflict between engineers and marketers: the experience of German engineers, Industrial Marketing Management, 32: 489– 499.

[11] Ouertani, M.Z., 2008, Supporting conflict management in collaborative design: An approach to assess engineering change impacts, Computers in Industry, 59: 882–893.

[12] Suh, N.P., 1990, The Principles of Design, Oxford University Press, New York.

[13] Suh, N.P., 1998, Axiomatic Design Theory for Systems, Research in Engineering Design, 10/4: 189-209.

[14] Suh, N.P. and Do, S.H., 2002, Axiomatic design of software systems, CIRP Annals - Manufacturing Technology, 49/1: 95-100.

[15] Arai, T. and Shimomura, Y., 2004, Proposal of Service CAD System: A Tool for Service Engineering, Annals of the CIRP, 53/1:397-400.

[16] Shimomura, Y. and Tomiyama, T., 2005, Service Modeling for Service Engineering, IFIP International Federation for Information Processing, 167: 31-38.

[17] Sakao, T. and Shimomura, Y., 2007, Service Engineering: A Novel Engineering Discipline for Producers to Increase Value Combining Service and Product-, Journal of Cleaner Production, 15/6: 590-604.

[18] Hara, T., Arai, T. and Shimomura, Y., 2009, A CAD system for service innovation: integrated representation of function, service activity, and product behaviour, Journal of Engineering Design, 20/4: 367-388.

[19] Cooper, A., 1999, The Inmates Are Running the Asylum, SAMS/Macmillan, Indianapolis, IA.

A PSS Approach in Software Development

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Abstract

Various studies reveal that over ninety percent of new software applications are unsuccessful in bringing the expected value added to their target markets. This is because software producers concentrate mainly on product innovation instead of seeing their software solutions as part of product-service systems. A methodology for concurrent planning and design of software-PSSs against multi-target functions is proposed in this paper. Borders between product and service are marked in a cost-effective way, keeping also a superior balance between customer and producer benefits. The concept is exemplified on a software-PSS related to business excellence assessment and analysis.

Keywords

Concurrent planning of PSS, new software development, PSS innovative design

1 INTRODUCTION

Software systems are characterized by flexibility, high complexity per unit of development time and "invisibility" [1], [2]. Therefore, development of software systems requires careful planning and continuous overpass of a multitude of challenges. In the common perception, a software project is seen successful if it meets the level of quality expected by the user, within a given development time and budget [3].

In this framework, various studies have revealed that meeting user expectations is the primary criterion for software system success [4], [5], [6]. Researches have shown that whether a software system is viewed as a success or failure depends on the perception of the person viewing the system [7]. Consequently, a software system may be considered successful by one user and a failure by another one [7]. Thus, user expectations must be correctly identified and constantly reinforced in order to avoid failures [4], [8], [9].

A critical aspect in this context is when users have improper assumptions about the value brought by the software system into the business framework, because then users may perceive that the objectives associated with the respective system have not been met [4], [5], [10]. Faulty expectations ("unrealistic" expectations) lead to lower levels of software system success as measured by perceived system quality, perceived information quality, or user satisfaction [4], [11]. Accordingly, software systems, after initial release, are subjected to continuous evolutions and modifications [12], [13], this representing the most costly part of the software system lifecycle [14].

Moreover, in the equation of success other stakeholders must be included (e.g. producer, integrators and consultants). For producers, commercial success is perceived as relevant profitability over system's life-cycle, meeting in the same time adequate rates of the financial indicators (e.g. IRR, NPV) [1], [15]. In the same context, application service providers, as well as consultants are changing the way a software system is sold, delivered and used, which might significantly influence user's perception on the value added which the respective system brings into its business.

Considering the mix of previously mentioned issues, the current trend in software product industry is "servicization" of software solutions; that is, provision of systemic solutions consisting of software products and services which jointly are capable of fulfilling final customer needs [16].

In other words, development of Product Service Systems (PSS) becomes an increasingly important strategy in achieving social, economic and, to certain extends, environmental sustainability in software industry, which advocates reducing resource consumption but delivering better, more widely available goods and services [17]. Actually, such models more adequately address the orientation of software production towards individual behaviours and highly personalised needs [18].

2 THE PROBLEM

The software literature provides many published papers and surveys that report alarming figures for software systems failures at various levels or discuss inconvenient software project situations [19]. Such failures take the form of either full collapse (e.g. project cancellation) or inability to fulfil partial but critical project goals, such as user satisfaction, project budget or time constraints [19].

For example, a survey on a representative sample of software projects, whose results are reported in the paperwork [20], indicates that 53% of them were unable to be delivered on schedule, within budget, and with the required functionalities, while 18% of the software projects were cancelled. According to [14], problems with cost and schedule estimations persist in spite of on-going research into effort and schedule estimation. Based on various sources, the same reference concludes that 26% of all software projects failed, and another 46% experienced cost and schedule overruns or significantly reduced functionality. Other reports reveal that software project implementations were often over budget and over time, and delivered less than the promised benefits [11].

Another reference, citing several sources, even indicates that over 90% of new software applications are unsuccessful in bringing the expected value added to their target markets [1].

In conclusion, the alignment of product, project and business decisions is a major problem in the software industry [2]. Mature design solutions based on the mix of material and immaterial components, which satisfy the requirements of each stakeholder are therefore essential for the business success [18]. In this effort, product and service concepts cannot be clearly disconnected [17], [18], [21]. In the combination product-service, the relative weight between product and service differs from case to case [21]. This also determines that products in general and software products in particular, should have capabilities to support the delivery of product-related services [22].

The role of software designers in such partnership is therefore critical, although the definition of specific methodologies to manage some critical aspects of the design process of PSS has rarely been considered in software design-related disciplines. Design of services in the frame of products should be adequate integrated in order to maximize customers' value [23].

In this respect, the present paper introduces an approach that concurrently plans and designs extended software products by considering multiple dimensions of value-to-customer (e.g. quality, price, ergonomics, operational cost, easy to use, etc.) and value-to-producer (e.g. development time, development cost, integration cost, etc.). It also allows outlining adequate borders between those components of the PSS which should be incorporated into the product and which should be included into the service.

The next sections of the paper describe the methodology of concurrent planning and design of software-PSSs against multi-target functions, as well as a case study for exemplifying its use into practice.

3 THE METHODOLOGY

The methodology relies on the fact that at the ground of any product or service which is developed for commercialization there is a market need that has to be satisfied. From this perspective, in most of the cases there are several options in formulating a solution for meeting a targeted market need. It might be found under the form of a pure service or a pure product, or mixes of products and services in different weights and combinations. The challenge is to establish the best PSS combination, or at least one from the set of viable PSS combinations, under a group of given constrains.

According to this idea, the proposed methodology for developing software-PSSs consists of the following steps:

Step 1: Define market need under the form of a set of requirements and rank these need-related requirements. For ranking, tools like ANP method [24] or AHP method [25] might be used.

Step 2: Define a set of target-functions in accordance to the market need and deploy them against the set of need-related requirements. Thus, value weights of target-functions in relation to the market need are determined. Correlations between target-functions have to be also established. QFD-type relationship and correlation matrices could be used to fulfil this step [26].

Step 3: For each target-function, a set of specific key requirements are formulated and further ranked (e.g. AHP method).

Step 4: For each target-function, the set of key value characteristics should be afterwards determined. This process is fulfilled by deploying the corresponding key requirements formulated at step 3. In this respect, QFD-type relationship matrices are applied. Further, value weights of the key value characteristics are calculated. Correlations between the key value characteristics for each target-function are established, as well as targets to be achieved. Where negative correlations occur, innovative problem solving is required.

Step 5: Formulate vectors of innovation for each negative correlation and for each challenging target. TRIZ method is a powerful tool to fulfil this process [27]. The resulted vectors of innovation represent paths towards which creativity and skills must be directed when local solutions are elaborated.

Step 6: Define major local PSS-specifications (major functionalities) to be fulfilled in relation to each target-function. This is performed by deploying into PSS-specifications the corresponding key value characteristics for each target-function. QFD-type relationship matrices are used in this respect. Value weight of each major PSS-specification is further calculated. In principle, a significant part of the major PSS-specifications are met in the case of more or all target-functions. By comparing the results of local deployments, one is able to see the impact which each major PSS-specification has in the equation of each target-function.

Step 7: Define a set of criteria to analyse the opportunity of implementing major PSS-specifications either to the level of product or service, or to the both, in various quantities. Rank criteria by means of AHP method.

Step 8: For each local set of major PSS-specifications establish the relationship level of each PSS-specification against each criterion from two perspectives: product perspective and service perspective. Calculate the result for each major PSS-specification by multiplying the importance of each criterion with the corresponding relationship level in relation to each major PSS-specification and adding the local results. Thus, for each local major PSS-specification a weight in relation to product and a weight in relation to service are determined. These weights provide a means for deciding how to implement each PSS-specification in the mix product-service (the case of local solutions).

Step 9: Use information from steps 4 (key value characteristics, weights and targets), 5 (vectors of innovation), 6 (PSS-specifications and weights) and 8 (product-service mix of distribution) to formulate local solutions of PSSs in relation to each target-function. Various tools can be used to support this step (e.g. CSDT [28]). Local solutions are detailed only at modules and sub-modules levels.

Step 10: Aggregate local solutions into an overall solution. In principle, the overall solution should comprise to the maximum possible extend the strengths of all local solutions. An aggregation algorithm is further proposed.

The target-function with the highest value weight in the set from step 1 will be taken as the starting point in the aggregation algorithm. It is symbolized with *PTF*. The other target-functions are grouped relative to *PTF*. *PTF* is correlated with the other n–1 target-functions in various ways: positive, negative or not correlated, as well as at various strengths. The type of correlation between two target-functions is determined by the correlations between their constitutive requirements. In this respect, the rest of the n–1 target-functions can be sorted on three categories: the group of those target-functions that are positive correlated with *PTF*, the group of those target-functions that are not correlated with *PTF* and the group of those target-functions that are negative correlated with *PTF*.

For each target-function (excepting *PTF*) a priority index is calculated by multiplying its value weight (from step 2) with the correlation coefficient (also from step 2) between the respective target-function and *PTF*. In the group of target-functions that are positive correlated with *PTF,* the target-functions will be ordered starting with the one having the highest priority index and ending with the one having the lowest priority index. The same rule is kept for the group of target-functions that are negative correlated with *PTF*. It is highlighted the fact that the correlation coefficients are <0 in the group of negative correlated target-functions, so the one with the highest priority index will have the lowest magnitude in absolute value. The target-functions that are not correlated with *PTF* will be ordered starting with the one having the highest value weight and ending with the one having the lowest value weight.

In the last stage, the aggregated solution is generated following an iterative approach. The aggregated solution will result as a "compromise & combination" of the set of *n* local solutions. In this respect, the following rule is applied:

(a) The solution corresponding to the *PTF* will be taken and analyzed together with the solution corresponding to the first target-function in the group of target-functions that are positive correlated with *PTF*. Because the two target-functions are positive correlated, the best ideas from the local solutions will be combined, resulting an improved hybrid solution.

(b) The hybrid solution from (a) will be then analyzed against the local solution corresponding to the second target-function in the group of the target-functions that are positive correlated with *PTF*. The new variant will result as a combination of the best ideas from the hybrid solution generated at phase (a) and from the current local variant.

(c) The process will go on in the manner above described until all target-functions from the group of target-functions that are positive correlated with *PTF* are consumed. After that, the group of no correlated target-functions is taken into account and the process is continued until all of these target-functions are consumed. At the end, the group of target-functions that are negative correlated with *PTF* will be taken into account. Because at this phase potential conflicts could occur, they have to be solved without compromises, if possible. In this respect, it is firstly required to identify pairs of conflicting problems between the compared variants. Afterwards, innovative solutions have to be formulated. Methods like TRIZ could offer a real support in this respect. At the end of this process, the complete overall solution will be defined.

Step 11: Further, by calculating the overall value weight of each major PSS-specification, one can establish cost targets for development, having as starting point a target budget. The overall value weight of each major PSS-specification is obtained by deploying all requirements belonging to all target-functions (see step 3) into PSS-specifications.

Step 12: Results from steps 10 and 11 are used for further detailing the software-PSS (detailed design and planning at component level). Use-cases, modelling languages (e.g. UML [1]) and other specific tools for software analysis and design could be used to support this step.

4 APPLICATION EXAMPLE

For exemplifying the practical application of the methodology, the case of a software-PSS related to business excellence assessment and analysis is here considered.

The market need, expressed as general requirements, is (step 1): RQ_1 - training on organizational excellence, RQ_2 - organizational excellence assessment, RQ_3 - consultancy on organizational excellence, and RQ_4 - formulation of improvement projects.

	TF_5					
	TF_4					0
	TF_3				-1	+1
	TF_2			+2	-1	+1
	TF_1		+2	0	-1	0
	TF:	TF_1	TF_2	TF_3	TF_4	TF_5
RQ:	Importance	Relationship matrix (bottom) and Correlation matrix (up)				
RQ_1	3.5	9	1	1	3	
RQ_2	4.0	3	9	3		27
RQ_3	1.4	9	1		9	
RQ_4	1.1	9			27	3
Value weight [%]		23.0	14.3	5.4	18.4	38.9

Table 1: Target-functions deployed against the need-related requirements.

The target-functions are (step 2): TF_1 - increased quality, TF_2 - increased learnability, TF_3 - increased ergonomy, TF_4 - low cost, TF_5 - short assessment duration. Table 1 summarizes steps 1 and 2 of the methodology.

A scale of [-2, -1, 0, 1, 2] was used for showing correlations between target-functions (negative, no or positive-correlated) and a scale of [0, 1, 3, 9, 27] for showing relationships between requirements and target-functions (0: no; 1: weak; 3: medium; 9: strong; 27: very strong relationship).

For TF_1, the following specific key requirements were formulated (and ranked using the AHP method): $KR_{1.1}$ - the solution should be easy to work with (25%), $KR_{1.2}$ - the solution should be reliable; it should work exactly as it's supposed to (42%), $KR_{1.3}$ - the software-PSS should be tolerant to errors (16%), $KR_{1.4}$ - the solution should be scalable; it should behave decently no matter how much data is to be handled (9%), $KR_{1.5}$ - the solution should be portable; the user should not be nailed down to a specific operating system (8%).

For TF_2, the following specific key requirements were formulated: $KR_{2.1}$ - the solution should be well-documented (63%), $KR_{2.2}$ - the solution should be consistent with other existing solutions (12%), $KR_{2.3}$ - all solution's constitutive elements should be clear enough to maximize user productivity (25%).

For TF_3, the following specific key requirements were formulated: $KR_{3.1}$ - all constitutive elements of the solution should behave as expected (31%), $KR_{3.2}$ - the user should have complete control on the solution (18%), $KR_{3.3}$ - permanently clear solution state (23%), $KR_{3.4}$ -only relevant information should be available to the user (28%).

For TF_4, the following specific key requirements were formulated: $KR_{4.1}$ - the solution should be ROI-attractive (82%), $KR_{4.2}$ - there should be a minimal setup cost (10%), $KR_{4.3}$ - there should be a minimal maintenance and support cost (8%).

For TF_5, the following specific key requirements were formulated: $KR_{5.1}$ - for a user which is familiar with organizational excellence models, the assessment session should be fast (30%), $KR_{5.2}$ - for an inexperienced user, completing a session should not take long (39%), $KR_{5.3}$ - an inexperienced user should easily understand the information on organizational excellence provided by the solution (31%).

Percentages in the brackets represent the local relative importance of the key requirements, as they have been determined with the AHP method.

For TF_1, the following key value characteristics were formulated: $KV_{1.1}$ - installation time, $KV_{1.2}$ - configuration / customization time, $KV_{1.3}$ - critical errors, $KV_{1.4}$ - number of assessment sessions to be handled, $KV_{1.5}$ - number of environments the solution might work in.

For TF_2, the following key value characteristics were formulated: $KV_{2.1}$ - documentation comprehensiveness, $KV_{2.2}$ - documentation access time, $KV_{2.3}$ - documentation topic access time, $KV_{2.4}$ - number of available languages, $KV_{2.5}$ - task understanding time.

For TF_3, the following key value characteristics were formulated: $KV_{3.1}$ - number of sessions after which a user becomes skilled in using the solution, $KV_{3.2}$ - complexity/ operation seen as number of constitutive elements/ operation, $KV_{3.3}$ - time for documenting during an assessment session.

For TF_4, the following key value characteristics were formulated: $KV_{4.1}$ - the initial investment for the user, $KV_{4.2}$ - the return on investment for the user, $KV_{4.3}$ - the maintenance costs, $KV_{4.4}$ - future releases costs, $KV_{4.5}$ - update costs.

For TF_5, the following key value characteristics were formulated: $KV_{5.1}$ - the assessment session duration for an experienced user, $KV_{5.2}$ - the assessment session duration for a new user, $KV_{5.3}$ - number of assessments after which a user becomes enough skilled in using the solution, $KV_{5.4}$ - assessment reports generation time, $KV_{5.5}$ - number of assessment report formats.

Table 2 highlights, for each target-function, the value weights and targets associated to the key value characteristics after the QFD-deployment process against the key requirements (step 4).

Three of the targets from table 2 are seen challenging: target for $KV_{1.5}$ - at least 3 environments in which the solution has to work, $KV_{2.5}$ - time to understand the task less than 1 minute, and $KV_{5.2}$ - the assessment session duration for a new user less than 1 day. Two of these three challenging targets are of higher priority from competitiveness point of view: targets for $KV_{2.5}$ and $KV_{5.2}$.

Analysing $KV_{2.5}$, the following mini-problem could be formulated: how to decrease task understanding time while making it (a) as simple as possible and (b) with minimal costs. TRIZ application [27] leads to the following vectors of innovation: (1) arrange "objects" in a way they can go immediately into action when required (e.g. intuitive/user-centric interface); (2) replace "stationary fields" with "moving fields" (e.g. dynamic help, including tutoring); (3) apply asymmetry (e.g. single format in, multiple formats out); (4) discard and regenerate parts (e.g. keep a pool of complex items for further use); (5) alternating (e.g. alternate service use with product use to fit better each task); (6) replace a continuous action with an impulse (e.g. use tutoring only where and when necessary); (7) make actions more "fluid" (e.g. use flexible ways to assess an issue); (8) enrich the "environment" (e.g. implement expert modules).

Regarding $KV_{5.2}$, the following mini-problem could be formulated: how to minimize the assessment session duration for a new user without increasing training or self-documenting time. TRIZ reveals the following vectors of innovation: (1) use sharing to counterweight parts of the system (e.g. division in multiple frames); (2) automatic adjustments (e.g. self-adjust scale); (3) change the flexibility and density (e.g. merging of modules, distributed completion/use of information); (4) enrich the "environment" (e.g. implement expert modules).

TF_1	$KV_{1.1}$	$KV_{1.2}$	$KV_{1.3}$	$KV_{1.4}$	$KV_{1.5}$
Local value weight [%]	10.7	12.4	29.3	21.7	25.9
Global weight [%]	2.5	2.9	6.7	5.0	6.0
Target	< 3 min	< 3 min	0	>100	≥3
TF_2	$KV_{2.1}$	$KV_{2.2}$	$KV_{2.3}$	$KV_{2.4}$	$KV_{2.5}$
Local value weight [%]	42.3	15.0	14.4	13.0	15.2
Global weight [%]	6.1	2.2	2.1	1.9	2.2
Target	>60 pp	<10 s	<3 s	≥3	<1 min
TF_3	$KV_{3.1}$	$KV_{3.2}$	$KV_{3.3}$	-	-
Local value weight [%]	35.1	47.0	17.9	-	-
Global weight [%]	1.9	2.5	1.0	-	-
Target	<5	<30	<30 min	-	-
TF_4	$KV_{4.1}$	$KV_{4.2}$	$KV_{4.3}$	$KV_{4.4}$	$KV_{4.5}$
Local value weight [%]	30.8	30.8	14.5	10.9	13.0
Global weight [%]	5.7	5.7	2.7	2.0	2.4
Target	<100 €	>250%	$\to 0$	$\to 0$	$\to 0$
TF_5	$KV_{5.1}$	$KV_{5.2}$	$KV_{5.3}$	$KV_{5.4}$	$KV_{5.5}$
Local value weight [%]	9.0	36.2	20.3	12.7	21.9
Global weight [%]	3.5	14.1	7.9	4.9	8.5
Target	< 2h	< 1day	≤4	≤1min	≥2

Table 2: Value weights and targets for *KV*s.

Vectors of innovation above presented are further considered as guiding patterns within step 9 of the methodology. The next step requires the definition of the major software-PSS specifications for each target-function.

Thus, for TF_1 we should have the following major PSS specifications: a setup and customization feature ($PSS_{1.1}$), a security policy centre for deciding access control to various data ($PSS_{1.2}$), a feedback centre, to report errors or inconsistencies ($PSS_{1.3}$), a migration feature from one environment to another one ($PSS_{1.4}$).

For TF_2, we should have: a documentation centre ($PSS_{2.1}$), a feedback centre ($PSS_{2.2}$) to report errors or inconsistencies, a start-up centre ($PSS_{2.3}$) to allow newbies to easily familiarize with the solution, even before actually using it.

For TF_3, the following PSS specifications are identified: a documentation centre ($PSS_{3.1}$), an assessment session manager, to easily add, edit or remove sessions ($PSS_{3.2}$), a status centre, where all important parameters of the solution should be available to the user ($PSS_{3.3}$).

For TF_4, major PSS specifications comprise: a setup and customization feature ($PSS_{4.1}$), a feedback centre, to report errors or inconsistencies ($PSS_{4.2}$), a migration feature from one environment to another ($PSS_{4.3}$), a documentation centre ($PSS_{4.4}$).

For TF_5, we should have: a documentation centre ($PSS_{5.1}$), an assessment session manager, to easily add, edit or remove sessions ($PSS_{5.2}$), an assessment centre, where the actual assessment of organizational excellence is done ($PSS_{5.3}$), a report generator ($PSS_{5.4}$), and an expert centre, where improvement projects (based on assessments) are suggested ($PSS_{5.5}$).

Deploying local *KV*s via QFD-type matrices (step 6) leads to the calculation of the local value weights of local PSS-specifications (see Table 3).

TF_1	$PSS_{1.1}$	$PSS_{1.2}$	$PSS_{1.3}$	$PSS_{1.4}$	-
Weight [%]	21.9	6.7	40.7	30.7	-
TF_2	$PSS_{2.1}$	$PSS_{2.2}$	$PSS_{2.3}$	-	-
Weight [%]	73.1	10.5	16.4	-	-
TF_3	$PSS_{3.1}$	$PSS_{3.2}$	$PSS_{3.3}$	-	-
Weight [%]	35.4	20.1	44.5	-	-
TF_4	$PSS_{4.1}$	$PSS_{4.2}$	$PSS_{4.3}$	$PSS_{4.4}$	-
Weight [%]	26.5	30.8	24.9	17.8	-
TF_5	$PSS_{5.1}$	$PSS_{5.2}$	$PSS_{5.3}$	$PSS_{5.4}$	$PSS_{5.5}$
Weight [%]	27.3	5.1	37.6	20.6	9.3

Table 3: Local value weights for PSS-specifications.

The following criteria set was defined and ranked in order to analyse the opportunity to implement major PSS specifications (step 7): adaptability (23.2%); development time (8.8%); development cost (16.5%); implementation time (5.5%); implementation cost (20.2%); quality of deliverables (25.7%).

Further on, the relationship level of each PSS specification against each criterion, from both product and service perspectives, for each local set of major PSS specifications are established (five local sets are elaborated). A scale of [0, 1, 3 and 9] is used in completing the relationship matrices. For space reasons, only the first matrix is shown entirely (see Table 4). For the other four cases, results are highlighted in Table 5.

TF_1: increased quality			$PSS_{1.1}$	$PSS_{1.2}$	$PSS_{1.3}$	$PSS_{1.4}$
Adaptability	23.2	p	9	1	3	3
		s	1	3	3	3
Development time	8.8	p	9	3	3	3
		s	3	1	1	0
Development cost	16.5	p	3	3	3	9
		s	1	1	1	3
Implementation time	5.5	p	9	9	9	9
		s	3	1	3	9
Implementation cost	20.2	p	9	9	9	9
		s	3	1	3	3
Quality of deliverables	25.7	p	1	1	1	1
		s	1	0	1	0
Product (p)	Mark		569	330	377	476
	Weight [%]		79.9	73.2	68.7	67.5
Service (s)	Mark		143	121	172	229
	Weight [%]		20.1	26.8	31.3	32.5

Table 4: Product-service distribution for TF_1.

TF_2		$PSS_{2.1}$	$PSS_{2.2}$	$PSS_{2.3}$	-	-
Product (p)	%	60.9	76.6	72.6	-	-
Service (s)	%	39.1	23.4	27.4	-	-
TF_3		$PSS_{3.1}$	$PSS_{3.2}$	$PSS_{3.3}$	-	-
Product (p)	%	64.5	85.3	86.1	-	-
Service (s)	%	35.5	14.7	13.9	-	-
TF_4		$PSS_{4.1}$	$PSS_{4.2}$	$PSS_{4.3}$	$PSS_{4.4}$	-
Product (p)	%	74.8	83.6	83.6	83.5	-
Service (s)	%	25.2	16.4	16.4	16.5	-
TF_5		$PSS_{5.1}$	$PSS_{5.2}$	$PSS_{5.3}$	$PSS_{5.4}$	$PSS_{5.5}$
Product (p)	%	88.5	88.1	82.5	77.5	65.6
Service (s)	%	11.5	11.9	17.5	22.5	34.4

Table 5: Product-service distribution for the target-functions TF_2, TF_3, TF_4 and TF_5.

Further on (step 9), the following five local solutions were formulated, one for each target function. The local solution for TF_1 - increased quality (detailed at generic module level) is: (a) there should be an internet site to assist the user in downloading and installing the product, (b) the site should also have a feedback module, to record user observations on the overall solution, (c) there should be a procedure for recording feedback from the user via a consultant, (d) solution customization should be carried out as a service (via expert/tutor), (e) there should be different versions of the product for each operating system or the product should be cross-platform, (f) there should be an export / import module for data in order to allow migration from one environment to another one (for example, from one operating system to another one, for the product component of the solution).

The local solution for TF_2 - increased learnability (detailed at generic module level) comprises the following: (a) training sessions on organizational excellence, both as integrated help in the software and as courses held by a consultant (expert), (b) automated feedback reports, provided by the software, (c) feedback procedures to be collected by a consultant / expert during solution implementation, (d) there should be a quick-guide on software usage and organizational excellence (for beginner users), both in the software and online, on the solution's site, (e) there should be a “demo” version to contain enough training material to make the solution attractive for SMEs (the intended target audience).

The local solution for TF_3 - increased ergonomy (at generic module level) is about: (a) assessment sessions should be managed by a dedicated module (to easily add, edit, and remove sessions), (b) an import / export feature should be built for backup purposes and / or switching to versions running on other platforms, (c) system status should be always visible (e.g. status & progress bars).

The local solution for TF_4 - cost (detailed at generic module level) is: (a) an offline setup wizard for installing the software, (b) a settings panel to allow the application customization, (c) there should be a procedure, maybe the first step of the implementation, to allow service customization / personalization, (d) an online feedback module (included in the site), (e) an error-reporting module, integrated in the software, (f) an import / export module for all user data, (g) an assessment session management module.

The local solution for TF_5 - assessment duration (detailed at module level) includes: (a) an integrated help module, (b) an integrated documentation module on organizational excellence, (c) an assessment session management module, (d) an assessment session module, where a session should be completed or revised, (e) a report generation module, based on a completed assessment session, (f) an expert module to generate recommendations based on the previously generated reports, (g) a procedure to analyse reports and expert module recommendations (direct meeting between user and consultant).

$PTF = TF_5$	TF_1	TF_2	TF_3	TF_4
Value weight [%]	23.0	14.3	5.4	18.4
Correlation relative to *PTF*	0	+1	+1	0
Priority index	0	14.3	5.4	0
Group (+, not or -)	not	+	+	not
Order	3	1	2	4

Table 6: Grouping TFs relative to *PTF*.

The aggregation process for formulating the final solution is the next step of the methodology. According to the algorithm from step 10 of the methodology, in this case study TF_5 (short assessment duration) is *PTF*.

Analysing Table 1 from step 2, we have TF_2 and TF_3 positive correlated with *PTF* and TF_1 and TF_4 not correlated with *PTF*. There are no negative correlations between *PTF* and other target functions. The priority indexes for TF_1, …, TF_4 are shown in Table 6.

The first integration process consists of combining local solution 5 with local solution 2, and further the resulted hybrid combined with local solution 3. The following intermediate solution was obtained: (a) a software integrated help module, (b) training sessions on organizational excellence, both as integrated help in the software (an integrated documentation module) and as courses held by a consultant (expert), (c) feedback reports, provided by the software (feedback on PSS usage, problems encountered, errors, inconsistencies, etc.); both automated and collected by a consultant / expert during solution implementation, (d) a quick-guide on software usage and organizational excellence (for beginner users), both in the software and online, on the solution's site, (e) a user friendly “demo” version to contain enough training material to make the solution attractive for SMEs (the intended target audience), (f) assessment sessions should be managed by a dedicated module (to easily add, edit, remove sessions), (g) an assessment session module, where a session should be completed or revised, (h) a report generation module, based on a completed assessment session, (i) an expert module to generate recommendations based on the previously generated reports, (j) a procedure to analyse reports and expert module recommendations (direct meeting between the user and the consultant), (k) an import / export feature should be built for backup purposes and / or switching to versions running on other platforms, and (l) system status should be always visible (e.g. status & progress bars).

The result is further aggregated with the local solution of TF_1, and the combination is finally aggregated with the local solution of TF_4. This integration process produces the (final) solution listed below. All modules and sub-modules (noted below with $PSS_{f.x}$, where *x* ranges from 1 to 16) that build the final solution are deployed against the initial requirements (the key requirements for TF_1, …, TF_5); a value weight is computed for each (sub)module (as required by step 11). Thus, we have:

- $PSS_{f.1}$ - a software integrated help module: 6.45%.
- $PSS_{f.2}$ - training sessions on organizational excellence, both as integrated help in the software (an integrated documentation module) and as courses held by a consultant (expert): 7.43%.
- $PSS_{f.3}$ - feedback reports, provided by the software (feedback on PSS usage, problems encountered, errors, inconsistencies, etc.); both automated and collected by a consultant / expert during solution implementation: 3.05%.
- $PSS_{f.4}$ - a quick-guide on software usage and organizational excellence (for beginner users), both in the software and online, on the solution's site: 9.45%.
- $PSS_{f.5}$ - a “demo” version to contain enough training material to make the solution attractive for SMEs (the intended target audience): 13.79%.
- $PSS_{f.6}$ - an offline setup wizard should be available; there should also be a site module to assist the user in downloading and installing the product: 1.61%.
- $PSS_{f.7}$ - a settings panel to allow the application customization: 3.27%.
- $PSS_{f.8}$ - a procedure, maybe over the first step of the implementation, to allow service customization / personalization: 5.98%.
- $PSS_{f.9}$ - assessment sessions should be managed by a dedicated module (to easily add, edit, remove sessions): 4.84%.
- $PSS_{f.10}$ - an assessment session module, where a session should be completed or revised: 6.46%.
- $PSS_{f.11}$ - a report generation module, based on a completed assessment session: 6.24%.
- $PSS_{f.12}$ - an expert module to generate recommendations based on the previously generated reports: 7.86%.
- $PSS_{f.13}$ - a procedure to analyse reports and expert module recommendations (direct meeting between user and consultant): 10.67%.
- $PSS_{f.14}$ - different versions for the product for each operating system: 5.71%.
- $PSS_{f.15}$ - an import / export feature for backup purposes and / or switching to versions running on other platforms: 3.41%.
- $PSS_{f.16}$ - system status always visible (e.g. status & progress bars): 3.82%.

Apparently surprising, the analysis revealed that the most important features to focus on are training-related: the demo version, the training sessions on organizational excellence or the quick-guide.

A problem domain document, use cases, an architecture document and a technical specification document were elaborated in step 12, based on the data obtained in steps 10 and 11.

A software application for assessing organizational excellence, named *business eXXplorer*, was developed to fulfil the product side of the software-PSS. Programming was done in Delphi and is now being ported to FreePascal / Lazarus which supports cross-compiling (thus being able to produce executables for Linux, Mac and Windows). The menu of *business eXXplorer* consists of the following items:

- Organizational excellence: a tutorial on what organizational excellence is and how it is assessed.
- User guide: the help section, where all topics related to *business eXXplorer*'s usage are described.
- Business assessment: opens the assessment session manager and, further on, the assessment module. It includes an intuitive guiding interface, and consistent help for each step.
- Result interpretation: opens the assessment session manager, so that the user can choose a (completed) session (called a “project” in *business eXXplorer*) and,

further on, the report generation and visualization module (which includes the expert module that issues recommendations).

- Settings: allows the application customization.
- Exit: closes *business eXXplorer*.

The interface of version 1 is available in Romanian only, but the next versions will support multiple languages.

Apart from the actual software, the *business eXXplorer* package consists of an internet site with free access (containing technical information, detailed explanations about organizational excellence, detailed description of *business eXXplorer*'s main features, a demo version for download, and usage examples consisting of assessment reports), a user manual, a quick-start brochure, a video tour of the software, and an automated setup tool.

Consultants can easily integrate and adapt their training and tutoring activities with the *business eXXplorer*'s features. Highlights about the main modules of *business eXXplorer* are further presented.

The user can browse through 13 major training topics on organizational excellence, grouped into two chapters (general information and assessment methods – see Figure 1).

An assessment session consists of self-evaluation against 164 criteria, grouped into 9 key business-related units: leadership, strategies, resource management, human resource management, processes, employee satisfaction, customer satisfaction, community satisfaction, and business performance.

Figure 1: The organizational excellence built-in tutorial.

Each criterion has detailed explanations; the interface is built in such a way that beginners might easily read them, while advanced users might focus just on choosing a conformity level (see Figure 2).

After an assessment session is completed, *business eXXplorer* generates specific reports. The report contains four sections, with both general and in-depth balanced analysis among business possibilities and results.

Figure 3 shows a temple-based visual report. Besides this, some other specific reports are generated by *business eXXplorer* (radar-based, bar-based, balance-based, criteria based, project comparison-based etc.; they are not visualized in this paper).

Moreover, the software-PSS solution elegantly integrates the vectors of innovation proposed at step 5 of the methodology (please review these vectors at page 4 of the paper). Also, during the aggregation process in step 10, the final solution was balanced distributed into product and service, considering information from Table 4 and Table 5 for decision making. This process is a creative one, therefore aggregation does not mean a "mechanical" integration of local solutions; it exploits local solutions to work out a superior global solution which incorporates the strengths of the local solutions and (if possible) brings additional value in the system.

In this context, the targets of the key value characteristics (see Table 2) have been used during the development, testing and validation phases of the final software-PSS solution. Just for informing, the proposed software-PSS solution meets entirely the planned targets.

Figure 2: The assessment session module (with help).

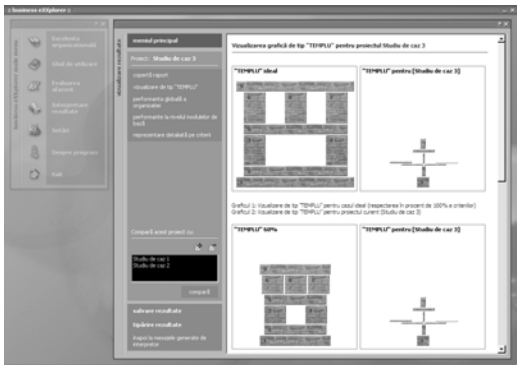

Figure 3: The report browsing module (the "business temple" representation).

5 FURTHER RESEARCHES

Researches to extend the proposed methodology by comprising wider aspects of the PSS's life-cycle, as well as high dynamics in changing stakeholders' values and requirements (both in meaning and intensity) in a continuously adapting global business environment will be further taken into consideration.

6 CONCLUSIONS

A methodology for concurrent planning and design of software product-service systems against a complex set of target-functions is introduced in this paper. The quality of the methodology arises from its potential to propose solutions that incorporate a superior balance between various aspects related to stakeholder's satisfaction, with the consideration of customer's needs as the leading vector. In order to achieve this goal, the methodology exploits the potential of structured tools of performance planning (e.g. AHP, QFD) and innovative problem solving (e.g. TRIZ, CSDT).

The methodology also provides an appropriate framework for adequate distribution of the functions/ features of the solution between product and service in the attempt to maximize value added performances both for customer and producer. The framework breaks down the complexity of the problem by facilitating, at a first stage, a concurrent focalization on separate target-functions to explore local potentials. Later on, the best local results are "combined" in a balanced way to define a mature global solution (or several mature solutions). From this perspective, the methodology stresses the key role that creativity plays in refining functionalities to a complex problem, based on “local” solutions to specific target-functions. The aggregation algorithm introduced by the methodology is, by itself, an effective mean for supporting the creative process.

Moreover, the vectors of innovation issued by the methodology allow a software designer not only to solve possible conflicts at early stages of the development process, but also help her/him identifying those distinctive features of the solution that are difficult to determine using a classic approach.

The case study introduced in the paper reveals the capability of the proposed methodology to handle both antagonistic aspects during the conceptualization and design phases of a new software-PSS, as well as less tangible issues with value added potential for the decision making process.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Futrell, R., Shafer, D. and Shafer, L., 2002, Quality Software Project Management, Prentice Hall.

[2] Barney, S., Aurum, A. and Wohlin, C., 2008, A Product Management Challenge: Creating Software Product Value Through Requirements Selection, Journal of Systems Architecture, 54: 576-593.

[3] Agarwal, N. and Rathod U., 2006, Defining “Success” for Software Projects: An Exploratory Revelation, International Journal of Project Management, 24: 358-370.

[4] Petter, S., 2008, Managing User Expectations on Software Projects: Lessons from the Trenches, International Journal of Project Management, 26: 700-712.

[5] Juristo, N., Moreno, A.M. and Sanchez-Segura, M-I., 2007, Analyzing the Impact of Usability on Software Design, The Journal of Systems and Software, 80: 1506-1516.

[6] Mantere, T. and Alander, J.T., 2005, Evolutionary Software Engineering, a Review, Applied Soft Computing, 5: 315-331.

[7] Pereira, J., Cerpa, N., Verner, J., Rivas, M. and Procaccino, J.D., 2008, What Do Software Practitioners Really Think About Project Success: A Cross-Cultural Comparison, The Journal of Systems and Software, 81: 897-907.

[8] Xie, G., Zhang, J. and Lai, K.K., 2006, Risk Avoidance in Bidding for Software Projects Based on Life Cycle Management Theory, International Journal of Project Management, 24: 516-521.

[9] Jung, H.W., 2007, Validating the External Quality Sub-characteristics of Software Products According to ISO/IEC 9126, Computer Standards & Interfaces, 29: 653–661.

[10] Zhang, X. and Pham, H., 2006, Software Field Failure Rate Prediction before Software Deployment, The Journal of Systems and Software, 79: 291-300.

[11] Bitzer, J., 2004, Commercial versus Open Source Software: The Role of Product Heterogeneity in Competition, Economic Systems, 28: 369-381.

[12] Liu, J.Y.C., Chen, V.J., Chan, C.L. and Lie, T., 2008, The Impact of Software Process Standardization on Software Flexibility and Project Management Performance: Control Theory Perspective, Information and Software Technology, 50: 889-896.

[13] Ajila, S.A. and Wu, D., 2007, Empirical Study of the Effects of Open Source Adoption on Software Development Economics, The Journal of Systems and Software, 80: 1517-1529.

[14] Verner, J.M., Evanco, W.M. and Cerpa, N., 2007, State of the Practice: An Exploratory Analysis of Schedule Estimation and Software Project Success Prediction, Information and Software Technology, 49: 181-193.

[15] Aurich, J.C., Fuchs, C. and Wagenknecht, C., 2006, Life Cycle Oriented Design of Technical Product-Service Systems, Journal of Cleaner Production, 14: 1480-1494.

[16] Aramand, M., 2008, Software Products and Services are High Tech? New Product Development Strategy for Software Products and Services, Technovation, 28: 154-160.

[17] Yang, X., Moore, P., Pu, J-S. and Wong, C-B., 2009, A Practical Methodology for Realizing Product Service Systems for Consumer Products, Computers & Industrial Engineering, 56: 224-235.

[18] Morelli, N., 2006, Developing New Product Service Systems (PSS): Methodologies and Operational Tools, Journal of Cleaner Production, 14: 1495-1501.

[19] Stamelos, I., 2009, Software Project Management Anti-Patterns, The Journal of Systems and Software, article in press.

[20] Han, W-M. and Huang, S-J., 2007, An Empirical Analysis of Risk Components and Performance on Software Projects, The Journal of Systems and Software, 80:42-50.

[21] Lenfle, S. and Midler, C., 2009, The Launch of Innovative Product-Related Services: Lessons from Automotive Telematics, Research Policy, 38: 156-169.

[22] Yang, X., Moore, P. and Chong, S.K., 2009, Intelligent Products: From Lifecycle Data Acquisition to Enabling Product-Related Services, Computers in Industry, 60: 184-194.

[23] Shimoura, Y., Hara, T. and Arai, T., 2009, A Unified Representation Scheme for Effective PSS Development, CIRP Annals: Manufacturing Technology, 58: 379-382.

[24] Büyüközkan, G., Ertay, T., Kahraman, C. and Ruan, D., 2004, Determining the Importance Weights for the Design Requirements in the House of Quality Using the Fuzzy Analytic Network Approach, International Journal of Intelligent Systems, 19: 443-461.

[25] Wang, H., Xie, M. and Goh, T., 1998, A Comparative Study of the Prioritization Matrix Method and the Analytic Hierarchy Process Technique in Quality Function Deployment, Total Quality Management, 9: 421-430.

[26] Akao, Y. and Mazur, G.H., 2003, The Leading Edge in QFD: Past, Present and Future, International Journal of Quality & Reliability Management, 20: 20-35.

[27] Altshuller, G., 2000, The Innovation Algorithm: TRIZ, Technical Innovation Centre.

[28] Brad, S., 2008, Complex System Design Technique, International Journal of Production Research, 46: 5979-6008.

Innovative Design Method of Product Service System by Using Case Study and TRIZ Method

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Abstract

This paper presents a TRIZ based eco-innovative design methodology to support designers to develop product service systems (PSS). This method is based on TRIZ, which was developed in the former Soviet Union by Altshuller, who had analysis over 400,000 patents to build 40 inventive principles and contradiction matrix tool. In this paper, current PSS cases are collected and analyzed to identify consumers' use habit in the PSS cases. Find out the relations between product and service in those cases. Analyzing product with its characteristics to get suggestions which for design new PSS. Then use the TRIZ 40 inventive rules to conclude innovative design rules for PSS. Product design may have more innovative possibilities by using these inventive rules. PSS innovation example was demonstrated to illustrate the effectiveness of proposed methods.

Keywords

PSS, Eco-Innovation, TRIZ

1 INTRODUCTION

The development of technology plays a crucial role in modern economic growth, but is also the key factor of environmental crisis. It is usually emphasizing the novelty and economic usefulness of an innovation product but neglects its environmental impact. Currently, many eco-design methods have been combined with eco-innovation. However, even there is eco-design method to design product, it's hard to say that all the eco-products are used by an eco-efficiency concept. Therefore a new concept of product service system (PSS) that defined a system of products, services, and supporting infrastructure to fulfil a customer need with less environmental impact than traditional ones is proposed [1-3]. Though there are many PSS examples that can be followed, it still needs a method to provide product designers some inspirations.

The use of TRIZ method in eco-innovative design tasks is one of the interests, which have been proposed since 2000 [4-5]. They identified ways in which tools and methodologies from TRIZ might be used in eco-innovation. The simplest way to adapt TRIZ into eco-innovation is using TRIZ classical method by identifying the contradiction parameters and finding suitable principles from contradiction matrix [4, 7-9]. Chen and Liu established the link between seven major eco-efficiency elements from WBCSD (World Business Council for Sustainable Development) with TRIZ engineering parameters and developed an inventive design method to solve engineering innovative design problem without contradiction information by using TRIZ inventive principles [10-12]. Chen [13] developed green evolution rules and ideality laws for eco-innovative design, which can help designer to locate an evolutionary direction in eco-design process. Chang and Chen proposed a design around and extension method [7, 14] and collected 40 eco-innovative examples for TRIZ inventive principles [15], which cover a wide range of products and processes design. Chen and Chen [16] used TRIZ method in design for active disassembly. Chen and Huang [17] proposed an eco-innovation method by integrating biomimetic concepts with TRIZ. Chen and Wu [18] proposed an eco-innovation method by combining TRIZ with iNPD process.

The use of TRIZ method in PSS development methodology is proposed by Abdalla [19-20]. Lin and Su [21] apply the TRIZ inventive principles to create new services. Kondoh and his co-authors [22] have proposed some rules for planning new eco-business or PSS. Chen and his co-authors [23] have proposed TRIZ ideality and trend of evolution in eco-business. Chen and Huang [24-25] have presented an eco-innovation method to support designers to develop product service systems (PSS). This method is based on TRIZ 40 inventive principles and contradiction matrix tool. Current PSS cases are collected and divided into five categories. A relationship table between TRIZ inventive principles and PSS cases is established in this paper to presents a new design guideline for PSS. Some green evolution rules are observed and identified by investigating patterns and lines of technological evolution of different PSS.

In this paper, current PSS cases are collected and analyzed to identify consumers' use habit in the PSS cases. Find out the relations between product and service in those cases. Several design tables are developed and used as tools for PSS eco-innovation. PSS innovation example was demonstrated to illustrate the effectiveness of proposed methods.

2 TOOLS FOR PSS ECO-INNOVATION

In this section, several design tools for PSS eco-innovation were presented and described in detail. The tools include some design table, PSS categories, TRIZ inventive principles, and PSS cases.

2.1 Eight PSS categories

Tischner and Verkuijl [1] have divided the PSS into three big categories: product, use and result orientated PSS. Furthermore, Tukker [26] has classified into eight small categories. The first two small categories, (1) product-related service and (2) advice and consultancy, are identified as first big category, product-oriented PSS, which product is owned by the user/consumer with added services. Second large category is use-oriented PSS which product is owned by the service provider and used by the consumer. The service provider sells functions

PP		Pr		IU		UC		CP		PV		PW		RT		UR	
Product Property		Price		Idle-Using Ratio		Using Cycle		Using Period		Product Volume		Product Weight		Rearrange Time		Used Ratio	
Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank	Level	Rank
Fixed / Solid	1	<100	1	<1	1	1 hr↓	1	1 hr↓	1	10^{-3} m^3↓	1	1Kg↓	1	0	1	1	1
		100 ~ 1000	2	1~2	2	1hr~ 1Day	2	1hr~ 1Day	2	15X 10^{-3} m^3	2	1~5	2	1 hr↓	2	2~10	2
Movable	2	1000 ~10,000	3	>2	3	1Day~ 1week	3	1Day~ 1week	3	65X 10^{-3} m^3	3	5~30	3	1hr~ 1Day	3	10~100	3
consuming / Non-Solid	3	10,000 ~100,000	4			1week~ 12 month	4	1week ~ 1 month	4	1 m^3	4	30~200	4	1Day~ 1week	4	100↑	4
		100,000 ~10 million	5			1 year↑	5	1 month ↑	5	1 m^3↑	5	200↑	5	1week ~ 1 month	5		
without main Products/ Solutions	4	>10 million	6							None	6	None	6	1 month ↑	6		
		Special price	7														

Table 1: Product's characteristic factor level table of PSS.

instead of products, such as leasing, and renting. Three small categories, (3) product lease, (4) product renting or sharing, and (5) product pooling, are classified as second big category. Third big category is result-oriented PSS which a customer only purchases a service result and does not care which products are used, such as new service by new technologies. The small categories, (6) activity management or outsourcing, (7) pay per service unit, and (8) functional result, are identified as result oriented PSS.

In this study, 103 PSS cases are collected and divided into above eight categories. Some PSS cases have more than one category since their feature can be classified into many small categories.

2.2 Product's characteristic factor level table of PSS

After collect 103 PSS cases, an index system to exploit similarities among PSS cases is proposed for identifying most similar PSS case in database as eco-innovation direction for new PSS problem. An index system signifies all the important characteristics required to classify different PSS groups. Each group is identified by a nine-digit alphanumeric code. Each digit is a notable feature and represented by a different number for each different PSS according to its characteristic. The significance of each digit is represented in detail later and also shown in Table 1.

Nine product's characteristic factor for PSS are product property (PP), price (Pr), idle-using time (IU), using cycle (UC), using period (CP), product volume (PV), product weight (PW), rearrange time (RT), and used ratio (UR) respectively. The level of each factor and the rank of each level are all shown in Table 1.

2.3 PSS case database

Each PSS case is recorded in database with information about this PSS, such as case number, categories, name of PSS case, service model, related product, Nine product's characteristic factor, and characteristic of PSS, as illustrated in Table 2. In Table 2, only partial list of PSS case database is shown. Detail list of all 103 PSS case database can be found in Reference 27. The characteristic of PSS is special business feature of each PSS case and contains four types, such as user interface for customer, business strategy, cost reduction, and increasing function or service efficiency. The number inside the bracket of the example of characteristic of PSS associated with each PSS case is the number of related TRIZ inventive principle.

2.4 TRIZ Inventive principles for PSS

The 40 TRIZ inventive principles were original developed for using in engineering and technology domain. They are not very suitable for employing into PSS innovation directly. Therefore, a new definition for each TRIZ inventive principle for PSS innovation is proposed in this study. A relationship table between TRIZ inventive principles, New definition, and PSS cases is established in this paper to presents a new design guideline for PSS, as illustrated in Table 3. In Table 3, only partial list of TRIZ inventive principles is shown.. Details of this table can be found in Reference 27.

2.5 PSS service modes

In addition to Tischner's eight PSS categories, a new service model categories for PSS based on motivation of service is proposed in this study. PSS cases are classified into six big service mode categories, such as potential value of product, saving of time & convenience, promotion competitive power, meets more needs, more specialized, and reducing cost, respectively. Furthermore, each six big service mode category is divided into three small service mode categories. Therefore, totally, there are eighteen small service mode categories, such as (A) remanufacture/ resale, (B) obtains the information, (C) reducing pollution, (D) appointment, (E) replace shipping, (F) service in everywhere, (G) change to sale function, (H) change business model, (I) unify function & entity, (J) multi-function, (K) extra service, (L) customization, (M) specialized management, (N) special se4rvice, (O) collection & reorganization, (P) sharing, (Q) software replace hardware, and (R) uses many times, respectively.

A position table for identifying the relationship between Tischner's 8 PSS categories and PSS service mode categories for all 103 PSS cases is shown in Table 4. Detail information about the case number shown in Table 4 can be obtained from Reference 27. As illustrated in Table 4, most PSS cases in product-oriented PSS are focused on "meets more needs" big service motivation category. As for use-oriented PSS, most PSS cases focus

Case No.	Categories (Tukker)	PSS case	Service mode	Related product	PP	Pr	IU	UC	CP	PV	PW	RT	UR
1	3	Recycling & remanufacture carpet	A	Carpet	1	4	2	1	2	3	2	4	1
5	4	Advanced rent mode	F, R	Bike; Renting station	2	3~4	3	2	2	3	2	3	3
34	7	24 hours self-washing store	R	Washing machine	1	4	3	2	1	4	4	1	3
49	2	Customized computer	L	Computer hardware	1	3	3	2	2	3	2	4	3
63	8,1	Advertisement service	F	Advertisement electronic monitoring system	1	3	1	4	5	4	3	5	2

Case No.	Characteristic of PSS (the number inside the bracket is the number of related TRIZ inventive principle)			
	User interface for customer	Business strategy	Cost reduction	Increasing function or service efficiency
1		1. The continuous revision maintenance carpet lengthens the servicing time (19)	1. Improving material for recycling & reuse (31)	1. The carpet material changes into reuse material (34) 2. Segment carpet into small unit (1)
5	1. Bank cooperation (38) 2. Mobil phone reservation (24)	1. Having multi-station for renting bike (14) 2. Member system (11) 3. Deposit (11)		1. The frame of bike adds on the electronic lock (11)
34		1. Business without manpower (2) 2. 24 hours business (12)		1. Joins throws the coin starting equipment (25)
49				1. Joins the service of guarantees against damage (20) 2. Provides the specialized consultation (29)
63				1. Utilizes the specialized design capability to design the outdoor advertising electronic monitoring system (32) 2, Outdoors electronic monitoring system regarding environmental durability (16)

Table 2: Partial list of PSS case database table.

on “reducing cots” big service motivation category and “(R) uses many times” or “(P) sharing” small service model categories. Furthermore, Many PSS cases are located in the “result-oriented PSS” category. In this category, most PSS cases are focused on “potential value of product, saving of time & convenience, promotion competitive power, and more specialized” big service motivation categories.

3 ECO-INNOVATION OF PSS

3.1 Design process for PSS eco-innovation

The tools, such as Table1-4, categories, TRIZ inventive principles, and PSS cases, for PSS eco-innovation developing in section 2 are organized as a design process for PSS innovation, as shown in Figure 1. As illustrated in Figure 1, the design procedure can be recognized as four stages. The significations of these four stages are explained in detail as follows.

3.2 First stage: find similar PSS cases

The designer can first propose the PSS problem that required improvement and find similar PSS cases based on Table 1 and Table 2. The first step is to identify the level value of nine product’s characteristic factor from the definition of Table 1 for target product. Next, designer can searching the most similar PSS cases from database of Table 2 with target product by comparing the level value of nine product’s characteristic factor. The PSS cases with low value of degree of difference will be the most similar cases. The degree of difference is calculated by the following equation.

$$\text{Degree of difference} = \sum_{i=1}^{9} |F_i - f_i|$$

No	TRIZ Inventive Principles	Redefinition of Principle in PSS Domain	Characteristic of PSS cases
1	Segmentation	1. Divides the object into independent components 2. Makes the object modualization 3. Increases the degree of division for object or service	1. Segment carpet into small unit (1) ......
2	Extraction	1. Takes out the partial functions to use 2. Takes out the partial flow to reduce harm	1. Business without manpower (34) ....
12	Equipotentiality	1. Change work's condition causes the object not to lift or lower 2. Change service pattern decreases with the competitor disparity	1. The traditional market use fast purchases window (81) 2. 24 hours business(34)
16	Partial, Overdone or Excessive Actions	1. Uses a stronger effect to promote the long-term potency 2. Uses durable material or long-life goods 3. uses more efficiency goods	1. Outdoors electronic monitoring system regarding environmental durability (63) .....
25	Service	1. The user may complete voluntarily 2. The manufacturer utilizes own specialty to complete the other entrepreneur complex or expensive service	1. Coin-operated laundry (34) ......
32	Changing the Color	1. Outward appearance art designing	1. Utilizes the specialized design capability to design the outdoor advertising electronic monitoring system (63) ......
.....	.....	.....	.....

Table 3: Partial list of TRIZ inventive principles for PSS.

Service Model / Categories (Tukker)			Potential value of product	Saving of time & convenience	Promotion competitive power	Meets more needs	More specialized	Reducing cost
			A Remanufacture/ Resale; B Obtains the information; C Reducing pollution	D Appointment; E Replace shipping; F Service in everywhere	G Change to sale function; H Change business model; I Unify function & entity	J Multi-function; K Extra service; L Customization	M Specialized management; N Special service; O Collection & reorganization	P Sharing; Q Software replace hardware; R Uses many times
Product Oriented	1	.Product-related service	13	3.16.63.91	66.81.41.71	56.64.84.86.99. 103	14.17.47	
	2	Advice and consultancy	43.77.78	16		49.51. 65	100.44	50
Use Oriented	3	Product lease	1.22		11.29		12	48.75
	4	.Product renting or sharing	22.74	5.76	29		23	5.6.25.36.37.74. 75.83.7
	5	Product pooling			73			38.59.70
Result Oriented	6	.Activity management /outsourcing.	8.22.78.79.80.82. 85.94.95.96.97. 102..13.10.45	72.87	29.92.93	68.86.84.51	14.18.39.58.89. 101. 102 15.55.90	48
	7	Pay per service unit.						31.32.34
	8	Functional result	43	2.28.53.54.63	35.68.27	40.60.67.98.19.5. 3.62	9.20.24.30.33.57. 4.21.26.88.46.61	61.52

Note: The number in this table is the number of PSS case.

Table 4: Relationship between 8 PSS categories and PSS service modes.

After finding the most similar PSS cases, designer can process into second stage.

3.3 Second stage: identify PSS categories

Based on the most similar PSS cases found in the first stage, one can identify Tukker's categories and service mode categories of each one from the information in Table 2. If the designer find the Tukker's categories or service mode categories from anyone of the most similar PSS cases are valuable for offering eco-innovation direction for target product, then move to third stage. Otherwise, go to fourth stage.

3.4 Third stage: find TRIZ inventive principles

In third stage, the designer can search the characteristic of PSS (special business feature of each PSS case) for

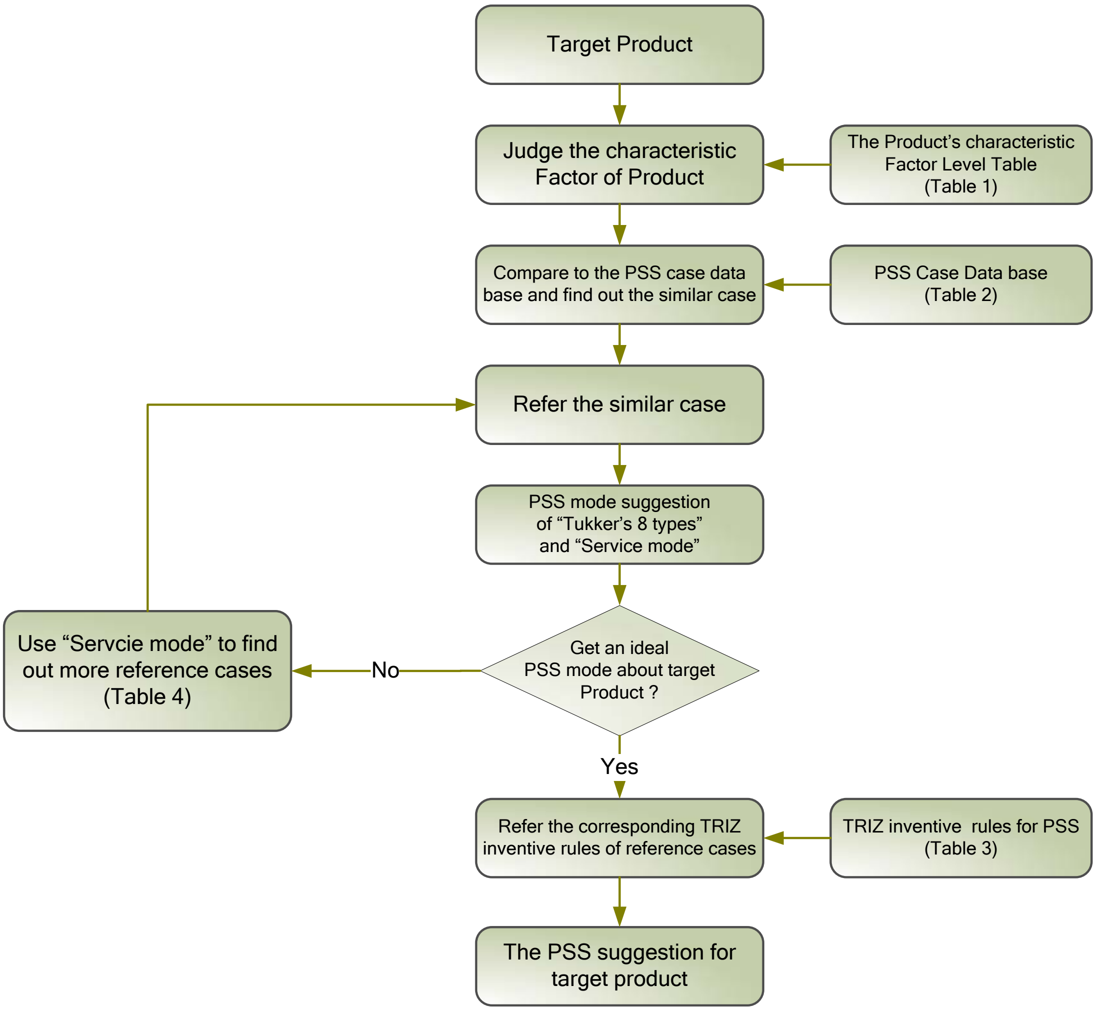

Figure 1: Flowchart of the PSS eco-innovation process.

selecting most similar cases from Table 2. The characteristic of PSS contains four types, such as user interface for customer, business strategy, cost reduction, and increasing function or service efficiency. Therefore, the designer can try to obtain new idea for PSS eco-innovation from the suggesting characteristic of PSS of each case in Table 2. Moreover, the number inside the bracket of the example of characteristic of PSS associated with each PSS case is the number of related TRIZ inventive principle. The designer can find the corresponding new PSS definition and related PSS cases for each TRIZ inventive principles from Table 3. Based on new definition of TRIZ inventive principles and related PSS cases, the designer can generate new PSS ideas.

3.5 Fourth stage: find other design suggestions

During the second stage, in case the finding PSS cases are not suitable to get an ideal PSS service mode. Then, the designer can move into stage four to obtain other different PSS cases for reference. In fourth stage, the designer can utilize information in Table 4 to obtain other PSS cases with the same motivation of service category of the most similar PSS cases in first stage. Selection of other PSS cases is based on the one identified in the Tukker's result oriented category. As another PSS cases are obtained, the designer can move forward to second stage.

4 NOTEBOOK EXAMPLE

4.1 Problem description

Under normal condition, the average life range of notebook is 5 to 7 year. However, due to short technical cycle, customers are eliminating notebooks as outmoded products before its reached end-of-life. Therefore, one of the environmental impacts of the using notebooks relates to waste of resource. How to innovate PSS for notebook to reduce waste of resource is the object of this notebook eco-design case. The effectiveness of proposed PSS innovation method will be shown in this section.

4.2 PSS eco-innovation of notebook

By following the steps in Figure 1, one can first find the level value of characteristic factor for notebook from the definition of Table 1, as shown in Table 5. Next, designer can searching the most similar PSS cases from database of Table 2 with notebook by comparing the level value of nine product's characteristic factor between Table 5 and each cases in Table 2.

PP	Pr	IU	UF	CU	PV	PW	RT	UR
2	4	3	2	2	2	2	4	3

Table 5: The characteristic factor level of Notebook.

The most similar cases in this problem with degree of difference equals 2 are shown in Table 6. From the information in Table 6, the Tukker's categories for PSS case 5 (advanced rent mode) and 49 (customized computer) can be identified as (4) product renting or sharing and (2) advice and consultancy, respectively. As for service mode categories, three types service mode, (F) service in everywhere, (R) uses many times, and (L) customization are identified from the information in Table 6. Therefore, two new PSS concepts, such as notebook rent mode and customized notebook, can come out directly from above information.

Case No.	Tukker's categories	PSS case	Service mode	Related product
5	4	Advanced rent mode	F, R	Bike; Renting station
49	2	Customized computer	L	Computer hardware

Table 6: The most similar PSS cases for Notebook.

If above new concepts can not applying directly to obtain eco-innovative design for notebook, then move to fourth stage by using service mode in Table 4 to find more other PSS cases for reference. By using Table 4, The PSS cases related to service mode (F) service in everywhere and (R) uses many times are case 5, 76, 63 and 48, 75, 25, 5, 36, 37, 83, 74, 6, 34, respectively. Among those PSS cases, case 63 and 34 are identified as the Tukker's result oriented category and selected as reference cases.

In third stage, the designer can search the characteristic of PSS (special business feature of each PSS case) for case 63 and 34 from Table 2.

Case 63 is the "advertisement service" PSS case with "advertisement electronic monitoring system" product. The business feature of case 63 is identified as "increasing function or service efficiency". The example of characteristic of PSS associated with case 63 are (1) utilizes the specialized design capability to design the outdoor advertising electronic monitoring system and (2) outdoors electronic monitoring system regarding environmental durability. The related TRIZ inventive principles are #32 (changing the color) and #16 (partial, overdone or excessive actions).

The self-washing store (case 34) have been identified its business feature as "business strategy" and "increasing function or service efficiency". The example of characteristic of PSS associated with self-washing store (case 34) are (1) business without manpower , (2) 24 hours business, and (3) joins throws the coin starting equipment, respectively. The related TRIZ inventive principles are #2 (extraction), #12 (equipotentiality), and #25 (self-service).

TRIZ inventive principles #2, #12, #16, #25, and #32 can be used in this notebook problem to innovate new PSS idea. Detail information of TRIZ inventive principles related to PSS can be obtained from Table 3. The designer can generate new PSS ideas for notebook as self-service notebook renting station operating 24 hours, as shown in Figure 2.

Figure 2: Concept of self-service notebook renting station

5 CONCLUSIONS

The PSS innovation design methods based on case study and the TRIZ inventive design method was developed. 103 PSS cases are collected and analyzed to identify consumers' use habit in the PSS cases. Several design tables are developed and used as tools for PSS eco-innovation. A notebook PSS case was demonstrated to illustrate the effectiveness of proposed methods. This new methods provide the designer a supporting tool to develop new PSS with less environmental impact.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Tischner, U., Verkuijl, M., 2002, Sustainable Product-Service co-design Network - First Draft Report, SusProNet, Web: www.suspronet.org.

[2] Goedkoop, M. J. , van Halen, C. J.G., te Riele, H. R.M., Rommens, P.J.M., 1999, Product Service systems,Ecological and Economic Basics, Report for the Dutch ministries of Environment (VROM) and Economic Affairs (EZ), pp. 17-19,March.

[3] Mont, O.,2002, Clarifying the concept of product service system, Journal of Cleaner Production, Vol. 10, pp. 237-245, June.

[4] Jones, E., Harrison, D., 2000, Investigating the Use of TRIZ in Eco-Innovation, The TRIZ Journal, September, 2000.

[5] Low, M.K., Lamvik, T., Walsh, K., Myklebust, O., 2000, Product to Service Eco-Innovation: The TRIZ Model of Creativity Explored, Proceedings of 2000 International Symposium on Electronics and Environment, San Francisco, California, May 8-10, 209-214.

[6] Chen, J.L., Liu, C.C., 2002, Green Innovation Design of Products by TRIZ Inventive Principles and Green Evolution Rules, 2002 International CIRP Design Seminar, Hong Kong, May 16-18.

[7] Chang, H.T., Chen, J.L., 2003, An Eco-Innovative Design Method Based on Design Around Approach, Third International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Ecodesign03, Tokyo, Japan, December 8-11.

[8] Kobayashi, H., 2003, Idea Generation and Risk Evaluation Methods for Life Cycle Planning, Third International Symposium on Environmentally

Conscious Design and Inverse Manufacturing, Ecodesign03, Tokyo, Japan, December 8-11.

[9] Mann, D., 2003, Systematic Sustainable Innovation, in Sustainable Innovation 03: Creating Sustainable Products, Services and Product-service-System, Towards Sustainable Product Design (Ed. M. Charter), 8th International Conference. Stockholm, Sweden, October 27-28.

[10] Chen, J.L., Liu, C.C., 2001, An Eco-Innovative Design Approach Incorporating the TRIZ Method without Contradiction Analysis, Journal of Sustainable Product Design, 1/4, 263-272.

[11] Liu, C.C., Chen, J.L., 2001, Development of Product Green Innovation Design Method, Second International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Ecodesign01, Tokyo, Japan, December 12-15, 168-173.

[12] Liu, C.C., Chen, J.L., 2001, A TRIZ Inventive Product Design Method without Contradiction Information, The TRIZ Journal, September 2001.

[13] Chen, J.L., 2002, Green Evolution Rules and Ideality Laws for Green Innovative Design of Products, Proceedings of Going Green - Care Innovation 2002, 4th International Symposium, Vienna, November 25-28.

[14] Chang, H.T., Chen, J.L., 2004, The Conflict-Problem-Solving CAD Software Integrating TRIZ into Eco-Innovation, Journal of Advances in Engineering Software, 35, 553-566.

[15] Chang, H.T., Chen, J.L., 2003, Eco-Innovative Examples for 40 TRIZ Inventive Principles, The TRIZ Journal, August 2003.

[16] Chen, J.L., Chen, W.-C., 2007, TRIZ Based Eco-Innovation in Design for Active Disassembly, 14th CIRP International Conference on Life Cycle Engineering, June 11-13, 83-87.

[17] Chen, J.L., Huang, L.-C., 2007, Eco-innovation of Products by Biomimetic Concepts, Fifth International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Ecodesign07 Tokyo, Japan, December 10-13

[18] Chen, J.L., Wu, C.-M., 2008, An Eco-innovation Method by Combining TRIZ with iNPD Process, 15th CIRP International Conference on Life Cycle Engineering, , Sydney, Australia, March 17-19.

[19] Abdalla, A., Bitzer B., Morton, D., 2004, Benchmarking TRIZ in the field of Product Service systems "PSS" , Proceedings of the 4th ETRIA TRIZ future Conference, Florence, Italy, 3-5 Nov.

[20] Abdalla, A., 2006, TRIZ Innovation Management Approach for Problem Definition and Product Service Systems, Shaker Verlag, Inc., Aachen, April.

[21] Lin, C. S., Su, C.T., 2007, An Innovative Way to Create New Services: Applying the TRIZ Methodology, Journal of the Chinese Institute of Industrial Engineers, Vol. 24, No. 2, pp. 142-152.

[22] Kondoh, S., Kurakwa, K., Kato, S., Umeda, Y., Takata, S., 2006, Analysis of Key Success Factors for Eco-Business through Case Studies in Japan, 13th CIRP International Conference on Life Cycle Engineering, Leuven , Belgium . May 31st to June 2nd.

[23] Chen, J. L., Masui, K., Kondoh, S., Mishima, N., 2006, Ideality and Trends of Evolution in Minimal Manufacturing and Eco-business, Proceedings of EcoDesign 2006 Asia Pacific Symposium Program, Tokyo, Japan.

[24] Chen, J. L., Huang, C.-P., 2009, A TRIZ Based Eco-Innovation Method for PSS, 16th CIRP International Conference on Life Cycle Engineering, Cairo, Egypt, May 4-6.

[25] Huang, C.-P., 2008, The Innovation of Product Service System Based on TRIZ Method, Master Thesis, Department of Mechanical Engineering, National Cheng Kung University, June 2008 (in Chinese)

[26] Tukker, A., 2004, Eight Types of Product Service System: Eight Ways to Sustainabilityu? Experiences from Suspronet, Business Strategy and the Environment, Vol. 13, pp. 246-260.

[27] Li, H.-C., 2009, Innovative Design Method of Product Service System by Using Case Study and TRIZ Method, Master Thesis, Department of Mechanical Engineering, National Cheng Kung University, June 2009 (in Chinese)

Project and Design Reviews in IPS²
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Abstract

While considerable work has been done in the field of IPS² design in recent years, Design Reviews (DR) in IPS² context is not given due attention. This work deals with Design Reviews in IPS² context as an extension of normal Design Reviews by early stepwise verification of product and service deliveries. Furthermore, IPS² Design Reviews differ from normal Design Reviews by continuous customer assessment for combined service/product use. Focusing upon the various stages of generic IPS² development processes, Design Reviews are introduced at key milestones and several quality gates of product development. This methodical framework outlines the difference between IPS² Reviews and normal reviews by focusing on key IPS² specific review criteria, elements, deliverables and participants for successful implementation of Design Reviews at each milestone or quality gates.

Keywords

Design Reviews, IPS², Product Development, Service Development

1 IPS² DEVELOPMENT

1.1 Introduction to IPS² development processes

Industrial product-service-systems (IPS²) are individualized, customer-oriented configurations of products and services, which affect each other due to their integrated development and provision [1]. IPS² development is triggered by various factors based on organisational requirements of either providing value to the customer in the form of intangible services or being more eco-friendly function provider. The intangible services associated with IPS² reward organisations with financial incentives and profitability. Furthermore, value adding services help organisations to see new previously unexplored opportunities and enable them to sustain and compete in cutthroat competitive global markets. Currently, there are numerous development process models which focus on product and service development processes. But these models do not deal with service delivery in detail [2]. The IPS² Design methodology proposed by Tim Sadek and E.G.Welp focuses on product and service allocation before they are designed [3].

The factors which associate IPS² with sustainability are eco-efficiency and dematerialisation. Some methodologies like the ProSecCo methodology which was funded by the European Union (EU) does not focus on environmental or social aspect of sustainability but instead aims at detecting opportunities for innovation by creating IPS² opportunities [4]. The BISS methodology focuses on constructing business models such that the created IPS² inherently induce sustainability. None of the methodologies focus on Design Reviews. Design Reviews apart from their customary purpose of reviewing the development of each project stage must also ensure that all the gate criteria associated with IPS² are fulfilled. Mueller [5] has developed an IPS² "Layer Method" which can be applied mainly in early development phases. The purpose of the Layer Method is to support the clarification of the design tasks as well as the conceptual design phase based on the terminology of Pahl et al [6]. This approach is used to analyse and synthesise IPS² ideas and concepts.

1.2 Sequenced stages in IPS² development

Arnold Tukker and Ursula Tischner [4] have formulated a practical guideline to IPS² development in the frame of the SusProNet project based on extensive practical research. The guideline guides the IPS² team by providing systematic methodical approach to IPS² development. Design Reviews in IPS² are based on this guideline wherein reviews are introduced at key milestones and quality gates of the IPS² development. These 5 key stages in IPS² development are:

1 preparation and introduction;
2 analysis on PSS opportunities;
3 IPS² idea generation;
4 IPS² design;
5 make implementation plan.

The overall approach of IPS² development is shown in Figure 1. In the preparation and introduction stage, the project initiator starts the project and sets up the project team. A workshop is conducted and experts from various departments like R&D, product design and marketing are invited. The IPS² project is given a title and the project charter is developed. Team members are assigned suitable responsibilities. Project start date and anticipatory end date are also established.

In the second stage, the team selects priority need areas that are most interesting to carry out the IPS² project. The existing system is analysed by SWOT analysis and possible windows of opportunities for IPS² are identified. The project team then defines relevant market segments and underlying client needs for the specified segment. Starting with the end user, a system map is established by adding main stakeholders and by sketching the flows and relationship between them. The potential problems and opportunities in the system map are identified and decision is taken whether the drafted IPS² development is feasible or not.

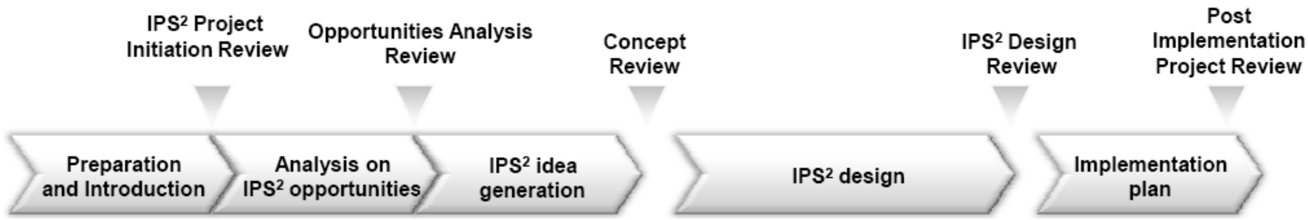

Figure 1 : Overall approach of IPS². [4]

In IPS² Idea generation stage, the team organises a one day workshop in which IPS² ideas are developed by considering underlying client needs and system SWOT report from the previous stage. After a detailed check the ideas are screened for their sustainability potential. The most promising ideas are scored regarding market/ financial potential and capability risks. Based upon the quality of these ideas, decisions are taken to proceed to the next step.

In IPS² design stage, the new PS System structure is formulated by making use of sustainability guidelines. Decision on make or buy is made for external development, production or provision. Furthermore the stakeholder‟s motivation matrix is developed showing all the partners, their contributions and benefits from the partnership. Finally the decision about proceeding to the next stage is taken.

In the final stage, the project team organises a workshop to specify implementation issues. This phase finishes with a summary of the business plan.

2 DESIGN REVIEWS

2.1 Introduction to Design Reviews

Design Reviews (DR) can be considered as a type or subset of Project Reviews or Gate Reviews applicable to the product development phase. The primary purpose of Project Review is to keep people informed of reality by providing clear and independently validated information to project stakeholders. Reviews help people to prevent cognitive biases and information bottlenecks [7].

Design Reviews (DR) as an important step in product development process are used throughout the product development process to evaluate the design in terms of costs, quality and delivery- They also help to ensure that most suitable knowledge and technology are incorporated into the design as well as to resolve possible problems instead of passing them downstream. [8]; [9]. Any product or process weaknesses, errors and problems are to be identified during DR. Experts from various departments work together to improve the design efficiency and design time ensuring product quality and minimising costs. Thus, the knowledge and technology are best used from both in-house and external sources. Design Reviews are a mandatory requirement according to the ISO9000 quality standard [11] to verify design at the end of each design output stage of the product development process.

According to Takashi Ichida and Edward C. Voigt [10], reviews follow this basic pattern:

- collecting and compiling information;
- defining quality targets;
- evaluating product and process designs and supporting operations;
- proposing improvements;
- defining subsequent actions;
- confirming readiness for the next stage.

2.2 Different Types of Design Reviews

There are two types of Design Reviews based upon their degree of formality in their implementation [9]. Formal Design Reviews (FDR) are reviews for which companies have standard policies and procedures. Each review is a key event in the process of product development and production planning. The development schedule clearly shows designated days for DR within each development phase. The responsible carry them out thoroughly, particularly at the transition from phase to phase. FDR are essential for consistent quality results. On the contrary, Informal Design Reviews (IDR) are prepared and conducted by individual design reviewers. IDR is used only as needed, for example if special issues arise and its effectiveness can vary greatly. It is a review that can be incorporated into any planning and design step as time and resources allow.

2.3 Review schedules

According to ISO 9000 [11], the schedule of Design Reviews is established for every developed product or service. The design is reviewed at some or all of the following intervals depending on the complexity of the design and on the risks involved.

Design Requirement Review – to assure the feasibility of the design requirements and to reflect the needs of the customer before starting the design phase.

Conceptual Design Review – to establish that the design concept fulfils the requirements before project definition commences.

Preliminary Design Review – to establish that all risks have been resolved and development specifications have been for each part of the product or service before beginning detailed design activities.

Critical Design Review – to secure the compliance of product or service parts with its development specification. The critical Design Review also helps to make sure that product specifications have been prepared before prototypes are manufactured.

Qualification Readiness Review – to establish the configuration of the baseline design and readiness for qualification before commencement of design proving.

Final Design Review – to establish that the design fulfils the requirements of the development specification before preparation for its production.

2.4 Service Design Reviews

Currently, there is no standard literature which focuses on Design Reviews in service context. ISO 9000 [11] describes a generic Design Review which is applicable for both product and services. A typical flowchart for the service design process is shown in Figure 2. Service reviews are incorporated at the requirement stage, conceptual design stage and detailed design stage.

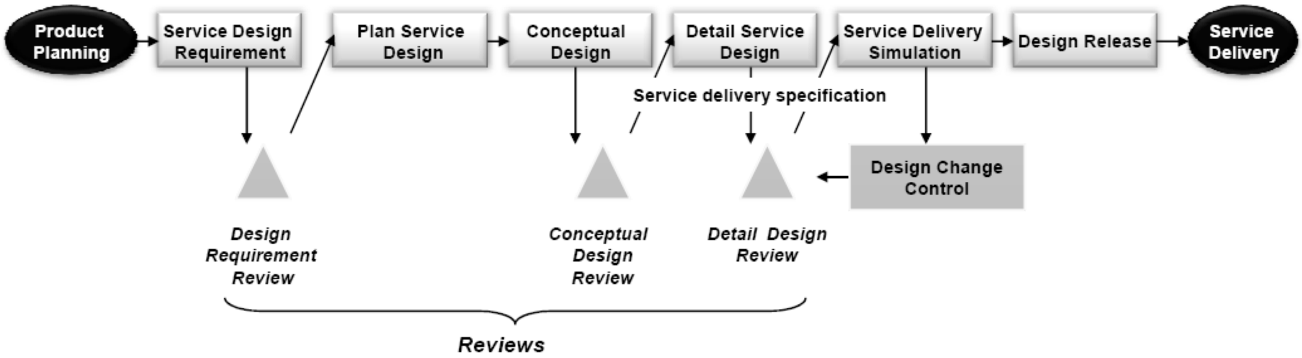

Figure 2 : Reviews in service design process. [11]

3 IPS² REVIEW PROCESSES

3.1 IPS² Development stages

The generic product development consists of following stages as shown in Figure 3. The Review process is conducted in the form of gate reviews at the end of each stage. Thus, the risks associated with the development process are effectively managed. Furthermore, it provides a systematic guideline for holding effective gate review meetings. Usually stage gate systems involve four to seven stages and gates depending upon the company or division [12]. IPS² development stages based on practical guideline to IPS² development developed by Arnold Tukker and Ursula Tischner [4] have already been shown in Figure 1. Gates at which Design Reviews are introduced in IPS² are established by comparing normal product development stages with IPS² development stages. Thus, IPS² Project Initiation Review, Opportunities Analysis Review, Concept Review, Preliminary Design Review, Specification Review, Final Design Review and Post Implementation Project Review forms the reviews at corresponding gates.

3.2 Assessment criteria for IPS² Design Reviews

During the course of the project, the IPS² development team may uncover potential problems that threaten the project‟s viability. This may result in serious changes in project charter or in the cancellation of the project. In order to determine unattractive projects as early as possible and prevent from pursuing them further, the project is assessed against the relevant gate criteria. As a part of the Gate Review, project members are required to give an update on these criteria. Furthermore, defining gate criteria simplifies the review process and provides methodical approach to the reviewers.

The fundamental idea of assessing a project at each gate is to ascertain whether the stage confirms to the gate criteria. In IPS² context, the following criteria have to be defined:

- sustainability;
- product and service delivery;
- value addition;
- financial return;
- strategic alignment

These criteria apply to each gate with varying degree. The explanation to these criteria is as follows:

Sustainability: The sustainability factor as per [4]; [13]; [14]; [15] is defined based on the magnitude of environmental impact reductions. Therefore, it is ecologic sustainability only and not taking into account economic and social sustainability elements. They are classified as mechanism leading to average, average to high and very high impact reductions. The activities and decision taken at various stages of IPS² development may have profound influence on the sustainability of the delivered IPS². Thus, it is very important to determine the influence of various stages on sustainability. Design Reviews with sustainability elements ensure that sustainability factors

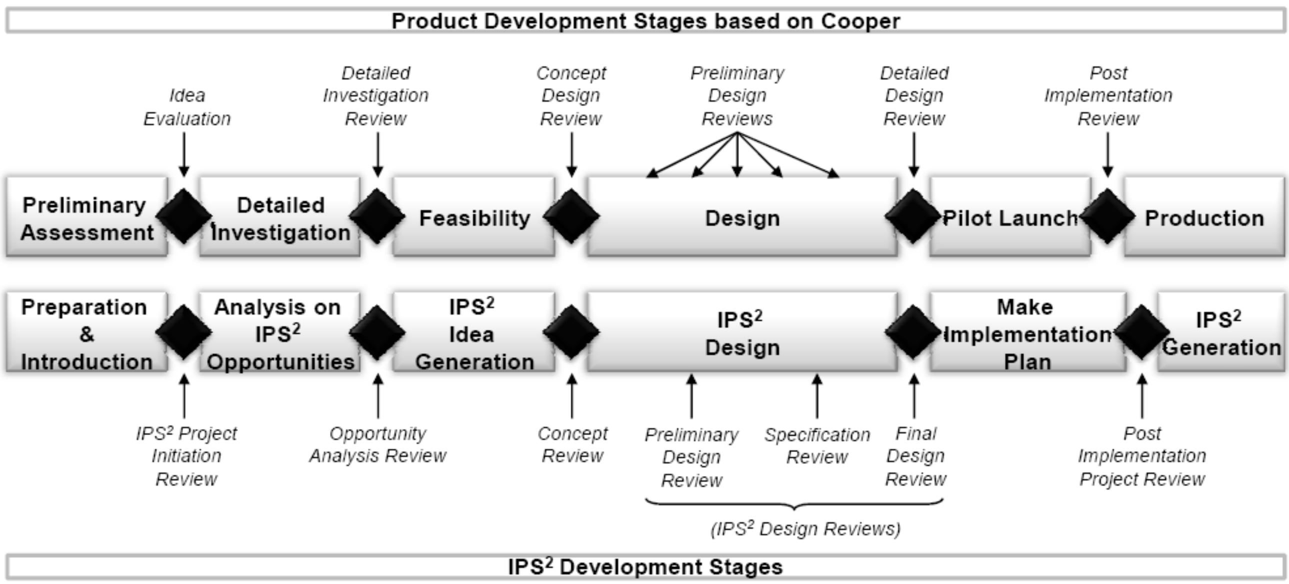

Figure 3: PSS development stages based on Cooper. [12]

are given due consideration at each stage.

Product and Service delivery: Design Reviews in IPS² context ensure stepwise determination of product and service deliveries. Proper allocation of products and services before they are designed allows partial substitution of product and service components in order to deliver more value to the customer [3]. The purpose of considering product and service deliveries in the Design Review process is to ensure that the design and development of products and the provision of services are planned, reviewed and verified to statutory functions and that requirements of the customers are met [16]. Therefore, the following is necessary:

- Customer needs are determined and reviewed.
- The scope of the products and services has to be clearly understood by the IPS² provider.
- Product and project plans have to be developed, communicated and followed.
- Roles and responsibilities have to be clearly defined;
- Where practical and appropriate, consultation and feedback processes have to be undertaken during planning and verification phases.
- Records have to be kept to demonstrate the planning, development and verification of the IPS² in accordance with the defined processes.

Value addition: The major incentive offered by the organisations to customers through IPS² is value addition. The ability to create and capture sustained added value is often seen as the key measure of success in business [17]. Moreover, the customer‟s willingness to invest in IPS² or preference over comparable competing offers is dependent upon the overall value of the IPS². The customer will only decide to adopt an IPS² if the overall value of an IPS² is positive and higher than that of competing offers [18]. According to Arnold Tukker [17] value addition elements are distinguished as:

- tangible and intangible value;
- an assessment whether intangible value to the customer through servicing outweighs the additional costs borne by the producer;
- an assessment whether investment and capital needs for the IPS² generation is justified and
- the ability to capture present value in the value chain, now and in the future.

Financial Return: Cost Accounting in the early development phase of IPS² helps the development processes in solving decision related problems [18]. Costs incurred in the future have to be adjusted to market conditions to ensure sound investments. Traditional costing methods determine costs for short term only. But life cycle oriented characteristics of IPS² with a payment oriented view on costs and revenues necessitate a strategic planning of costs with long term focus. Target costing in IPS² focusing on long term promises to solve this problem by enabling life cycle optimisation of the balance between costs and revenues. Assessing an IPS² concept therefore needs to be based on the Net Present Value (NPV) of costs and revenues [19]. The advantage of this approach is that the primary decision and payment interdependencies through the IPS² life cycle analysis are revealed. This is especially important with regard to interactions of products and downstream services and the payments connected to them. Managing the costs incurred over the entire IPS² life cycle is essential to decide whether the supplier aims at gaining profit mainly through servicing or by investing into reliability of the product during IPS² conception.

Strategic Alignment: Before considering IPS², it is imperative to know if IPS² fits company‟s product line and business strategy. In order to balance both the customer‟s and the organisation‟s perspective, corporate structure drivers and customer process drivers are defined [19]. Corporate structure drivers are customer‟s know-how, resources and organization strategy. Customer process drivers include processes which are significant for the customer‟s value creation and the frequency in which they occur.

Customers with high a level of know how tend to choose more complex solutions than the latter. Hence an increase in knowledge can be ascribed to choosing automatic rather than manual execution of processes. Similarly, customers with high liquid capital rather tend to choose the automation of processes whereas companies with high labour capital tend to choose the manual execution of processes. Based upon management strategy, organisations can be classified regarding their focus on core competencies. Depending upon core competencies, organisations can decide whether to make or buy. Likewise, organisations can be also categorically distinguished based on their inclination to executing a value based management approach.

3.3 Review processes against gate criteria

Figure 4 shows how the project is assessed against gate criteria in between two stages of product development. These criteria are checked at all review stages to determine whether the project adheres to the fundamental IPS² idea while being economically viable to the companies. The relevance of these criteria may vary with the review stage and the type of IPS². To ensure that these criteria are given adequate consideration throughout the IPS² development process, they are structured as mandatory requirements in Design Reviews. By reviewing through these criteria, companies can be guaranteed that they are not deviating from the main focus of the project and also assist them in deciding whether to proceed with the project or not.

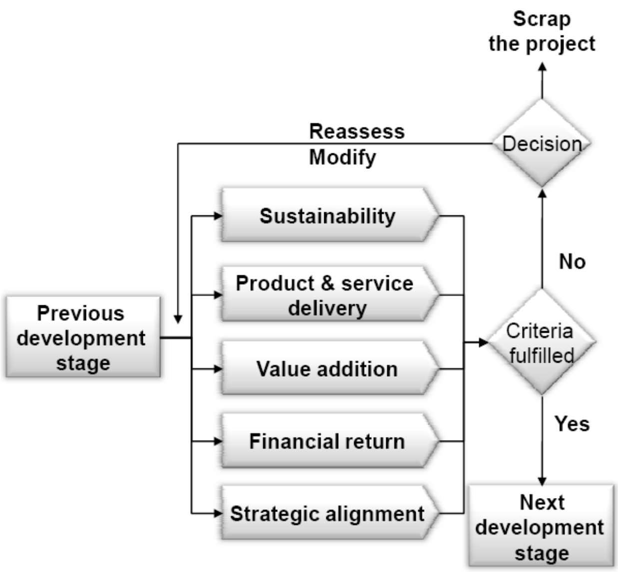

Figure 4: Assessment of the stages against the criteria.

Table 1 shows the relevance of these criteria on Reviews at various stages. The importance of the criteria at each Gate Review is specified on a generic level. The management can thus decide and make suitable amendments to the table to suit their business and management strategy. E.g. companies intending to offer IPS² to the customer by delivering more service options without focusing on sustainability can assign more value

Table 1: Gate criteria at various review stages.

Review type	*IPS² Project Initiation Review*	*Opportunities Analysis Review*	*Concept Review*	*IPS² Design Review*	*Post Implementation Project Review*
Sustainability	Preliminary assessment to ascertain whether the IPS² solution can be made sustainable or not.	The existing system has to be evaluated using SWOT analysis for its sustainable dimension based on factors like Material efficiency, Energy efficiency, Toxics and Environmental risks, Waste Minimisation, reuse, recycling, Transportation and mobility efficiency.	The proposed IPS² has to be assessed for its sustainable dimension based on factors like Material efficiency, Energy efficiency, Toxics and Environmental risks, Waste Minimisation, reuse, recycling, Transportation and mobility efficiency.	Detailed design must have used sustainability guidelines proposed by Suspronet [4].	Assessment to ascertain the degree to which IPS² is sustainable.
Product and Service delivery	Preliminary identification of product and service delivery concepts.	The existing system must be evaluated for product and service deliveries.	Integrating product and service delivery based on Heterogeneous modelling approach [3].	Integrated product and service modelling using any approach.	Description of product and service in the final management report.
Value addition	Preliminary assessment of customer needs based on market research; preliminary assessment of competitive solutions and opportunity for differentiation.	Benchmarking competitors. Generate product and service requirements based on voice of customer. Compelling value proposition established.	Update to product and service requirements. Assessment of ability of IPS² to meet customer requirements.	Confirmation of fulfilment of value addition elements in Detailed Design to those planned in conceptual stage.	Assessment to ascertain whether planned value addition elements are attained.
Financial Return	Preliminary estimation of the project's viabilty in financial terms. Break even analysis and Net Present Value can be used.	The existing system has to be evaluated using SWOT analysis for its economic dimension based on factors like market position and competitiveness, profitability, long term business development risk, partnership, cooperation, macro-economic effect and market influence.	The proposed IPS² solution has to be compared with existing system based on profitability of provider and customer, savings in time, material use etc. Target costing has to be established. Assessment should be made regarding likelihood of achieving target costs.	Assessment to confirm whether projected costs at concept stage do not exceed target costs.	Assessment to confirm whether costs at implementation stage are below target costs.
Strategic Alignment	Assessment of strategic fit between company's business focus and core competencies. Preliminary justification of resource allotment to the project.	Update on the previous gate regarding assessment of strategic fit and justification of resource allocation.		Decision to make or buy and selection of partners.	

to the product and service criteria than to the sustainability criteria.

As there are numerous methodologies focusing upon service development and IPS² development, companies can choose any methodology for designing the IPS² based upon their requirement. The developed review methodology is still applicable irrespective of the design methodology employed by the company.

3.4 Review processes in IPS²

Design Reviews in this work are inspired by Arnold Tukker and Ursula Tischner‟s practical guideline to IPS² development. Even if classic Engineering Design Reviews are not only focused on reviewing individual criteria sets, this goal is even more eclipsed in IPS² reviews. Keeping aligment on delivering the target values of IPS² delivery between the different stakeholders during the development, issue escalation, design compromises, the creation of task forces were needed and the steering of operational execution of design amongst all partners, including the new partners such as clients, service members and so on, is more in the focus here and is even more difficult into the bargain. All those issues are subject matter of any IPS² review and are therefore not mentioned as specific goals for single review types.

In order to identify the importance of Design Reviews on their underlying stages, it is imperative to understand the basic activities of the corresponding stages. The Reviews identified based on this guideline are:

- IPS² Project Initiation Review;
- Opportunities Analysis review;
- Concept Review;
- IPS² Design Review;
- Post Implementation Project Review.

In subsequent sections each review process is explained by describing the activities of the respective stage, entry requirements for the review process, tools used, deliverables and participants of the review process. Entry requirements refer to the possible documentation that is required before the start of the review process. Criteria checklist is a report confirming that all the criteria that are listed in section 3.2 are fulfilled. The major difference between the IPS² reviews with the conventional reviews is the participation of customers and the provision or commissioning department. Although the participation is not listed as mandatory in the individual review stages, they can still take part actively based on the IPS² requirements.

3.5 IPS² Project Initiation Reviews

The IPS² Project Initiation Reviews correspond to the “Preparation and Introduction” stage. The major activities in this stage are planning the project, setting up the project plan and familiarising team members with IPS² concepts. The Initiator starts the project and sets up the project team. A project charter is developed by deciding an IPS² project title. Appropriate responsibilities are assigned to the team members. The project start date and anticipatory project end are also established. Normal project planning tools can be used during this stage. A workshop is conducted to educate the team members about the benefits of the IPS². The project definition is the mandatory entry requirement to the IPS² Project Initiation Review.

Goals: The primary goal of IPS² Project Initiation Reviews is to secure that all team members and stakeholders are familiar with the concept of IPS² in general. *:* It has to be ensured, that the project charter for the pre-design phases is fully developed and all responsibilities are assigned. The reporting structure has to be reviewed concerning the deliverables of project stakeholders. This sets the kick off for IPS² opportunity analysis.

Deliverables: Project/ program/team charter, program requirements/ deliverables, budget approval, project timing, quality goals (if applicable), project tracking, a record of workshop held for familiarising team with IPS² concepts, criteria checklist are the deliverables of the review process. The criteria checklist ensures that factors such as sustainability, product and service delivery, value addition, financial return and strategic alignment are reviewed at this stage.

Participants: The participants required for the review process are the planning team, departments responsible for controlling, project management, product and service development as well as the customers.

3.6 Opportunities Analysis Reviews

The Opportunities Analysis Reviews correspond to the “Analysis on IPS² opportunities” stage. The major activities in this stage are selecting priority need areas, analysis of the existing system, analysing client needs, drafting system map and finally making decisions regarding the continuation of the project. Using priority setting matrix, the need areas are selected by the project team. Then, system SWOT is carried out for the current and future situation in the need area and key problems, drivers for change, and windows of IPS² opportunities are identified in the system. Economic, environmental and social inefficiencies are also identified during this process. For the selected area, relevant market segments and their underlying client needs are identified by the project team. The system map of the current system showing various actors and activities, financial flows, information, important problems and opportunities is drafted. In the end, the project team decides on the continuation of the project. The project charter is the mandatory entry requirement to the Opportunities Analysis Review.

Goals: In the Opportunities Analysis Review the analysis of needs of the customer has to be reviewed. Furthermore, the SWOT analysis report and the market analysis have to be verified. In the end there is a go or no-go decision for the next stage.

Deliverables: Priority matrix, 5 why analysis report, CT trees or QFD, SWOT report with environmental, socio-dimensional and economical dimension, system maps, information flow diagram, process flow diagram, decision sheet and criteria checklist are the deliverables of the review process.

Participants: The participants required for the review process are the planning team, marketing, departments responsible for controlling as well as the product and service development.

3.7 Concept Reviews

The Concept Reviews correspond to the “IPS² Idea Generation” stage. The major activities in this stage are generating IPS² ideas, checking the completeness of generated ideas, describing ideas, selecting priority ideas and finally making decisions regarding the continuation of the project. This stage is conducted as a one day workshop. At the start IPS² ideas are developed by taking underlying client needs and the system SWOT. Creativity tools like brainstorming, sustainability guidelines and consumption cycle analysis can be used. Using IPS² innovation matrix, the team performs a check if the most relevant ideas have been generated. Then the ideas are described in a one page IPS² description format. Using IPS² sustainability screen, the ideas are screened for their sustainability potential (economic, environmental and social). The ideas are filled into the portfolio diagram to select the most promising ones. IPS² ideas are scored against market/financial potential and the final decision is taken regarding the continuation of the project. The stage 2 decision sheet is the mandatory entry requirement of the Idea Generation Review.

Goals: The generated conceptualised IPS² solutions should be consolidated to one single concept of the IPS² that shall be designed. Therefore, the concept has to be verified and validated with the customer.

Deliverables: Brainstorming records, IPS² innovation matrix, IPS² description format, IPS² sustainability screen, portfolio diagram, Go/ no-Go scoring system, criteria checklist are the deliverables of the review process.

Participants: The participants required for the review process are the planning team, departments responsible for controlling, product and service development as well as the project management and the customer.

3.8 Preliminary Design Reviews

The Preliminary Design Reviews correspond to the “Concepts and preliminary design for subsystems” stage.

Goals: In the Preliminary Design Review, the preliminary design has to be verified for its robustness and quality. The approval from change engineering department has to be reviewed in case of any design changes.

Deliverables: Deliverables are Design Tools, Go/no-Go evaluation criteria and criteria checklists.

Participants: The participants required for this review process are the planning team, departments responsible for controlling, product and service development as well as the project management.

3.9 Specification Reviews

The Specification Reviews correspond to the “Specification of product, service and IPS² modules”.

Goals: In the Specification Review, the specification of the product, service and IPS² modules have to be verified. The approval from change engineering department has to be reviewed in case of any design changes.

Deliverables: Design tools, specification standards, Go/no-Go evaluation criteria and criteria checklists are the deliverables of the review process.

Participants: As participants for the review process, the planning team, the departments responsible for controlling, product and service development as well as the project management are required.

3.10 IPS² Final Design Reviews

The IPS² Design Reviews correspond to the "IPS² design" stage. The major activities in this stage are concluding design, deciding on make or buy issues, selecting additional partners where needed and finally making decisions regarding the continuation of the project. The new IPS² system structure is worked out and the detailed design of the system is carried. Sustainability guidelines can be used in design process. System map is developed by mapping activities and material flows, information flows and financial flows. The decision regarding make or buy is taken and potential partners are identified for the elements not produced by the own firm. The assessment about how to proceed is made and implementation plan is formulated. The stage 3 decision sheet is the mandatory entry requirement of the Detailed Design Review.

Goals: Goals of the Design Review are to verify the IPS² products and services as well as the dependencies between them on a technical level. Decisions on make-or-buy, manufacturing location and service partners have to be taken. The final business model as well as first contract drafts have to be verified and validated too.

Deliverables: Solution element brief, make buy decision sheet, stakeholder motivation matrix, Go/ no-Go evaluation criteria, criteria checklist are the deliverables of the review process.

Participants: The participants required for the review process are the planning team, departments responsible for controlling, product and service development as well as the project management.

3.11 Post Implementation Project Reviews

The Post Implementation Project Review corresponds to the "Develop implementation plan" stage. The major activities in this stage are defining implementation issues and summarising management presentation. A workshop is organised by the project team to specify implementation issues. The stage ends with a business plan and presentation which summarises the project. The stage 4 decision sheet is the mandatory entry requirement of the Post Implementation Project Review.

Goals: The concrete implementation of the IPS² has to be reviewed in this process. All documentations for the manufacturing and provision processes have to be completed and reviewed. The milestones for the start of production and provision have to be determined in a decision by consensus of all stakeholders, especially the producers, customer and service providers.

Deliverables: Standard management presentation, criteria checklist are the deliverables of the review process.

Participants: The participants required for the review process are the planning team, departments responsible for controlling, product and service development as well as the project management. Furthermore, the production manager, the service provider and the customer have to be present.

3.12 Draft of IPS² development process

The milestone based reviews can be applicable to Mueller‟s draft of IPS² development process also. Figure 5 shows the synergies between Tukker‟s and Mueller‟s approach to IPS² development. In Contrast to the Tukker methodology which focuses extensively on the stages prior to the design, Mueller‟s methodology mainly deals with the design phase. Furthermore, Mueller‟s development stages ranging from the preliminary design to the final design of IPS² can be clustered under Tukker‟s IPS² design stage. Therefore, IPS² Design Review comprises of the following reviews:

- Preliminary Design review;
- Specification Review;
- Final Design Review.

The gate criteria are applicable to these design stages. The relevance of the gate criteria is comparatively higher than in the preceding reviews.

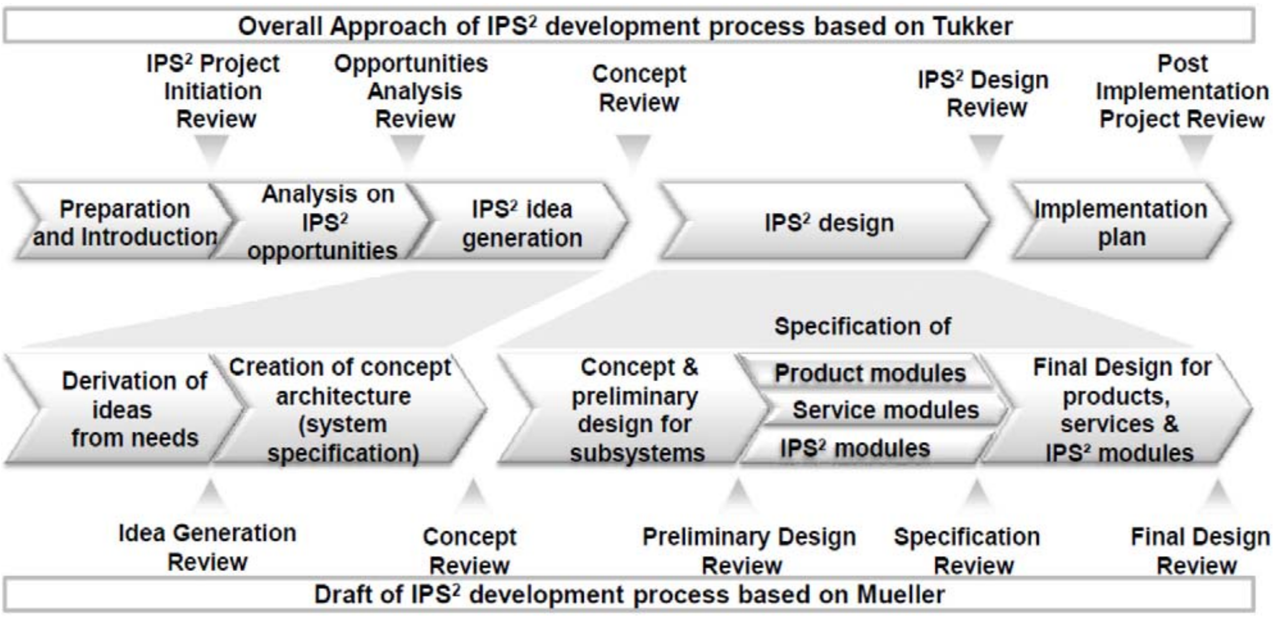

Figure 5: Reviews in IPS² development.

4 OPEN ISSUES AND FURTHER RESEARCH

This Paper has so far addressed the development of an IPS² Project and Design Review guideline for including reviews in the IPS² project milestone schedule. It has intentionally not yet elaborated on the Design Review process itself, therefore, it is a lot about "what" and not very much about "how". This is going to be the next step in our research work. An incomplete list of open questions shows the complexity of issues still to solve in this context:

- How can the stage of IPS² development be verified?
- What are the dependencies between product and service components in IPS² development and how do they influence the business model, the IPS² provider consortium or single stakeholders" interests?
- How can these very dependencies be taken into account when decisions are made?
- How can the complex interdependencies of products and processes in IPS² be brought down to a level where stakeholders from different areas of expertise can have a discussion that is still valuable enough to make robust and sustainable decisions?
- How can experiences from the IPS² provision phase be incorporated in further developments?
- How can a roles and responsibilities concept for the different Design Review types look like?
- What are the necessary actions for effectively and efficiently preparing, carrying out and reinforcing IPS² Design Reviews?
- How can IPS² Design Review processes be computer aided without overstraining the stakeholders with elaborate user interfaces?
- What functionalities are necessary for such a system to provide essential assistance to the Design Review process?
- Is the Design Review still a scenario for the future or might it be replaced by the long predicted collaboration workspace where everybody is working and developing with the very same model all the time?

Those open questions have been focussed on in our current research work. First results are already in sight.

5 CONCLUSION

This work gives a generic guideline to the implementation of Design Reviews during IPS² development. This guideline is applicable to any IPS² development irrespective of the development methodology used. As this work is a first step towards installing IPS² Reviews as a core process step in IPS² development, there is ample scope for further research. As Design Reviews are directly dependant on product development processes, it is essential to have a common IPS² development methodology which can be universally used. Further work in this regard could be directed at developing specific review methodologies for specific types of IPS². Web based reviews are currently very popular in Software Design Reviews. Developing similar web based solution for IPS² Design Reviews could also be a worthwhile proposition for the companies providing IPS².

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Meier, H., Uhlmann, E., Kortmann, D., 2005, Hybride Leistungsbündel- Nutzenorientiertes Produktverständnis durch interferierende Sach- und Dienstleistungen, wt Werkstattstechnik online, 07/2005, Springer-VDI-Verlag, ISSN 1436-4980.

[2] Müller, P., Blessing, L., 2007, Development of Product-Service Systems, Comparison of product and service development process models, Engineering Design and Methodology, University of Technology, Berlin.

[3] Welp, E.G., Sadek, T., 2008, Conceptual Design of Industrial Product Service Systems (IPS²). Based on the extended heterogenous modelling approach. International Design Conference-Design Dubrovnik, Croatia.

[4] Tukker, A., 2004, New-business for old Europe, Product-Service development as a means to enhance competitiveness and eco-efficiency, Final Report of Suspronet.

[5] Mueller, P., Kebir, N., Stark, R., Blessing, L., PSS Layer Method- Application to Microenergy Systems.

[6] Pahl, G., Beitz, W., Feldhusen, J., Grote, K., 2007, Engineering Design – A Systematic Approach, Third Edition, Springer-Verlag, London.

[7] Oakes, G., 2008, Project Reviews, Assurance and governance, Gower Publishing, Aldershot, UK.

[8] Voigt, E.C.,1996, Product design review, a method for error-free product development, Productivity Press, Portland, Oregon.

[9] Dhillon, B.S., 1996, Engineering Design: A Modern Approach, Irwin, R. D., a Time Mirror Higher Education Group, Inc. Company.

[10] Ichida, I., Voigt, E.C., 1989, Product design review, Productivity Press, Portland, US.

[11] Hoyle, D., 2008, ISO 9000 Quality Systems Handbook - updated for the ISO 9001:2008 standard: Using the standards as a framework for business improvement.

[12] Cooper, R. G., 1990, Stage Gate Systems: A new tool for managing new products, in: Business Horizons, 4(33) 1990, Elsevier, pp. 44-54.

[13] Manzini, E., 2002, Sustainable Solutions, New Business Ideas and New Ideas on Business, working paper, INDCAO, CIR.IS, Politecnico di Milano.

[14] McDonough, W., Braungart, M., 2001, The next industrial revolution, In *Sustainable Solutions*, Charter M, Tischner,U (eds),. Greenleaf: Sheffield.

[15] Zaring, O. (ed.), 2001, Creating Eco-Efficient Producer Services, Report of an EU project, Gothenburg Research Institute, Gothenburg.

[16] Port of Townsville Limited, 2006, Product & Service Delivery process.

[17] Tukker, A., 2004, Business Strategy and the Environment, Published online in Wiley Interscience.

[18] Karger, M., Richter, A., Sadek, T., Strotmann, W.C., Flexibility of Industrial Product Service Systems – An Assessment Based on Concept Modelling. 3rd Annual Conference on Business Market Management, St. Gallen, 2008

[19] Rese, M., Strotmann, W.C., Karger, M., Which Industrial Product Service System fits best? Ruhr-University Bochum, Marketing Department, Bochum.

Session 4B:
Resource Management

Structural Model of Resources in Product Service Systems - A Prerequisite to Portfolio Design and Planning

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Abstract

Industrial companies face tremendous challenges to plan the resources needed to meet future market demands when implementing a PSS based solution portfolio. This paper deals with enhancing the PSS research landscape by presenting an approach to enable better resource-planning in PSS based businesses. In particular, a model is proposed which links resource structures with customer offerings. Linkages are implemented, which connect resources and their use in processes. The model contributes to better understand the complexity in resource structures and elements in the PSS and helps to better understand and describe the structural integration of resources in PSS. This is an important prerequisite for the planning of PSS and allows a qualitative and quantitative description of the service resources allocation enabling companies to build the competence needed to meet customer requirements. A case study based approach was applied for model development.

Keywords

Industrial Product Service System, PSS Resources Structure, Design and Planning of PSS

1 INTRODUCTION

PSS become more and more important to European companies in business to business relationships in order to differentiate from competitors and to get customer loyalty by delivering value in use to the customer [2, 12]. In times of a world wide economical crisis as we currently face the PSS concept turns out to be a sustainable strategy ensuring constant turnover and high margins [22].

While companies are changing from technology providers to solution suppliers their service portfolio is enlarged by highly individualised, customer supporting services. At the same time service business is still characterised by an intense market growth especially in new markets as the wind energy sector.

These trends face companies with tremendous challenges when implementing a PSS based solution portfolio. PSS are mostly complex architectures with different layers of design. Offering customized solutions to the customer therefore requires a systematic design of the product-service-portfolio as well as a systematic planning of the resources needed to meet future market demands.

Since service engineering has more and more established as an important research discipline much attention has been paid on concepts addressing a systematic design of services and PSS. But these concepts do not deal with the planning of service resources respectively PSS resources. This is remarkable because in the well established field of physical product development the production planning became an elemental part of the product development process and was especially discussed in the context of simultaneous engineering [21].

Companies suffer from a lack of concepts which allow them to pan their PSS resources and thereby to ensure a high resource availability and efficiency. When companies face the question which PSS resources have to be build up and in what extent to hit market demand and to guarantee performance readiness, companies have to act intuitively missing conceptual support.

This paper deals with enhancing the PSS research landscape by presenting an approach to enable better resource-planning in PSS based businesses. The model contributes to a better understanding of the complexity in resource structures and elements in the PSS. Moreover it describes the structural integration of resources in PSS. This is an important prerequisite of the PSS planning and allows a qualitative and quantitative description of the service resources allocation enabling companies to build the competence needed to meet customer requirements.

2 RESOURCE PLANNING PERSPECTIVE ON PSS

In the scientific community PSS are extensively discussed as “Solution Systems”. Belz has first introduced the term Solution System to describe the integrative character of the solution delivered [2].

The underlying strategy of Solution Systems as illustrated in Figure 1 is to substitute the subsequent and single offerings by integrated value adding solutions which lead to lasting relationships to closely link providers and customers on an emotional level [14].

The Solution System concept takes a marketing dominant perspective on PSS as one possible variant out of many. The resource planning perspective on PSS as described in the following is in line with the Solution System perspective and bases upon the System Theory.

In the System Theory a system is defined as a mental framework consisting of elements, the relations between these elements and environmental boundaries [3]. Accordingly a PSS is an integrated combination of products and services as illustrated in Figure 2.

As shown in Figure 2 a PSS is configured by different tangibles such as capital goods, spare parts and intangibles such as repair services, remote services, joint project management and others [19]. *Relationality* (meaning a high number of system element relations) and *Integrativity* (meaning a high degree of integration of the different system elements) are constitutive characteristics of PSS [1, 10]. These characteristics as well as the fact

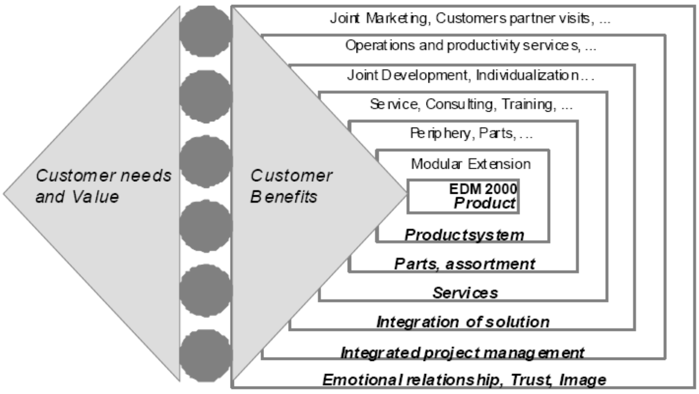

Figure 1: Solution system to deliver value to the customer (Source: [2, 14]).

that companies offer different PSS for different customers cause a system inherent complexity. This complexity is constituted in the product structure of PSS and challenges the resource planning.

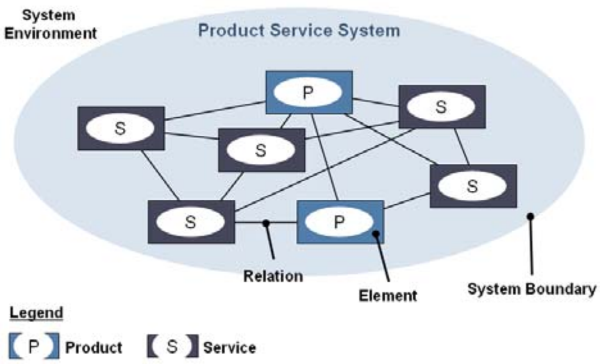

Figure 4: PSS according to System Theory.

Analogous to the Material Requirement Planning (MRP) of physical goods, information on the product structure is a basic input for PSS resource planning [17]. Thinking about the product structure of PSS, it has to be made clear that a major difference between resource planning of physical goods and the resource planning of PSS arises from the fact that service are also system elements of PSS and therefore part of the PSS product structure.

Physical products as the result of production process emerge on an output layer. Their product structure only contains consumption factors as production process input for instance modules, assemblies and devices. The production process with its non-consumable resources is out of the product structure's scope. But services as intangible goods also include a process and resource layer as part of the service itself in addition to the output respectively result layer as shown in Figure 3 [20].

For that reason the production process, consumption factors and non-consumable resources are part of the PSS product structure.

As a consequence the existing approaches and models to describe the usage of resources in products (e.g. in the field of production planning respectively the Material Requirement Planning) are not applicable to PSS resource planning. Therefore a new methodical approach is required which takes service characteristics into account and helps companies to build up performance readiness harmonized with market demand.

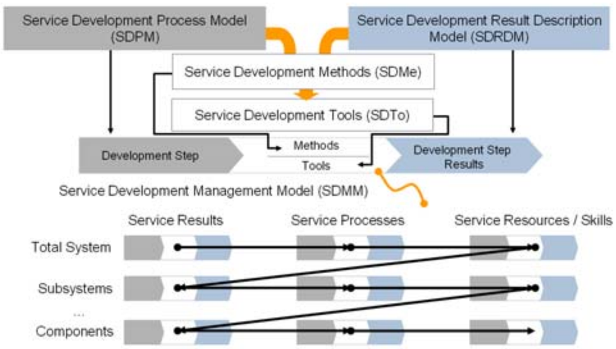

Figure 3: Architecture for service engineering - essential components and service-layers [Source: [20])

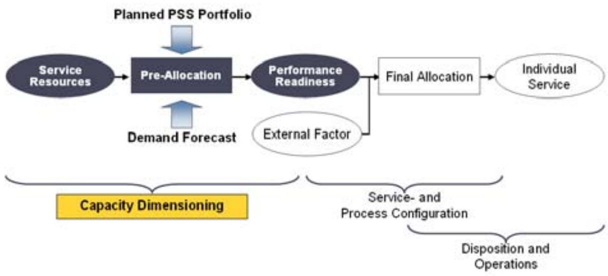

Figure 4: Service Production Process (Source: [4])

Such an approach can be located in the field of middle term resource planning. In this context an adequate resource capacity dimensioning is crucial to build up performance readiness by pre-allocating service resources as shown in Figure 4. Dimensioning the resource capacity of PSS implicates the determination of PSS production resources according to type, extent and structure.

3 STRUCTURAL MODEL DESCRIBING THE USAGE OF RESOURCES IN PSS

Planning PSS resources requires frameworks and methods which help to describe the product structure of PSS and especially the way how resources are integrated in the PSS product structure. Information on the usage of resources is considered to be crucial for an adequate PSS resource planning. It enables companies to break down demand forecast for customer solutions into resource demand and to pre-allocate service resources in an efficient way. Similar to the product structuring methods well-known from the middle term production resource

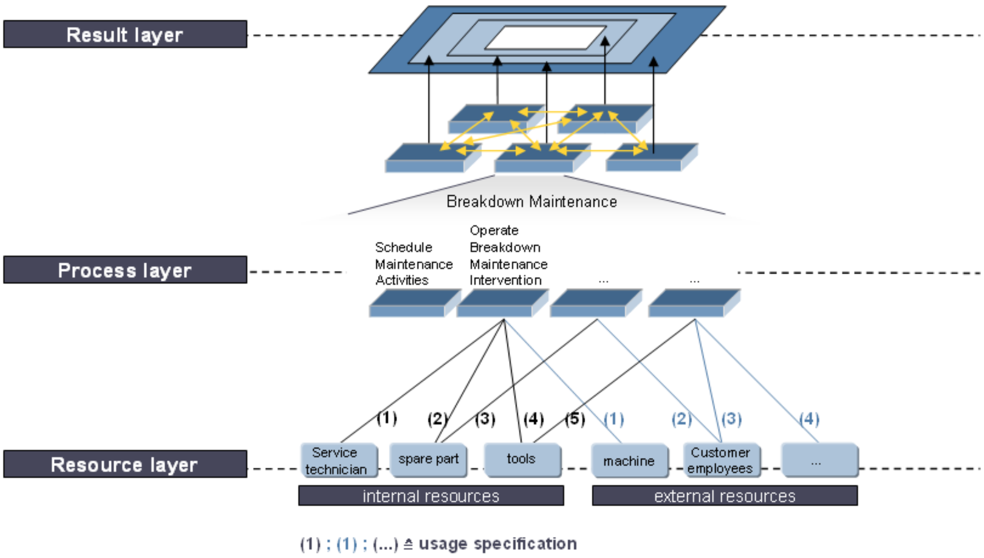

Figure 5: Structural model: usage of resources in PSS

planning a structural model for the description of the usage of resources in PSS is introduced here as an initial starting point to plan PSS resource. The model's main contribution to an adequate resource capacity dimensioning arises from describing the product structure of service resources according to a where-used list of physical goods. This model as illustrated in Figure 5 comprises three different structure-layers according to the service engineering architecture as described before.

The result layer contains the customer individual solution offered by the PSS. The added value is agreed by contact and manifested in the service level agreements (SLA).

The process layer comprises the production processes needed to gain the output required to fulfil the SLA on the result layer [5]. The processes are customized by PSS specific configuration. In this understanding the search-space for customer solution on the result layer is determined by the possible process combinations of all processes handled by a company.

The resource layer contains all internal and external resources which are necessary to perform the process on the process layer. In this layer the external factor in form of customer resources is integrated in the PSS. In the consequence all service specific characteristics evolving from the integration of the external factor have influence on the middle term resource planning. The PSS resources are bundled on the process layer by their use in process [4]. The usage specification indicated by the number in brackets is fundamental to the resource planning and leads over to the following explanation concerning the qualitative and quantitative resource description required to specify demand.

But before we come to the qualitative and quantitative resource description, the structural model's practical relevance is pointed out by the example given in Figure 6.

This graphical presentation works with a tree structure used in the same way as to visualize a part list respectively the where used-list [16]. On the result layer the customer solution includes 95% availability for use of e.g. a machine tool in the customer's production line. To ensure this performance bond different processes are necessary on the process layer as e.g. breakdown maintenance, preventive maintenance and so on. Behind each of these general processes there are sub-processes. Both have to be pre-configured PSS-individually. To ensure performance readiness resources are needed on the resource layer like service-technicians, spare parts, maintenance tool equipment etc. These resources are pre-allocated by the pre-configured processes [9].

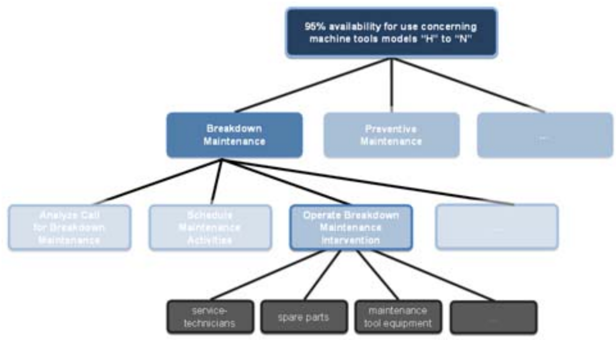

Figure 6: Practical example of structural model [Source: [9])

Without the description of the qualitative and quantitative usage of resources in PSS a reliable middle term production planning of PSS gaining a sufficient accuracy is not possible. For this purpose first an approach is introduced how to describe PSS resources in a qualitative way and then an adequate approach is proposed describing PSS resources in a quantitative way.

3.1 Qualitative Description of PSS Resources

To get an imagination of different resource categories and possible parameters characterising the resources we take a closer look at the term "task". In an organizational point of view a task can be subdivided into three elements [15]: task manager, materials and information. These three elements are used as resource categories in the following.

The role of the *task manager* usually is filled by personnel staff providing the required skills and qualification to provide the performance needed in process.

The infrastructure, equipments, tools, information and communication systems needed to perform service here are summarized as *materials*.

The *Information* required as an input factor for the service production process contains working schedules, parts lists, drawings, instructions etc.

The resources covered by these three resource categories can be further characterised by using description parameters. Such parameters evolve in particular application context and can not be described generally. There are also three parameter categories each linked with the three resource categories: object, environment and performance activity.

The *object* represents the external factor and is crucial for the pre-allocation of the PSS resources. The parameters emerging in this category relate to the object's characteristics as e.g. special machine Know-how (related to the resource category task manager), the functional specification of a spare part (related to the resource category materials) or the content of an instruction training (related to the resource category information).

The working *environment* also has influence on resources required. Parameters as e.g. special language skills (related to the resource category task manager), measured data specification (related to the resource category materials) or sector specific information about production processes (related to the resource category information) rank among this parameter category.

The *performance activity* provides all information given by performing the task itself and is related to the task's object. Parameters of this category are e.g. qualifications and skills needed to perform the task (related to the resource category task manager), IT System suitability of remote or condition monitoring service related to the resource category materials) or task specific education (related to the resource category information).

To structure the qualitative description of PSS resources we propose the *typology* method as an approach established in numerous industrial and research projects [14]. By the use of typology the complexity arising from resource variety is reduced while at the same time the level of abstraction and compression is rising up by information reduction to the essential. Thereby one *resource type* is defined as a combination of certain parameter values and covers several resources in praxis. The resource types result from a combination of certain parameter values across the different parameters. To generate resource types in a structured way the following steps are essential:

a. Derivation of resource categories.
b. Definition of parameters and parameter values.
c. Visualization in morphological boxes.
d. Selection PSS specific parameter values.
e. Definition of resource types.

In the following part theses steps are described in detail.

a. Derivation of resource categories

As mentioned before the three resource categories task manager, materials and information are not structured as detailed as necessary for an middle term planning. Aiming at a more detailed resource description every group is divided into further subcategories. These subcategories constitute so-called resource classes. One resource class contains all resource types that can be described by the resource category's parameters. As the derivation of resource classes depends on the specific use case it has to be decided which derivation is appropriate when the case arises.

b. Definition of parameters and parameter values.

From a practical and scientific point of view there are lots of parameters suitable to describe resources. One of the challenging tasks applying typology is to find the right parameters and number of parameter values. However, to get a qualitative description of PSS resources it is very important that only those parameters and parameter values adding relevant information to the description model are included. At last the final quality of the parameters and parameter values is proven during the definition of types [7, 13]. It should be noted that all resources belonging to a resource category have a similar basic structure and can be described through the same parameters. Nevertheless, while defining the parameters and parameter values there are some criteria that should be considered in order to keep the degree of complexity on a low level and to minimise the definition effort [11, 14]:

- Each parameter should have minimum two parameter values.
- Each parameter should add an essential information value.
- The parameter values should be accessible.
- The parameters should be differentiable.
- The parameters should not be redundant or correlate with each other.

c. Visualization in morphological boxes

Morphological Boxes as shown in Figure 7 allow a visualisation of the resource types and solve as a structural framework for the qualitative resource description.

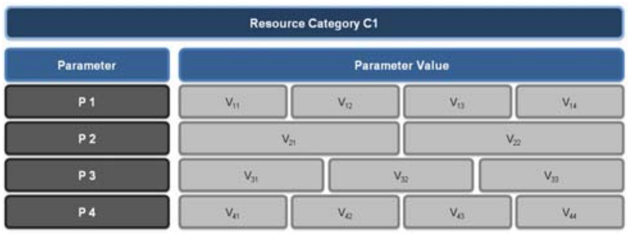

Figure 7: Morphological Box

In the Morphological Box the parameter values are linked to the parameters characterising a specific resource category. Schuh characterises such Morphological Boxes as a parameter-value matrix [16]. Using this parameter-value matrix, complex problems can be structured comprehensively and without overlap [6, 8].

Up to this point the process of resource type generation is related to a specific company but does not reference a specific PSS of the company. From here on the following steps are PSS specific.

d. Selection PSS specific parameter values

As PSS are created for homogenous customer groups with similar demand structures, PSS provide certain parameter values to be selected. Nonetheless it is not possible to predefine customer groups and their demand structures because they depend on the use case. That is why generally admitted parameters respectively the parameter values cannot be specified either. In the concrete use case the parameter value selection depends on the object, environment and performance activity of the PSS.

e. Definition of resource types

The maximum number of potential resource types that can emerge in one resource category correlate with the category's number of parameters and parameter values. Theoretically every combination of the particular parameter values is possible so that the number of resource types increases rapidly. A first restriction of possible combinations is made by the PSS specific parameter value selection. Another restriction to the possible combinations evolves from the fact that only a realistic parameter value selection that is close to reality, is permitted in this step. Consequently, the complexity is reduced to a manageable extent. To visualize the particular resource types which are defined in this step we revert to the morphological boxes again.

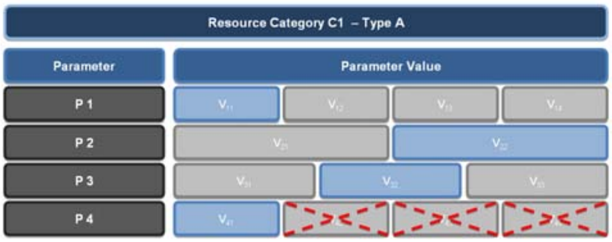

Figure 8: Visualization of a specific Resource Type

As shown in Figure 8 a resource type is visualized in the resource category specific morphological box by highlighting the parameter values that specify the resource type. The parameter values which have been excluded by the PSS specific parameter value selection are cancelled by red lines.

As the PSS resource structural model is depicted as a tree structure the integration of the qualitative description model into the structural model requires an adequate way of description. For that reason and considering a systematic overview about the different types belonging to one resource category, the "Resource Type Structural Tree" is introduced here. Figure 9 points the constitution of one resource category's types out by adding the use case specific parameter values top down. At the tree's bottom all resource types are defined.

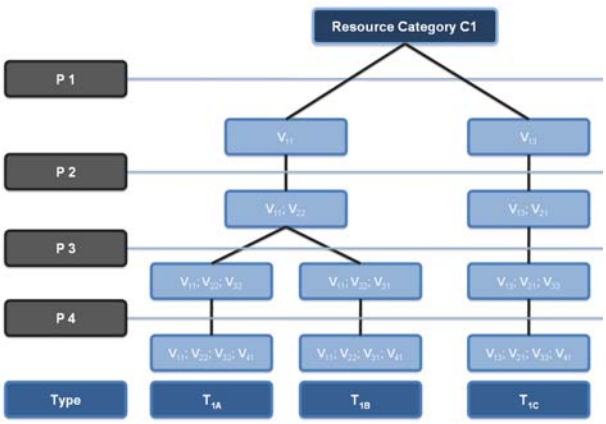

Figure 9: Resource Type Structural Tree

3.2 Quantitative Description of PSS Resources

After the qualitative description of PSS resources has been discussed in detail, we now lay our attention on the quantitative description. In terms of enabling the specification of the PSS resource demand measuring units have to be found making the defined resource types despicable on a quantity basis. For this purpose the resource types are divided into three groups as pictured in Figure 10.

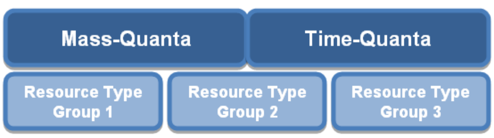

Figure 10: Quantitative Description of Resource Types

The first group of resources types can be specified adequately by time-quanta, the second group by mass-quanta and the third group by both - time- and mass-quanta.

The quantitative resource calculation in PSS within the scope of e.g. scenario based demand forecasting or quantitative characterisation of a company's resource pool is out of scope of the description model introduced in this article. Nevertheless the model is required to provide an overview of the quantitative resource demand of a specific PSS or a company's resource pool. Such an overview is given by the matrix shown in Figure 11.

Figure 11: General Overview of Quantitative Resource Specification

This matrix vertically comprises all resource categories emerging in a PSS and horizontally contains all resource category specific resource types. In this matrix the mass- and time-quanta can be used for the quantitative resource specification.

4 SUMMARY AND FUTURE PROSPECTS

The aim of this article is to enhance the PSS research landscape - especially Service Engineering as the main research discipline focussing on the planning and development of PSS - by presenting an approach to enable better resource-planning in PSS based businesses. A Resource Planning Perspective on PSS taking the characteristics of service into account is considered to provide an adequate framework for the description of the PSS product structure and the usage of resources in PSS.

The structural model describing the usage of resources in PSS introduced constitutes the basis of a qualitative and quantitative description of the resources needed to hit customer demand. This is the first step on the way to a systematic resource planning. A next challenge will be to calculate the resource demand forecast and to match qualitatively and quantitatively the resources' demand with an existing resource pool of a company.

Mastering this challenge means to enable companies to plan their PSS resources in a more efficient way and as a result to enhance resource efficiency as well as ensure performance readiness as required by customers.

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6 REFERENCES

[1] Baines, T.S et al (2001): State-of-the-art in product-service systems, Pro.IMechE 2007 Vol.221 Part B:J. Engineering Manufacture 1543.

[2] Belz, C. (1997): Leistungssysteme. In: Thexis, Leistungs- und Kundensysteme. Kompetenz für Marketing-Innvoationen, Schrift 2, 1997, S. 12-39.

[3] Bertalanffy, L. v. (2006): General System Theory. 15. Auflage. New York.

[4] Burr, W. (2005): Chancen und Risiken der Modularisierung von Dienstleistungen aus betriebswirtschaftlicher Sicht. In: Herrmann, T.

(2005): Konzepte für das Service Engineering: Modularisierung, Prozessgestaltung und Produktivitäts-management, S.17-41. Physika Verlag, Heidelberg.

[5] Corsten, H., Gössinger, R. (2007): Dienstleistungsmanagement. Oldenburg Verlag, München.

[6] Disselkamp, M. (2005): Innovationsmanagement: Instrumente und Methoden zur Umsatzung in Unternehmen. Gabler verlag, Wiesbaden.

[7] Förster, H.-U. (1988): Integration von flexiblen Fertigungszellen in die PPS. In: Hackstein (Hrsg.) (1988): FIR + IAW Forschung für die Praxis, Band 19, Springer Verlag, Berlin.

[8] Hauschild, J. (1997): Innovationsmanagement. Vahlen Franz GmbH, München.

[9] Hübbers, M. (2009): Unveröffentlichte Case Study im Rahmen des vom BMBF geförderten Forschungsprojektes HyProDesign, Förderkennzeichen 01FD0674.

[10] Mont, O.K. et al (2008): Clarifying the concept of product-service system. In: Journal of Cleaner Production 10 (2002) 237-245.

[11] Pepels, W. (2006): Produktmanagement: Produktinnovation, Markenpolitik, Programmplanung. Oldenburg Verlag, München.

[12] Ramaswamy, R. (1996): Design and Management of Service Processes – Keeping Customers for Life Reading: Addison-Wesley.

[13] Scherer, J. (1991): Zur Entwicklung und zum Einsatz von Objektmerkmalen als Entscheidungskriterium in der Beschaffung. Fördergesellschaft Produkt-Marketing, Köln.

[14] Schmidt, C. (2008): Konfiguration überbetrieblicher Koordinationsprozesse in der Auftragsabwicklung des Maschinen- und Anlagebaus. Shaker Verlag, Aachen.

[15] Schmidt, G. (2003): Methoden und Techniken der Organisation. Dr. Görtz Schmidt Verlag, Giessen.

[16] Schuh, G. (2005): Produktkomplexität managen. Hanser Fachbuchverlag, München.

[17] Schuh, G. (Hrsg.) (2006): Produktionsplanung und -steuerung. Grundlagen, Gestaltung und Konzepte. Springer-Verlag, Berlin.

[18] Schuh, G., Friedli, T, Gebauer, H. (2004): Fit for Service: Industrie als Dienstleister. Carl Hanser Verlag, München.

[19] Schuh, G. and Gudergan, G. (2008): Fakten und Trends im Service 2008. Klinkenberg Verlag, Aachen.

[20] Schuh, G., Gudergan, G. (2009): Service Engineering as an Approach to Designing Industrial Product Service Systems. In: Roy, Rajkumar (Editor) (2009): Industrial Product-Service Systems (IPS ²), Proceedings of the 1st CIRP IPS2 Conference. Cranfield University Press.

[21] Specht, G., Beckmann, C. and Amelingmeyer, J. (2002): F&E Management. Kompetenz im Innovationsmanagement. Schäffer-Poeschel Verlag, Stuttgart.

[22] Thomassen, P. , Gudergan, G. (2009): Fakten und Trends im Service 2009. Klinkenberg Verlag, Aachen.

Process Oriented Production System for Service Providing Companies

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Abstract

Design and realization of services are affected by high individuality and high requirements of quality and productivity. To meet these requirements, numerous approaches have been developed in service research. Although these existing approaches allow a selective methodological support of service design and realization, concepts that transparently display the interrelations between existing approaches and thus allow a coordinated and standardized methodological support of service design and realization are not common. Furthermore, an organizational framework for service providing companies that enables staff to continuously improve both service quality and productivity on the job is missing. To close these gaps, the concept of process oriented production systems that evolved from companies producing physical goods represents a promising starting point. This paper therefore illustrates a framework for a process oriented production system for service providing companies.

Keywords

Service, Production System, Methodology

1 INTRODUCTION

In recent years, market structures and competitive environment of service markets continuously changed. This also led to an increasing dynamic of innovation in the service sector [1]. As a consequence, service providing companies cannot gain advantages in competition by being the cost, quality or technology leader in the market. Furthermore, differentiation by innovative and sustainable services became a crucial factor of success.

To increase competitiveness and to fulfil customer requirements, service providing companies are forced to offer services of high individuality while ensuring high quality and productivity [2]. Thereby, it is up to the service providers to design and organize the service processes in a way that guaranties efficiency in terms of productivity and cost effectiveness. To meet these requirements, numerous approaches have been developed in service research. Although these existing approaches allow a selective methodological support of service design and realization, concepts that transparently display the interrelations between existing approaches and thus allow a coordinated and standardized methodological support of service design and realization are not common. Furthermore, an organizational framework for service providing companies that enables staff to continuously improve both service quality and productivity on the job is missing [3].

To close these gaps, the concept of process oriented production systems that evolved from companies producing physical goods represents a promising starting point. This paper therefore discusses chances and limits of transferring the concept of process oriented production systems to service providing companies and illustrates a framework for a process oriented production system for service providing companies. A concept for planning, implementing as well as steering the process oriented production system for service providing companies completes this paper.

2 SERVICES

2.1 Characteristics of Services

In the research community, the definitions of service are multifaceted. Up to now, there is no definition available that is generally accepted. Already existing definitions can be classified into following categories: enumerative, negative, institutional and constitutive definitions [4]. From a scientific point of view, the constitutive definition represents the most suitable. It defines service based on specific constitutive attributes [4]. Thereby, there is no global consensus in research concerning these service attributes.

The American literature distinguishes between four main characteristics specifying services:

- Intangibility: Services are predominantly performances of actions rather than objects that can be perceived using any of the physical senses.
- Heterogeneity: Service products quality is subject to variability because services are delivered by people to people.
- Simultaneity of production and consumption: Service products are typically produced and consumed at the same time – consumption cannot be separated from the means of production.
- Perishability: Services must be consumed as they are provided. In general, they cannot be saved, stored, returned or carried forward for later use or sale [5].

Authors in British literature also base their definitions on these characteristics. Additionally, relations between them are introduced. In this way, intangibility and cus-tomer integration are pointed out as the two main characteristics of services [5]. Thereby, the other service characteristics could be derived from the two main characteristics, e.g. perishability could be derived from intangibility and both simultaneity and heterogeneity could be derived from customer integration. German authors also consider intangibility and customer integration as the main service characteristics. Based thereon, every other characteristic can be derived [6]. Depending on the kind of service, external factors can be personnel resources as well as objects (e.g. physical goods) of the customer.

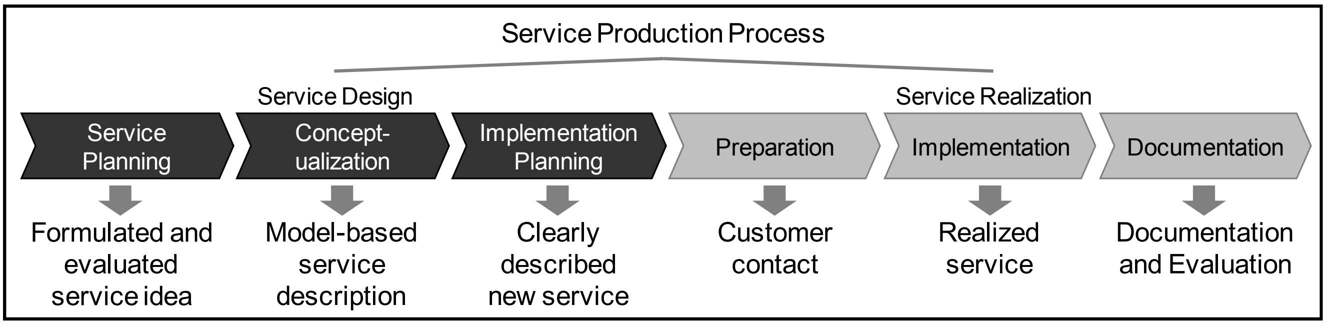

Figure 1: Service Production Process.

When designing and realizing services, three dimensions of services need to be distinguished [4]:

- The result dimension: service components provide the customer with a certain set of expected func-tionalities.
- The process dimension: service realization is based on different processes that continuously change the state of both the service provider and the customer.
- The infrastructure dimension: the company offering the service provides the resources needed for executing the service realization.

2.2 Service Production Processes

A service life cycle consists of two main phases: service design and service realization, whereas service realization follows the service design process [7]. This service life cycle is also referred to service production [8] (Figure 1).

Service design comprises both the planning and the conceptualization of a service as well as the preparation of service realization [9]. Within the service realization, certain activities (process dimension) were carried out on or with the external factors by the service provider applying certain resources (potential dimension). The aim of the activities is to generate an expected result (result dimension). Customer interaction as one of the core characteristics of services primarily takes place during the service realization phase [9].

Service Design

Already existing approaches to systematic service design (e.g. [10]) mostly comprise three main phases:

- Service Planning
- Service Conceptualization
- Implementation Planning

Service planning comprises all activities necessary for finding, formulating and evaluating service ideas. After the analysis of internal potential, an analysis of the market situation follows. Based on the results, promising service ideas are chosen, formulated in detail and evaluated in a next step. Thus, service planning aims at getting formulated and evaluated service ideas.

The aim of the service conceptualization phase is to substantiate the idea gathered in the service planning phase. Thereby, the components of a service are defined and described by means of predefined service models comprising all characteristics of services. The result of this phase is represented by a model-based service description evaluated against feasibility and marketability.

Implementation planning aims at guaranteeing a systematic and efficient implementation of the service realization phase. This comprises the planning of the resources as well as the processes necessary for the implementation of service realization. At the end of this phase there is a completely designed service.

Service Realization

The service realization process can be divided into three main phases as well:

- Preparation
- Implementation
- Documentation

The preparation comprises the contacting as well as the planning of the later implementation. By contacting the customer, the appointment for the service implementation is granted. The implementation planning then focuses on the definition of the scope of work as well as the allocation of the required resources.

The implementation phase comprises the substantiation of the initial situation of the customer as well as the realization of the expected service result.

Following the service implementation, the information gathered during the servicing processes are documented and analyzed.

2.3 Service Production Management

Two essential functions of the service production management can be derived from the characteristics of service production processes:

- Service production has to be of a continuous customer orientation. Thereby, already existing infor-mation provides the basis for both design and realization of service providers' activities that aim at providing the customer with an expected result [11].
- With respect to the efficiency of both the service production processes realized within the service providing company as well as the interaction with the customer, design and realization of service produc-tion processes has to consider the importance of the customer and to take advantage of him [12].

Strategic Service Management

The establishment, development and continuance of a service oriented business culture represent the essential strategic task of an intentional service management. This requires a consistently implementated customer orien-tation as a central value of the business culture [13].

The definition of standards concerning customer integration represents the major task of the functional service management. Thereby, the form of customer interaction during the service production has to be de-fined considering spatial, chronological, functional and social criteria.

Operational Service Management

The constitutive service characteristics as well as stra-tegic decisions affect a multitude of activities that aim at supporting both design and organization of the service production. According to Stauss, these activities can be summarized as follows [14]:

- Tangibility management
- Management of environmental aspects
- Capacity management

- Time management and scheduling
- Human resource management
- Customer management
- Process management
- Quality management

2.4 Conclusions for Methodological Service Support

To strengthen the competitive situation of service providing companies as well as to improve their market position, services have to be realized in a high process and product quality, comparable to the standards of the production of physical goods. Therefore, it becomes necessary that the engineers involved in design and realization of service production processes would link the methods and tools that are already established in the production of physical goods. The experiences made in this step will help them to design and organize costumer oriented and innovative service production processes more efficiently [15].

3 PROCESS ORIENTED PRODUCTION SYSTEMS

The idea of process oriented production systems as they are widespread in companies producing physical goods goes back to the Toyota Production System (TPS).

The founder of Toyota, Sakichi Toyoda and his engineer Taiichi Ohno developed the so called Toyota Production System (TPS) to cope with the market pressure under turbulent market conditions [16]. The TPS can be regarded as a general framework and philosophy to organize the manufacturing facilities and processes at Toyota as well as the interaction of these facilities and processes with the suppliers and customers to provide best quality, lowest cost, and shortest lead time through the elimination of the seven forms of waste [17]. Thereby, one basic idea was the involvement of all employees [17]. Thus, a process was introduced that helped Toyota to continuously change the performance of the production for the better. Thereby, the basic idea is the increase of efficiency of the production by a stepwise continuous improvement.

Process oriented production systems represent a metho-dological framework that comprise basic principles, methods and tools necessary to design and organize production processes to produce marketable goods. Due to the success of the TPS and the need to continuously improve the own business, the TPS and several of its inherent methods have been adopted by many European producing companies in order to improve productivity and flexibility of the production [18]. Thereby, very often an adjustment of the basic principles, methods and tools according to the company individual requirements took place. Approaches to support production system planning and design are above all considering waste avoidance in the sense of lean manufacturing [19].

4 TOWARDS A PROCESS ORIENTED PRODUCTION SYSTEM FOR SERVICE PROVIDING COMPANY

In order to maximize product and process quality in service production, process oriented production systems as already established in the physical goods industry can be taken as a promising starting point.

Based on an analysis of current process oriented production system concepts, the following fields of action for the design and implementation of process oriented service production systems can be identified:

- To support the continuous improvement process in service production as well as to enhance the motivation of the employees, the characteristics of services require the visualization of services respectively the materialization of the services by means of tangible elements.
- The context of service realization significantly affects the service quality experienced by the customer. Thus, in view of design and organization of service production processes, environmental aspects have to be taken into account as well.
- The intangibility of services leads to increasing demands on the capacity management of the service provider that aims at realizing, evaluating and eliminating quantitative, qualitative, chronological ore spatial deficits between the customer demand and service providers offerings.
- Time management of physical goods production mainly focuses on the minimization of the throughput time while guaranteeing high quality products right in time. A comprehensive time management in service providing companies differs significantly. Thus, e.g. the analysis of customers time structures as well as his subjective and objective time perception, the planning of capacities provided by both customer and service provider as well as the scheduling of service production processes have to be taken into account.
- During service production, the employees of the service provider are often interacting with the customer. Thus, both the behaviour as well as soft skills of the employees becomes a significant role for the service quality and productivity perceived by the customer. Therefore, human resource management in service providing companies has to be comple-mented by service specific approaches.
- An efficient design and organization of service production processes also makes high demands on the customer, e.g. in view of providing necessary information. Therefore, the steering of customers' behaviour in situations of interaction between the customer and the service provider has to be taken into account. Furthermore, the management of cus-tomer relationships becomes a crucial role since services very often are realized in long term cooperation between customer and service provider.

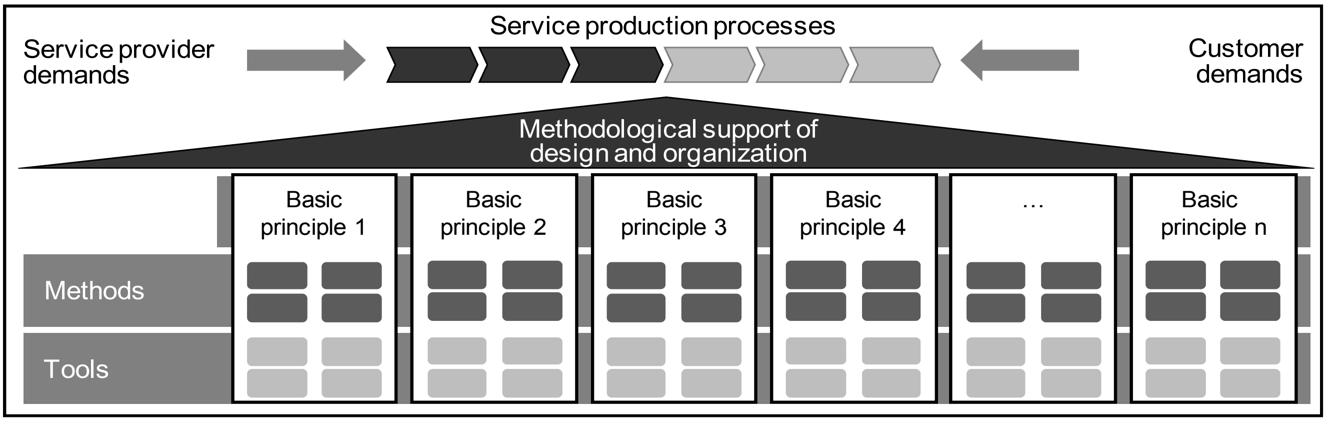

Figure 2: Methodological Support of Service Production Processes.

- Since design and realization processes significantly are responsible for the quality and productivity of the service production, planning, organization, steering and controlling of service production processes have to be supported by appropriate methods. Thereby, customer integration has to be considered.

Approaches conceptualizing service quality (see e.g. [20, 21, 22]) consider a lot of aspects that can be reduced to the characteristics of services. These aspects have to be taken into account during the development of a comprehensive quality management supporting the planning, steering, measurement and improvement of service quality.

5 FRAMEWORK CONCEPT

5.1 Objectives

To enhance the controllability of service production processes represents the main objective of the process oriented production systems for service providing companies. Thus, both quality and productivity of the service production would increase strongly. The approach of the process oriented service production system thereby increases the understanding for the fundamentals of both design and realization of services as well as their methodological support.

The integration of already existing methodological approaches supporting design and organization of service production processes thereby not only enhaces the transparancy of single methods and tools in view of their effectiveness. Furthermore, fundamental interrelations between the methods and tools become clearer. In this way, an active design, controlling and assessment of service production processes becomes feasible.

Hence, further objectives can be derived as follows:

- A coordinated and standardized methodological support of service production processes requires a systematic identification of company specific demands. Based thereon, an approach has to be provided that allows the service provider to systematically and individually identify and develop basic principles of methodological support as well as appropriate methods and tools included therein. Thereby, the mutual interrelations between the basic principles as well as the methods and tools included therein have to be taken into account.
- The way of realizing the customer integration in service production processes plays a key role for the effectiveness of service production. Therefore, the condition of the customer as well the resulting effects on both design and organization of the service production have to be described transparently and considered in view of the methodological support. This also includes the interface between customer and service provider.
- Design and organization of service production is influenced by multiple factors. Thus, the identification of customer and service providers objectives as well as of resulting demands on the service production has to be supported by appropriate methods. Thereby, influenceable and non-influenceable environmental aspects of service production have to be taken into account, too. Thus, the basis for the systematic integration of basic principles, methods and tools to a process oriented service production system is laid.
- The transparency of the performance of the process oriented service production system represents a further objective. Based on the individual characteristics of the service production, an approach to systematically measure the performance of the process oriented service production has to be provided as well. This also represents a basis for the systematic derivation of improvement potentials of the production system as a whole.

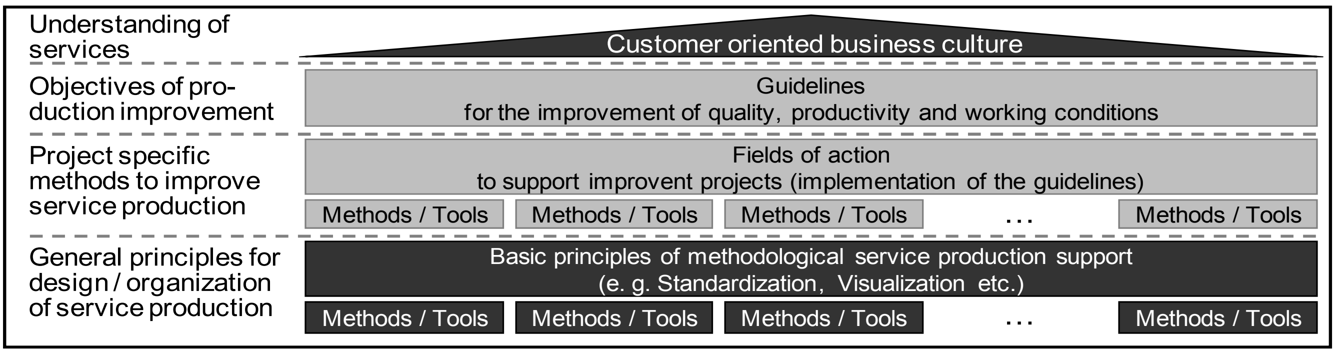

Figure 3: Process Oriented Service Production System: Overview.

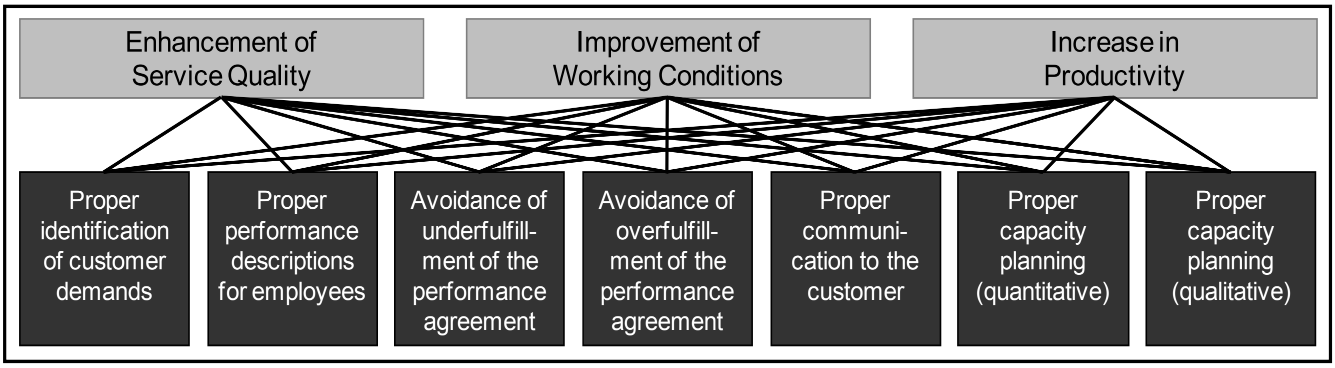

Figure 4: Guidelines for the Elimination of non-efficient Production Processes.

5.2 Overview

The process oriented service production system as a general framework and philosophy to design and organize the processes of service production comprises four essential elements (Figure 3):

- The understanding of service characteristics as well as the realization of a customer oriented business culture represents a necessary prerequisite to be fulfilled by every staff member.
- Basic principles of methodological service production support build enables the personnel to execute the service production processes in a predefined manner. In cause of occuring problems, the methods and tools help the employees to understand the problem and to analyse the causes of the problem.
- To avoid inefficient (wasteful) service production processes, the staff has to be enabled in order to identify these processes. The service production specific guidelines thereby represent a helpful mean.
- In case of identified inefficient service production processes, appropriate measures have to be taken in order to improve the service production processes. The systematic development of these solutions addressing a few fields of action is supported by a set of project specific methods.

5.3 Business Culture

Service oriented behavior highly depends from the specific situation of both customer and service provider. Thus, it comprises behavior pattern that exceed formalized instructions. From a personnel point of view it requires a high degree of freedom concerning the scope of the employees as well as their self dependency.

The service oriented business culture as the core element of the process oriented service production system therefore covers different points:

- Customer orientation in all production processes
- Production processes as the center of all business oriented action
- Customer management
- Forms of customer interaction
- Advancement of service orientation of the personnel being in contact with the customer
- Social and communicative skills of the personnel
- Abilities to emotional labour
- Prioritization of initializing and management of long term customer relationships

5.4 Guidelines

The process oriented service production system contains universal rules for the organization of service production that enables the staff of service providing companies to execute his specific tasks while contributing to enhance the efficiency of service production as well as to improve working conditions. Thereby, improvements can only be realized by identifying and solving existing problems.

The guidelines for the identification of inefficient service production processes (Figure 4) provide a helpful tool to the personnel and enable them to identify weaknesses of the established production processes. Thus, deficits in view of service quality, service production productivity as well as working conditions can be identified systematically by the employees on the job.

5.5 Basic Principles of Methodological Support

The basic principles of methodological support comprise methods and tools that support both design and organization of service production processes as a whole. Thereby, most of the basic principles (e.g. visualization or continuous improvement) are universal, while the methods and tools included in these principles can be adapted individually according to the company specific requirements.

The most common basic principles for the methodological support of the service production are e.g.:

- Standardization
- Continuous improvement
- Visualization
- Quality management
- Skill oriented human resource management

For example, visualization (e.g. in form of process models) helps to clarify service production processes, service results as well as required resources. Thus, the personnel are enabled to identify weaknesses in processes that build the basis for a continuous improvement process.

5.6 Project Specific Methods

The basic principles of methodological support provide a non-exhaustive basis for a continuous improvement process, realized in iterative cycles of well-known phases (plan, do, check, and act). Furthermore, service specific methods have to be provided by the process oriented service production system that helps the employees to execute this iterative cycle.

This is realized by a sample of methods and tools that supports the execution of specific improvement projects within the service providing company. The methods and tools thereby address different field of action:

- Understanding existing problems,
- Analysis of causes,
- Development of product or process improvements,
- Planning of remedial action,
- Taking selective measures,

- Testing measures for target achievement,
- Improvement of taken measures
- Definition of new standards.

6 REALIZATION

6.1 Overview

Within the concept supporting the realization of the process oriented service production system, firstly objects and processes of service production as well as their interrelations are structured systematically. In this context, also the personnel of the service provider are considered, comprising the agents in view of the design, controlling and assessment of service production processes.

Subsequently, activities for planning, designing, implementing and steering of the process oriented service production system are described. Their realization is supported by appropriate process models as well as corresponding methods and tools.

6.2 Planning

The management decision to implement a process oriented service production system represents the initial point for the planning phase. In this phase, focus is both on the development of organizational and operational prerequisites for the implementation of the production system as well as on the establishment of a service oriented business culture. In context of the latter, the clarification of interrelations between the design and organization of the service production and service oriented business ethics are of importance. This also applies to the importance of structural changes within the service providing company.

In a first step, an analysis of operational structures in context of service design and realization takes places. This analysis is complemented by an analysis of methods and tools supporting service production processes and already established within the service providing company. Further on, analyses take place in order to get transparency in view of the product portfolio, the design and realization of the customer interface as well as the influenceable and non-influenceable environmental aspects of service production. Based on the results of these analyses, an assessment of the current efficiency of the service production is realized.

The specification of customer and service provider demands on the design and organization of the service production follows in the next step. The identification of starting points for a coordinated and standardized methodological support of service production processes concludes the planning phase.

6.3 Design

In context of the design phase, the detailed composition of the process oriented service production system takes place.

The system configuration covers the selection of the approach to the company specific configuration of methods and tools. Furthermore, the basic principles providing already existing methods and tools to methodologically support the service production (e.g. capacity, customer, quality, process ore time management methods) are specified systematically. The system configuration is complemented by the development of a concept increasing professional and social skills of the personnel. Thus, the employees are qualified to actively participate in both design and improvement of the service production.

Based on the system configuration, the process oriented service production system is structured in detail. Thereby, the methods and tools applied in context of the production system as well as the scope of both methods and tools are specified according to the predefined customer and service provider objectives (e.g. the establishment of company-wide production standards or the enhancement of transparency of production processes). Parallel, the definition of appropriate key figures to control the efficiency of the methodological support takes place.

6.4 Implementation

The next phase covers the implementation of the process oriented service production system as well as the realization of the concept increasing the skills of the personnel. Thereby, this phase aims at a continuous implementation of a coordinated and standardized methodological support of service production.

The chronology of implementation of methods and tools in the service providing company represents an important factor for the success of the process oriented service production system. Therefore, the sequencialization of the methods and tools to be implemented takes place at the beginning of the implementation phase. Further on, this phase comprises the implementation of an appropriate organizational and operational structure within the service providing company as well as the company-wide communication of the concept as a whole. A completed implementation of the production system determines the phase of system implementation.

The concept increasing both professional and social skills of the personnel aims at acquaints the employees with the possibilities offered by a systematic methodological support of service production processes. In this way, the personnel’s orientation in their working environment is enhanced. Furthermore, a more efficient planning, performance and controlling of production processes that are realized by the employees becomes possible. Thereby, special requirements result from customer integration as well as the resulting customer interaction.

6.5 Steering

The steering of the process oriented service production system aims at continuously improving the efficiency of service production processes as well as improving the methodological support of the design and organization of the service production. Thereby, two aspects have to be distinguished.

In context of the operational steering the guidelines for the elimination of inefficient production processes as presented above are provided. By means of these guidelines, the personnel are enabled to identify deficits in service production processes. Thus both immediate measures as well as corrections of service production processes can be realized.

The strategic steering addresses both the continuous improvement of the mechanisms to avoid inefficient service production processes as well as measures to the strategic adaptation of the processes oriented service production systems, e.g. in case of changing customer and service provider requirements to the design and organization of service production processes.

7 SUMMARY

To increase competitiveness and to fulfil customer requirements, service providing companies are forced to offer services of high individuality while ensuring high quality and productivity. Thereby, it is up to the service providers to design and organize the service processes in a way that guaranties efficiency in terms of productivity and cost effectiveness.

To meet these requirements, there are numerous existing approaches that allow a selective methodological support of service design and realization. This paper provided a concept that transparently displays the interrelations between existing approaches and thus allows a coordinated and standardized methodological support of service production processes. Furthermore, the approach of a process oriented production system for service providing companies enables the personnel to actively take part in a continuous improvement process enhancing the efficiency of service production processes.

8 REFERENCES

[1] Bullinger, H.-J., Meiren, T., Service Engineering – Entwicklung und Gestaltung von Dienstleistungen. In: Bruhn, M., Meffert, H. (Eds.), 2001, Handbuch Dienstleistungsmanagement, Gabler, Wiesbaden

[2] Jaschinski, C., 1998, Qualitätsorientiertes Redesign von Dienstleistungen, Shaker, Aachen

[3] Spath, D. (Edt.), 2003, Ganzheitlich produzieren, Log_X, Stuttgart

[4] Scheer, A.-W., Grieble, O., Klein, R., Modell-basiertes Dienstleistungsmanagement. In: Bullinger, H.-J., Scheer, A.-W., 2003, Service Engineering, Springer, Berlin

[5] Lasshof, B., 2005, Produktivität von Dienst-leistungen, Thesis, FernUniversität Hagen

[6] Bullinger, H.-J., Schreiner, P., Service Engineering: Ein Rahmenkonzept für die systematische Entwicklung von Dienstleistungen. In: Bullinger, H.-J., Scheer, A.-W., 2003, Service Engineering, Springer, Berlin

[7] Luczak, H., 2000, Service Engineering – Der systematische Weg von der Idee zum Leistungsangebot, TCW-report, München

[8] Sontow, K., 2000, Frühe Phasen des Service Engineering - Dienstleistungsplanung in Unter-nehmen des Maschinen- und Anlagenbaus, Thesis, RWTH Aachen

[9] Ramaswamy, R., 1996, Design and Management of Service Processes – Keeping Customers for Life, Edison Wesley, Reading

[10] Luczak, H., Liestmann, V., Winkelmann, K., Gill, C., 2002, Service Engineering industrieller Dienstleistungen. In: Bullinger, H.-J., Scheer, A-W. (Eds.), 2002, Service Engineering, Springer, Berlin

[11] Kleinaltenkamp, M., Integrativität als Kern einer umfassenden Leistungslehre. In: Backhaus, K., Günter, B., Kleinaltenkamp, M., Plinke, W., Raffée, H. (Eds.), 1997, Marktleistung und Wettbewerb – Strategische und operative Perspektiven der marktorientierten Leistungsgestaltung, Gabler, Wiesbaden

[12] Kleinaltenkamp, M., Dahlke, B., Der Wert des Kunden als Informant – auf dem Weg zu einem „knowledge based customer value“. In: Günter, B., Helm, S. (Eds.), 2003, Kundenwert – Grundlagen, innovative Konzepte, praktische Umsetzungen, Gabler, Wiesbaden

[13] Gurt, J., Elke, G., Zimolong, B., 2008, Dienst-leistungsmanagement: Erfolgsfaktoren Servicekultur und Commitment, wt Werkstattstechnik online, 98: 573-580.

[14] Stauss, B., Engelmann, K., Kremer, A., Luhn, A., 2007, Service Science – Fundamentals, Challenges and Future Developments, Springer, Berlin

[15] Eversheim, W., Jaschinski, C., Reddemann, A., 1997, Qualitätsmanagement für Nonprofit-Dienst-leister, Springer, Berlin, Heidelberg, New York

[16] Ohno, T., 1998, Toyota Production System – Beyond large Scale Production, Productivity Press, Portland

[17] Liker, J. K., 2004, The Toyota Way, McGraw-Hill, New York

[18] Herrmann, C., Thiede, S., Stehr, J., Bergmann, L., 2008, An environmental perspective on Lean Production, The 41st CIRP Conference on Manufacturing Systems, Tokyo, Japan, 26-28 May: 83-88.

[19] Cochran D. S., Arinez, J. F., Duda, J.W., Linck, J., 2001, A Decomposition Approach for Manufacturing System Design, CIRP Journal of Manufacturing Systems 20: 371-389.

[20] Donabedian, A., 1980, The Definition of Quality and Approaches to its Assessment, Health Admini-stration Press, Ann Arbor

[21] Grönroos, C., 1982, Strategic Management and Marketing in Service Sector, Marketing Science Institute, Cambridge

[22] Parasuraman, A., Zeithaml, V., Berry, L. L., 1985, A Conceptual Model of Service Quality and Its Implications for Future Research, Journal of Marketing 49: 41-50.

Reference Architecture for Dynamical Organization of IPS² Service Supply Chains in the Delivery Phase

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Abstract

Flexibility is one of the main demands onto the organization of delivering Industrial Product-Service Systems (IPS²). IPS² development specifies all product shares, service shares and their interdependencies in an IPS² product model. The management of the service deliveries ans resources is the task of the IPS² organization. For the containment of influences, a reference architecture for dynamical organization to create and operate IPS² service supply chains is developed.

This paper describes a reference architecture for the IPS² organization by an modular organzition unit concept and how processes within the operation of IPS² can be managed by software agents.

Keywords

Industrial Product-Service System, IPS², IPS² organization, IPS² network, service supply chain, multi-agent system

1 INTRODUCTION

Industrial Product-Service Systems are characterized by an integrated and mutually determining process of planning, developing, provisioning, and using product and service shares [1]. Providing IPS² is based on a long term relationship between a customer and the IPS² provider. This implies a need to organize the delivery of service processes focusing customer conditions and the realized IPS². Future unknown influences or changing customer requirements demands a dynamic organizational system with strong customer integration [2]. Thereby not only the organizational structure of the IPS² provider but also the service supply chain is affected. Every partner in this service supply chain needs the qualifications to solve problems out of a heterogeneous field of requirements. The delivery processes determine resource attributes and necessary decision knowledge. The IPS² organization is responsible to plan and schedule delivery resources for right time, right quality and right place. Challenge is to find the right balance between over capacity to avoid supply shortages and high fixed costs. Thus the planning and scheduling have to be changed until the service process is finally started. An IPS² organization reference architecture helps to organize the delivery of IPS² service processes in service supply chains. For efficiency reasons communication and coordination between the supply chain partners are handled via software agents. Also controlling of manual and semi-automated as well as an execution of automated process steps is being realized by software agents.

2 IPS² ORGANIZATION REFERENCE ARCHITECTURE

2.1 IPS² Product Model

The IPS² product model is built up by the developed and configured product and service shares, all necessary technical and physical resources for delivering the service processes and its economic valuation in the state of the IPS² development.

The IPS² product model contains the process model that specifies the service processes of the delivery phase [3]. To achieve a desired quality and result the process model is described with attributes for the needed resources. A task of the IPS² organization is to find the resources to realize the service processes of the IPS² product model. The IPS² organization structure is created by finding the necessary resources for the process elements and by establishing coordination units that can schedule the resources.

The creation process for the IPS² organization structure will be initiated for the first time when developing an IPS². During the delivery and use phase of the IPS² life cycle the IPS² organization structure can change by gaining knowledge about the behavior of resources, behavior of IPS² system components, quality of service delivery result or replacement of resources or processes. The IPS² organization reference architecture describes a model for structuring intra-organizational and supplier resources within an IPS² service supply chain.

2.2 Structural Reference Framework

The customer integration is a requirement for the delivery planning and scheduling of IPS². Existing organizational structures and planning methods have the disadvantage of being optimized either for production processes or service processes. New ways for intra-organizational structures and supply chains become necessary. Controlling raising product and process complexities with these structures have to be a new key competence for IPS² providers. Interconnections between the production and the service domain result out of the new IPS² product model. The need and initialization of service deliveries can be linked with the behavior or condition of the IPS² component shares. For example preventive maintenance has a long time variance for the delivery time instead of the breakdown that has got no time variance because of the condition of the machine tool.

Manifold papers about the organizational integration of industrial services state that a universal solution does not exist [4]. Every company has to decide which organizational structure should fit best by weighing pros and contras. Therefore a modular organization structure needs to be developed [5]. The modular concept for enterprise networks developed by Picot et al. [6] provides the structural and characterizing framework for the concept of this paper.

A new understanding of partnership roles and responsibility for actions during the IPS² lifecycle is developed to guarantee that the customer has always one permanent contact person [7, 8]. The IPS² provider represents as the One Face to the Customer (OFC) and manages all communication in the network. Target of the IPS² provider is to optimize the service delivery processes in time, quality and costs. He can distribute service process shares to network partners to create a service supply chain. Capacities of this service supply chain have to be planned and scheduled to guarantee an efficient and qualitative high service delivery.

In the context of our research a modular organization unit (MOU) concept has been introduced that represents the resources for the service delivery processes [9]. With these modular organization units a structure for the IPS² network can be created and adapted on changing circumstances during the delivery and use phase of an IPS². Figure 1 illustrates the exemplary implementation of modular organization units on existing organizational structures and the combination of the units to a network.

Different network partner types are identified to work together in an IPS² network to deliver IPS² service processes. The different types of IPS² network partners are customer, IPS² provider, IPS² module supplier, service supplier and component supplier [7, 8]. Each partner has an individual part of the IPS² to deliver and can coordinate this in different ways. The MOUs combine resources of network partners that have the abilities to deliver service processes with desired requirements. If the IPS² provider decides to outsource a service process resource he has to assure that his intellectual property will be protected.

The MOUs are used to get a process oriented structure. With sharing service delivery parts to network partners centralized and decentralized combinations evolve. Centralized organizational structures can help to coordinate external MOUs and to share service relevant knowledge. Decentralized organizational structures will work autonomous, but they can be coordinated from a centralized MOU in the form of customer provider relationship. Synchronal to the implementation of a MOU a software agent is instantiated for communication and coordination.

An example for a maintenance process will show possible situations that determine the creating of an IPS² network.

3 NETWORK POOL

3.1 Process Modeling

For the buildup of a company network for service delivery and especially to realize the needed potentials for a special process the fully described service process is needed. Most of the process descriptions exist only in a very abstract way that will lead to uncertain conditions for process planning and scheduling.

To reduce the uncertainty in the service delivery the process must be described as detailed as possible. This description can be developed for the IPS² product model by the IPS² provider or can be estimated concerning the

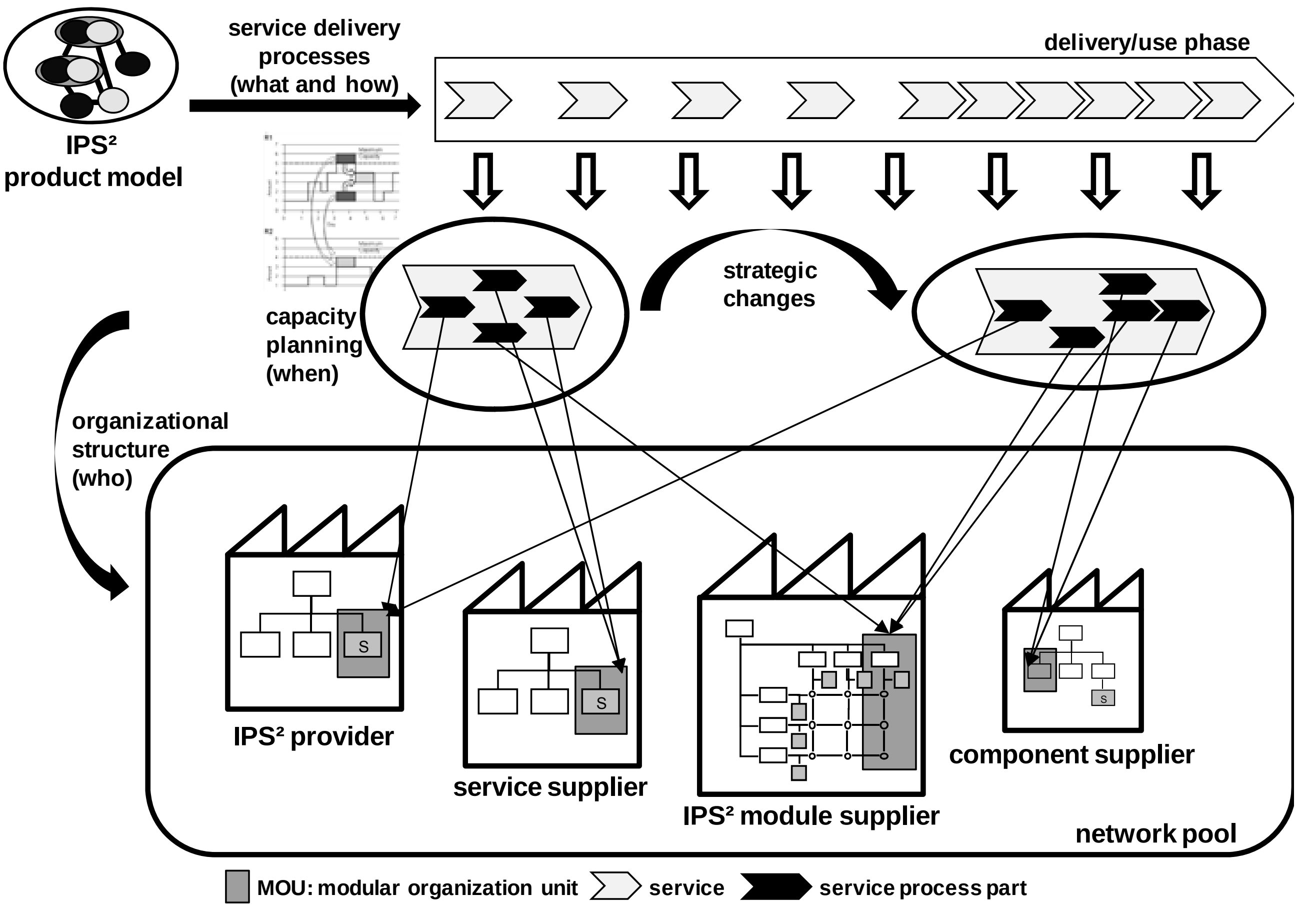


Figure 1: Network architecture for IPS² service supply chains

product design.

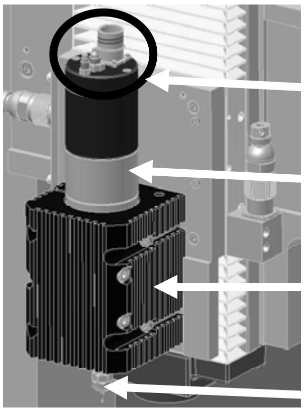


Figure 2: 3D-Model of the machine tool component milling spindle

The IPS² product model also includes construction drawings of the product share of the IPS² (Figure 2). By these drawings the interdependencies of the used parts and e.g. needed tools can be named. Further the process step of e.g. disassembling of a machine tool component is analyzable.

Therefore the methods-time measurement (MTM) is useable [10]. The MTM is a method to characterize and analyze mainly manual processes in the industrial field, especially in mass production. This is important for the planning phase to identify, how long a person, e.g. a technician, needs to finish an action.

The exemplary, manual process to show the reference architecture for dynamical organization of IPS² is an exchange of a milling spindle. The scenario of a milling machine tool is selected for the research project TR29, so that the process "spindle exchange" is based on the built-on realization of this scenario.

To ensure e.g. the availability of an IPS² in an availability oriented IPS² business model, special planning and monitoring systems of the shares in the operation phases can be used. Therefore this paper presents a method for the dynamical organization to achieve the guaranteed availability of a critical machine tool component.

The spindle is the core component of a milling machine tool. This component is therefore function relevant for the production with this machine tool and has to last high stresses, e.g. by the cutting force.

The detailed MTM result in 14 different process steps, wherein three steps are defined as optional. These optional steps can be activated by inspection of the technician, which result in e.g. the exchange of screws (Figure 3). Optional process steps are not often used in the task "spindle exchange", but have to be considered to reach a high detailing of all process influences and to reduce the uncertainty.

The duration for the process delivery is 22 minutes beginning with process step 1 "Preparation of workplace" and ending with process step 14 "Pack tool case up and mark old spindle" and the main resource is the service executing "technician". That means that the process starts with the arrival of the technician at the machine tool and ends with his departure.

The process "spindle exchange" is described with the following resources and their belonging attributes. The attributes can be used to characterize the resources:

- Technician,
- Tool case,
- Wrench, size 12,
- Wrench, size 8,
- Hex-wrench, size 8,
- Torque wrench, size 5,
- Screw driver, slotted, size 6,
- New spindle,
- Case of new spindle,
- Marker for the used spindle,
- Box for the tool fastener,
- Hardware for control and function test of the spindle,
- Software for function test of the spindle,
- Technical documentation of the spindle,
- Optional: Head mounted display (HMD) for support of the technician,

Code	MTM-1 spindle exchange page 0
Description	Spindle exchange
Start	Preparation of workplace
Content	Sub processes 1-11 (Options sub process 4.1 and sub process 5.1)
End	Function test
Limitation	Times valid for spindle exchange by IPS² provider

No.	Notation	Code	TMU	A x H	Overall TMU	Conversion [min.]
1	Preparation of workplace	MTM page 1	12420.7			7.45
2	Take tool fastener out	MTM page 2	326.4			0.19
3	Realize machine condition for the spindle exchange	MTM page 3	155.7			0.09
4	Disaggregate the spindle for supply	MTM page 4	2564.3			1.54
5	Check hoses and exchange them if necessary	MTM page 4.1	2689.2	2	5378.4	3.23
6	Check screws for the cover of the spindle and exchange them if necessary	MTM page 4.2	167.8			0.10
7	Loosening of the spindle carrier	MTM page 5	183.0			0.11
8	Check screws for the carrier of the spindle and exchange them if necessary	MTM page 5.1	167.8			0.10
9	Insertation of the new spindle in the spindle carrier	MTM page 6	527.0			0.32
10	Aggregate the new spindle with the supply	MTM page 7	1038.0			0.62
11	Realize machine condition for the new spindle starting	MTM page 8	155.7			0.09
12	Take tool fastener in	MTM page 9	2037.7			1.22
13	Function test	MTM page 10	13886.7			8.33
14	Pack tool case up and mark old spindle	MTM page 11	426.2			0.26
	Sum		36746.2		42124.6	22

Figure 3: List of sub steps for the process "spindle exchange"

- Optional: Hose, length= 2 m, diameter= 6 mm, nontransparent,
- Optional: Hose, length= 2 m, diameter= 6 mm, transparent,
- Optional: Screws, 2 units, M5x40 and
- Optional: Screws, 4 units, M8x70.

With this resource list it is possible to combine resources into clusters of company profiles (Figure 4). These profiles can be used for the job announcement and the IPS² provider has the possibility to identify his competences for this process delivery (see 3.2). With the denotation by the IPS² provider a first decision has been made which resources have to be outsourced to network partners.

Company profile: **Employment agency** Related resource: Technician	**Company profile:** **Technician support** Related resource: HMD
Company profile: **Spindle manufacturer** Related resource: - New spindle - Technical documentation - Marker for old spindle	**Company profile:** **Hardware supplier** Related resource: Hardware for control and function test of the spindle
Company profile: **Plastic part manufacturer** Related resource: - Case for new spindle - Tool case - Optional hoses - Box for tool fastener	**Company profile:** **Tool manufacturer** Related resource: - Wrench, size 12 - Wrench, size 8 - Hex-wrench, size 8 - Torque wrench, size 5 - Screw driver, slotted, size 6
Company profile: **Software programmer** Related resource: Software for function test	**Company profile:** **Screw manufacturer** Related resource: Optional screws

Figure 4: Potential company profiles

To characterize the process more in detail and to show the influences and interdependencies of the process elements, the integrated enterprise modeling language can be used [11]. Method for object oriented business process optimization (MO²GO) uses the integrated enterprise modeling language to model the "spindle exchange" process in a software tool (Figure 5).

In this model the attributes for the resources can be allocated and be revised after accepting the job. E.g. initial information's about the resource "technician":

- Needed qualification and skills,
- Needed delivery time,
- Needed delivery cost.

Resulting attributes after job acceptance:

- Service process delivery duration, timetable,
- Membership: IPS² provider.

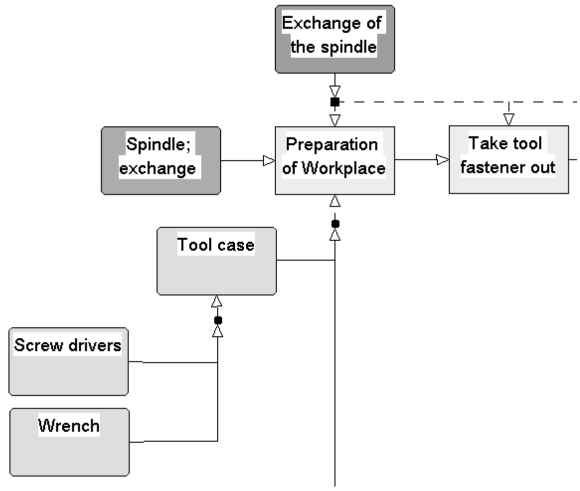


Figure 5: Process model in MO²GO for the process "spindle exchange"

This model can be used by the IPS² provider to generate detailed information for the different network partners by the retention of process overview. To guarantee the availability of e.g. a machine tool, this overview is very important and has to be realized also by the selected network partners.

3.2 Network Cases

The resources for the maintenance example can be categorized in standard tools, process individual tools, spare parts and optional helping tools. The spindle will be supplied by the spindle manufacturer. He provides the spindle with a transportation case, technical documentation and a stamp to mark the spindle. A supplier of plastic parts can offer the box for the tool fastener and replacement hoses. Screws can be supplied by a dealer for such mass products. Standard tools for the technician and more specialized tools like the torque wrench are available from tool manufacturer. The HMD is an additional tool to get support from an expert who guides the user through a problem [13]. Suppliers for HMD offer the unit for rental in the IPS² network. Network partners can rent the HMD and can get help by using it if they need it.

Four strategies based on different combination to find suppliers for the resource groups exist to find resources. The strategies vary from delivering all processes with internal resources of the IPS² provider to externalize all parts. Figure 6 shows the network combinations for the four cases. By assigning process elements to a supplier the IPS² provider has to establish a coordination unit that controls the delivery time, quality and cost goals. The HMD can be used for all four strategies. Every time when the technician is not able to solve the maintenance himself he has the possibility to use the HMD to get contact to a back-office expert.

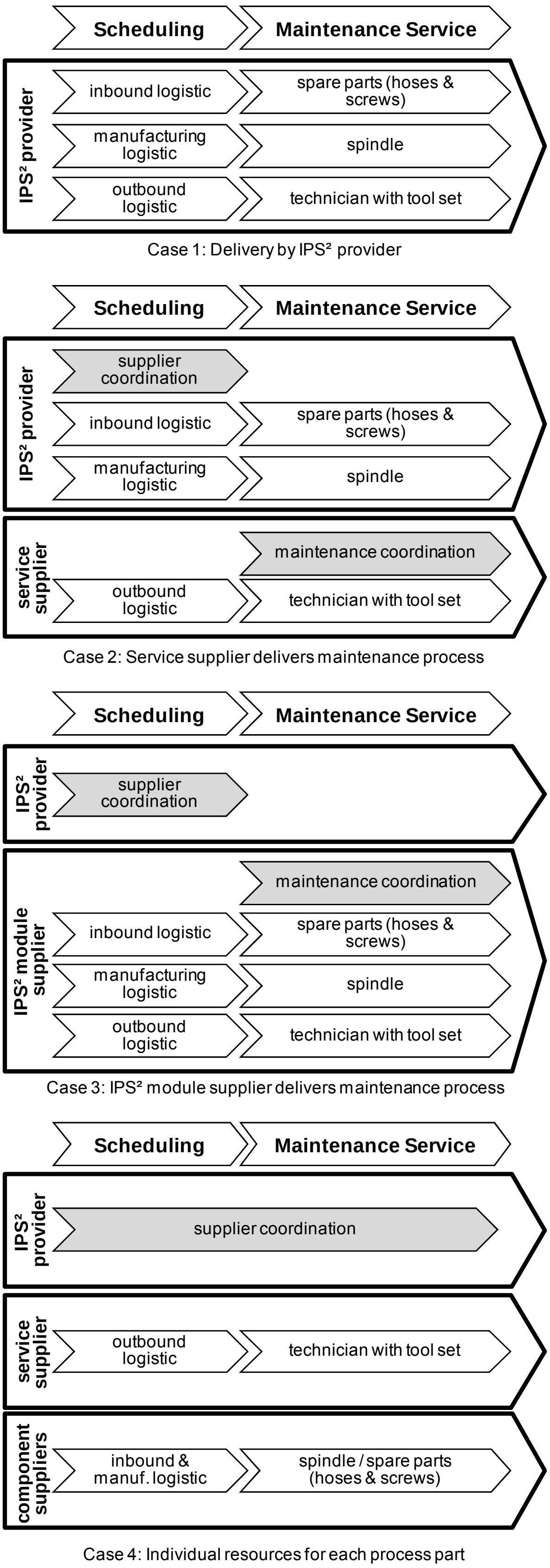


Figure 6: Strategies for IPS² networks for the example of spindle maintenance

The delivery process in the cases is divided in two parts. The first process part describes the scheduling which is necessary to guarantee that the process can be realized. The second process part describes the maintenance service process itself. For the scheduling processes the network partners have to make different logistical coordination. Logistics can be inbound, manufacturing or outbound logistics [13].

Case 1: Delivery by IPS² provider

The needed resources for the maintenance process, like tools, spare parts, are delivered by IPS² provider. The IPS² provider is also in charge of coordination and scheduling of the service delivery process. This could be the case if the IPS² provider is the manufacturer of the spindle and has the resource capacity to make the service business. The IPS² provider decides to build up a service supply chain with component suppliers for tools and spare parts. Spare and wear parts, like screws, will be bought from a dealer and stored at the IPS² provider side. A technician has a tool set with the categorized tools and spare and wear parts. The technician, a new spindle, the plastic parts will be scheduled by an organization unit from the IPS² provider to deliver the maintenance process.

Case 2: Service supplier delivers maintenance process

The IPS² provider decides to use a service supplier for the maintenance process. The service supplier has to provide the resource “technician” that is able to make the service based on the process model. The spindle, spare parts and plastic parts are provided by the IPS² provider. All parts, this includes the technician, is scheduled by the IPS² provider. A coordination unit by the IPS² provider is necessary that can communicate with the resources to change for example time schedules. The coordination unit has to manage the availability of the service resources together with finding the best time of delivery for the customer. This case could exist if the IPS² provider is the manufacturer of the spindle, but has not enough capacity of its service resources to deliver the process itself.

Case 3: IPS² module supplier delivers maintenance process

Maintenance of the spindle is provided by an IPS² module supplier. The IPS² module supplier is inside the network of the IPS² provider to develop a micro production machine tool with an integrated milling spindle. The spindle has a high complexity and needs individual services to guarantee the availability. Therefore the IPS² provider has decided to outsource the process of spindle maintenance to the IPS² module supplier. The exchange spindle, spare parts and hoses have to be organized by the IPS² module supplier. Thus two coordination units become necessary. One becomes necessary for coordination by the IPS² provider and the IPS² module supplier and another coordination unit between the IPS² module supplier and his suppliers.

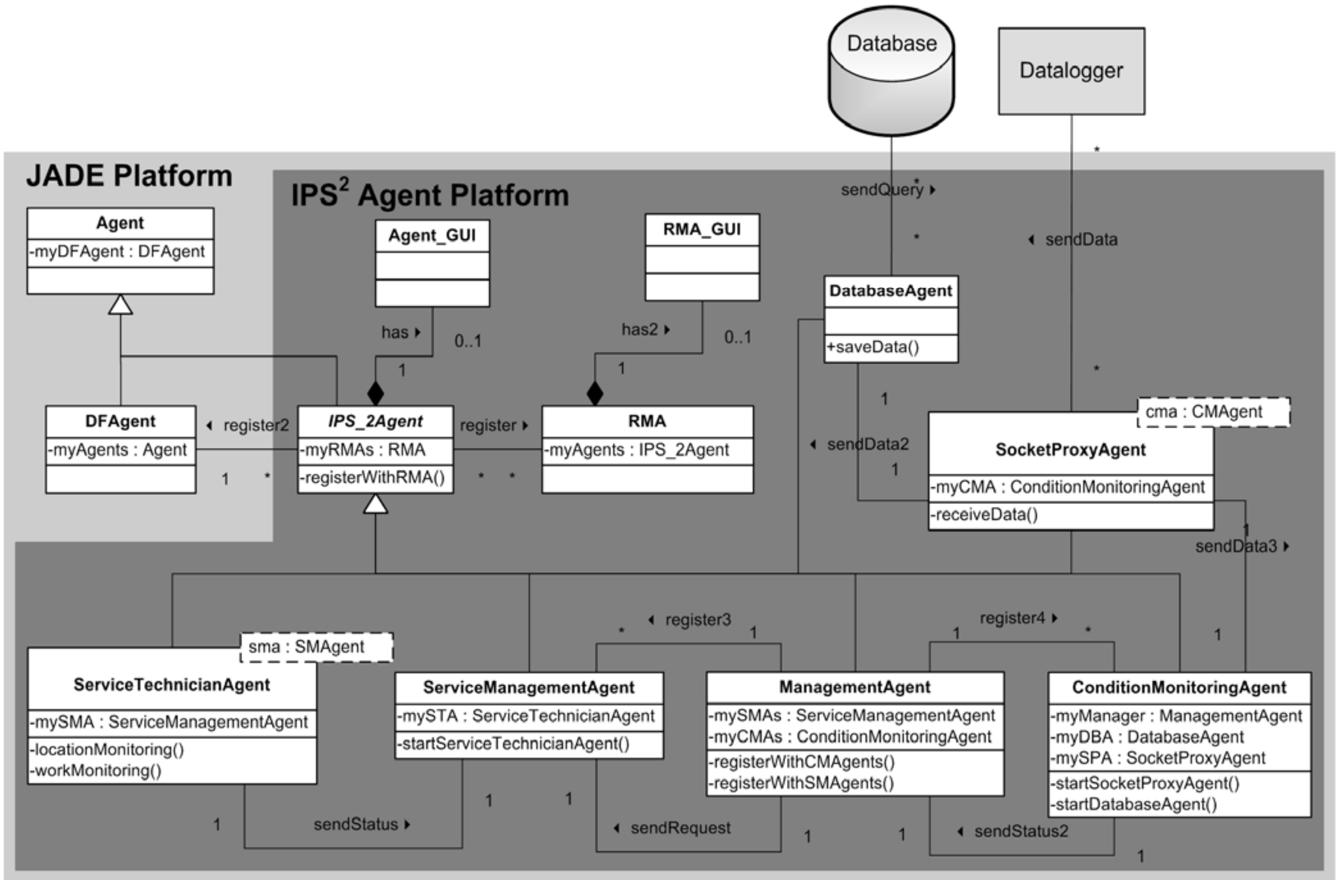
Case 4: Individual resources for each process part

The IPS² provider outsources all maintenance parts to external suppliers, but he keeps hold of the coordination responsibility. This case has the advantage that no capacity has to be considered if a job has to be coordinated. An IPS² provider can change the time of delivery by making new requirements for the service process or by negotiating with each partner individual. A possible service supply chain can have a coordination unit of the IPS² provider and every supplier is directly connected with this coordination unit.

4 SOFTWARE AGENTS

Meanwhile the use of software agents within personal information management [14], support of business processes [15] and electronic commerce [16], [17] is common practice. In contrast, commercial software agent applications in the field of industrial production are still rather seldom. An example is the ongoing research project SOPRO (Self Organizing PROduction). One focus

of the project aims at enabling parts of the production system including workpieces to autonomously optimize production processes by cooperation and coordination.
For these purpose machine tools, assembly lines and workpieces are equipped with miniaturized embedded microprocessors with integrated sensors and wireless communication interfaces. Based on software agent technology, these so called process eGrains are able to percept and act following their implemented goals [18], [19]. Aspects of integrated product and service shares are disregarded.
According to the idea of IPS² software agent systems can be used to build up the initial IPS² network [8] as well as to support IPS² in the delivery and use phase, taking into account integrated treatment of product and service shares including the human factor. Every object that is involved in IPS² delivery and use has defined tasks specified in the IPS² product model.
All these objects should be represented by software agents due their interactions needed to ensure proper use of the IPS² [20]. Thereby involved shares and their tasks vary depending on the customer needs and the chosen IPS² business model. In principal, these models can be divided into function, availability and result oriented IPS² business model. The agent class structure model of the availability oriented IPS² business model is exemplarily shown in Figure 7. As mentioned before the specifications of the software agents to be implemented depend on the involved shares and their roles within the IPS² product model. The distinction of different cases as given in chapter 3.2 is used to define roles of and interactions between the software agents and therewith the general system architecture while concrete descriptions of service processes like the MTM of the spindle exchange help to determine interfaces for software agent perception and action, e.g. using sensors respectively actors.
Within the research project SFB/Transregio 29 a multi agent system based on JADE (Java Agent DEvelopment Framework) [21] for the support and control of IPS² operation was developed.
Figure 8 shows the graphical user interface (GUI) for the creation and administration of the software agent. It provides initialization and termination of IPS² agents using predefined agent classes (cf. Figure 7). The GUI also visualizes the communication of agents and offers debugging features for the development software agent.



Legend:

- Agent: Base agent class provided by JADE platform
- DFAgent: Director Facilitator Agent provides yellow pages service
- IPS_2Agent: Abstract agent class in an availability oriented IPS²
- Agent_GUI: IPS² agent specific GUI
- RMA: Remote Management Agent provides administration GUI
- RMA_GUI: Administration GUI
- SocketProxyAgent: Provides TCP/IP interface
- DatabaseAgent: Provides database functionality for knowledge database
- ManagementAgent: Controls IPS² operation and is central communication node
- ConditionMonitoringAgent: Monitors condition of product shares and adapts process data
- ServiceManagementAgent: Manages, initializes and terminates ServiceTechnicianAgents
- ServiceTechnicianAgent: Monitors state of service processes and supports service measurements

Figure 7: Agent class structure model at the example of availability oriented IPS²

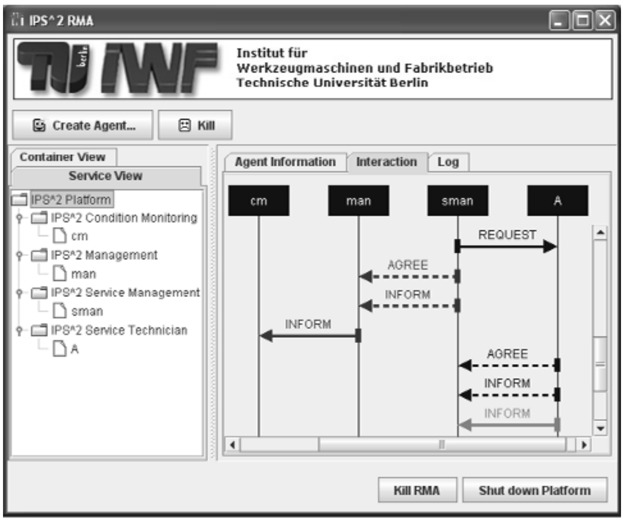


Figure 8: Administration GUI for IPS² software agents with communication visualization

5 SUMMARY

Industrial Product-Service Systems are delivered by a network, whereby the network partners are chosen with respect to their competences and tasks needed for IPS² delivery. These tasks are specified in the product model. This product model includes detailed descriptions of product and service shares as well as a list of all required resources. Due to future unknown influences or changing customer requirements IPS² demand a dynamic organizational system with strong customer integration. Therefore, a reference architecture is proposed in this paper that is able to deal with changing demands by dynamic adaption of the organizational structure of the IPS² network. For this reason, the concept of modular organization units was introduced.

The use of the methods-time measurement (MTM) for the analyzation of processes within IPS² delivery was presented at a micro production scenario. This process analyses is an important prerequisite for the built-up of the IPS² network. While MTM enables to identify time constraints the integrated enterprise modeling defines the attributes for the resources that have to be provided by network partners.

The paper closes with the presentation of a multi agent system for the support of initial network generation and IPS² operation. Since software agents can be applied on machine components as well as on human actors software agent technology is an adequate tool for automated coordination and communication within an IPS² network. In a next step human actions within service processes have to be analyzed more in detail to optimize the cooperation between human actors and technical systems.

In future research optimization methods and interdependencies to find optimal module sets or combinations of modules by using of software agents have to be investigated.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Meier, H., Uhlmann, E., Kortmann, D., 2005, Hybride Leistungsbündel - Nutzenorientiertes Produkt-verständnis durch interferierende Sach- und Dienstleistungen, wt Werkstattstechnik online, 7/2005, pp. 528 – 532, Springer, ISSN 1436-4980

[2] Krimm, F.O., 1995, Beitrag zur Produktionsplanung und -steuerung von technischen Dienstleistungen, Doctoral Thesis, Universität Dortmund

[3] Meier, H., Kortmann, D., 2007, Leadership- From Technology to Use; Operation Fields and Solution Approaches for the Automation of Service Processes of Industrial Product- Service- Systems, In: Takata, S., Umeda, Y. (Hrsg.), Advances in Life Cycle Engineering for Sustainable Manufacturing Business- Proceeding of the 14th CIRP Conference on Life Cycle Engineering, pp. 159 – 163, Springer-Verlag London 2007 Limited, ISBN 978-1-84628-934-7

[4] Engelhardt, W.H., Kleinaltenkamp, M., Reckenfelderbäumer, M., 1993, Trägerschaft und organisatorische Gestaltung industrieller Dienstleistungen, in: Simon, H. (Hrsg.), Mainz et al., Industrielle Dienstleistungen, Schäffer-Poeschel, Stuttgart

[5] Frietzsche, U., Maleri, R., 2003, Dienstleistungsproduktion, In: Bullinger, H.-J., Scheer, A.-W., Service Engineering, Springer, Berlin, pp. 199 – 233

[6] Picot, A., Reichwald, R., Wiegand, R.T., 2003, Die grenzenlose Unternehmung – Information, Organisation und Management, Gabler, Wiesbaden, ISBN 3-409-52214-X

[7] Meier, H., Völker, O., 2008, Industrial Product-Service Systems - Typology of Service Supply Chain for IPS² Providing, Proceedings of the CIRP-MS Conference, Tokyo, Japan, pp. 485 – 488, Springer-Verlag, ISBN 978-1-84800-266-1

[8] Meier, H., Uhlmann, E., Krug, C.M. Völker, O., Geisert, C., Stelzer, C., 2009, Dynamic IPS²-Networks and -Operations Based on Software Agents, in Proceedings of the 1st CIRP IPS² Conference, Cranfield, UK, 2009, pp. 305 – 310, Cranfield University Press, ISBN 978-0-9557436-5-8

[9] Meier, H.; Völker, O., 2009, Organizational Requirements by Offering Industrial Product-Service Systems, Proceedings of 42nd CIRP Conference on Manufacturing Systems, 3 – 5 June 2009, Grenoble, France, (Electronic Resource)

[10] Bokranz, R., Landau, K., 2006, Produktivitäts¬management von Arbeitssystemen: MTM-Handbuch. Stuttgart: Schäffer-Poeschel

[11] Müller, P., Stelzer, C., Geisert, C., Uhlmann, E, Knothe, T., 2008, Kernprozesse hybrider Leistungs¬bündel. wt Werkstattstechnik online, 7-8/2008, pp. 581 – 586, Springer, ISSN1436-4980

[12] Gegusch, R.; Geisert, C.; Hoege, B.; Stelzer, C.; Roetting, M.; Seliger, G.; Uhlmann, E., 2009, Multimodal User Support in IPS² Business Model, in Proceedings of the 1st CIRP IPS² Conference, Cranfield, UK, 2009, pp. 125 – 131, Cranfield University Press, ISBN 978-0-9557436-5-8

[13] Hering, E., 1999, Taschenbuch für Wirtschaftsingenieure. Carl Hanser Fachbuchverlag München, ISBN 3-446-21149-7

[14] Jennings, N., Wooldridge, M., 1996, Software Agents, IEE Review, January 1996, p. 17 – 20

[15] Taveter, K., 2004, Agile Engineering of B2B Automation Systems, ERCIM News No. 58, Special: Automated Software Engineering, July 2004, pp. 60 – 61

[16] Liu, S., Turban, E., Lee, M.K.O., 2000, Software Agents for Environmental Scanning in Electronic Commerce, in: Information Systems Frontiers, Vol. 2, No. 1 / January 2000, Springer Netherlands, pp. 85 – 98

[17] Schneider, G., 2009, Electronic Commerce, Course Technology, Cengage Learning, ISBN 978-1-4239-0305-5

[18] N.N., 2009, Von Softwareagenten und e-Grains, press release 15/2009, Fraunhofer Institute for Production Systems and Design Technology, http://www.ipk.fraunhofer.de/pr/medieninfo/mi_2009/mi_15

[19] www.sopro-projekt.de, accessed 11-13-2009

[20] Uhlmann, E., Geisert, C., 2009, Availability Oriented IPS² Supported by Software Agents – Feedback Control Approaches for Robust IPS² Operation, in Proc. of the 2nd International Seminar on IPS², Berlin, 23-24 March 2009, pp.63 – 67

[21] JADE web site, http://jade.tilab.com/, accessed 11-11-2009

Resource Planning of Industrial Product-Service Systems (IPS²) by a Heuristic Resource Planning Approach

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Abstract

Industrial Product-Service-Systems (IPS²) are specified by delivering value in use to the customer while both product and service shares occur integrative over the whole life cycle. Thus they comprise several degrees of freedom, such as the partial substitution of product and service shares or the integration of customers' resources, which the operational resource planning of IPS² deals with. Furthermore it has to optimize the schedule regarding several aims like costs or constant work load. This article describes the Heuristic Resource Planning Approach for IPS² which combines e.g. randomized search heuristics and evolutionary algorithms.

Keywords

Industrial Product-Service Systems (IPS²), advanced planning and scheduling, process planning

1 INTRODUCTION

Already at the end of the 1960s Theodore LEVITT [1] made a statement that is still valid for current industrial applications: „People don't buy products; they buy the expectation of benefits". Therefore a comprehensive customer orientation is essential and thus a shifting from product sales to value sales will be realized.

The requirements and demands from the customer are rising and an upward trend towards customized solutions can be recorded; customers not only request products of high quality and high technology. They want to be placed in a position to operate these products optimally and request for a complete service offer [2]. This demanding attitude at the customer side though presupposes an efficient service design at the machine or service provider. The requirements of customers and providers are met by consequently offering Industrial Product-Service Systems (IPS²) with integrated services for all phases of the product life cycle [3, 4], what justifies the increasing meaning of industrial services by focusing on the customer use [5],

This solutions providing will also shift the relationship to a risk sharing between the customer and the provider. Focusing on the value provision Industrial Product-Service Systems enable innovative, life cycle spanning customer-provider relationships and new business models. In the context of innovative business models, the provider undertakes more and more responsibility for individual process steps up to the responsibility for the complete operation of a plant [6]. Hence the customers are freed from the control of the highly-complex processes and are able to focus on their actual core competences. The customer-provider relation will develop to an integrative cooperation, where the established separation between provider and customer will be dissolved more and more, depending on the business model.

1.1 Problem and purpose of the IPS² resource planning

The intangible service shares of Industrial Product-Service Systems provide a value to the customer via the complete life cycle; thus the detailed planning of service processes along the entire life cycle gains importance.

The resources linked with the services are a critical factor for the successful service execution; achieving the necessary availability is based on them. The planning of these resources has to be considered not only in the phase of service delivery but already in the phase of service design; all further products and services are designed in advance together with the product core during the integrated development of an Industrial Product-Service System.

Great impact of IPS² on the planning's complexity is their dynamic behavior over the life cycle: Within the designed solution space the occurrence of an IPS² can change over time due to changing customer demands and provider abilities; this dynamic of cause effects the use phase with its relevant processes. Other requirements are flexibility and real time capability to allow high work load. This is reached by evolving the service delivery from randomness to planning based on operating experience: The continuous optimization of service processes during their repeated execution (ramp up) allows faster and cheaper service execution overall; depending on the number of installed IPS² also the knowledge increases over the use phase.

The required resources for all processes have to be analyzed, planned and optimized. The capacity planning primary has to analyze the resource needs and make a first scheduling with respect to the numerous specifics of Industrial Product-Service Systems: In the first planning step all the single resource needs are analyzed and combined the best way. Therefore all customer specific restraints of all processes as well as their relevant data have to be carried along [7]; furthermore the IPS² specifics (see next chapter) have to be considered. Afterwards the total resource requirement can be calculated and optimized continuously by the operational resource planning, while in the short term it has to deal with emergencies and unscheduled jobs (such as repairing machine break-downs); therefore its methods and approaches have to operate in real-time.

The strategic capacity planning has a relatively long term planning horizon; hence the degrees of freedom are wide. But this variety of possibilities also implies the optimization regarding several aims. On the other hand, the operational resource planning especially has to deal with unscheduled jobs, which leads to changing priorities.

Regarding the resource planning at first a quick solution for a planning problem is needed to balance between calculation time and performance of the optimization result. Afterwards, or for example during an overnight replanning run, the more complex variances' applications can be examined for further optimization. As a planning problem in most cases means the dissatisfaction of a customer it should be solved as soon as possible; in this case the optimization aims are changed to enable the execution of all necessary processes; i.e. costs become second most important on this short term issue.

The basic scheduling is similar to classical travelling salesman problems and the transition times can be reduced by using algorithms specialized therefore. But there are several resources and processes at several places all connected via numerous interrelationships. This implies inner constraints due to the structure of all Industrial Product-Service Systems to be planned.

A process in this context means every action to be done by the provider, e.g. the execution of a service process as well as the delivery of a spare part or sending a software update. A resource means all required machines, material, personnel, tools et cetera. A critical resource in this case is a resource running above or significantly below their maximum capacity; a critical process is a process that cannot be executed until its deadline due to a lack of resources (i.e. it uses one or more critical resources). A solution in this context means a certain combination of resources and processes including the whole scheduling (i.e. the complete planning) for all Industrial Product-Service Systems to be planned.

1.2 IPS² specifics impacting the planning

Industrial Product-Service Systems are especially characterized by delivering value and fulfilling customer demands without stating clearly with exactly what combination of products and services this is done. Thus Industrial Product-Service Systems imply some specific variances [8]; the main are:

- variance in time;
- variance of resources;
- variance of processes;
- variance of allocation time;
- service distribution;
- partial substitution of product and service shares;
- integration of customers' resources;

The **variance in time** describes the possibility to reschedule a process, e.g. a regular maintenance, within a certain time span. It is a specific variance of IPS², as all processes are developed with an individual due date and a possible time span around, which can be used by the provider without reconsulting the customer; e.g. a regular maintenance has a great variance in time, while a break down repair has to be executed immediately. In general there is the possibility to reschedule a delayed process itself or one of the other processes planned for the critical resource at that time.

The **variance of resources** characterizes the opportunity to perform a process with several resources optionally; using the variance of resources means to shift the delayed process or another process to their alternative resource. For example a maintenance process can be rapidly executed by an expert or more slowly by a lower skilled worker.

The **variance of processes** specifies the existence of different processes reaching the same aim of customer satisfaction; those alternative processes are principally different and require different resources. For example a weak part can be replaced repeatedly or substituted by an improved part once.

The **allocation time** can be varied by making the technician or the spare part use different means of transportation, i.e. drive by car or use a plane.

Service distribution is the sourcing of certain resources or the outsourcing of entire processes within the network; it is a specific variance as Industrial Product-Service Systems are highly complex and will be offered in dynamic networks.

The **partial substitution of product and service shares** is a major characteristic of Industrial Product-Service Systems, as the only aim is to fulfil the customers' requests independent from a certain combination of products and services. For example in case of a machine breakdown you can either send a replacement part to the customer (mainly product) or you can repair the existing part on-site (mainly service); both processes allow to restart the machine afterwards. From the planning's point of view this variance is only a special kind of the variance in processes: the processes to be planned as well as the required resources are changed by choosing another product-service combination.

Another degree of freedom is the possibility of **using customer's resources**, e.g. maintenance personnel; this appears due to the high level of collaboration associated with Industrial Product-Service Systems. The customer is an essential part of the IPS²-network; like every other network partner his resources can be requested and used by the provider. Thus from the planning point of view the service distribution and the integration of customers' resources coincide to one variance: requesting processes or resources to the network.

If for one resource sometime the maximum capacity is exceeded (critical resource), at that point in time not all planned processes can be executed; there is at least one process that will be delayed. In this case the variances can be used to solve the planning problem.

The rescheduling or shifting of processes might be illustrated in a Gantt chart; nevertheless nothing of the complex consequences of those process alterations can be visualized thereby. Furthermore the classical visualizations of a planning problem are only able to cope with the less complex variances, as there are many interrelations between the different resources by being linked via several processes: Replanning a process always impacts all other processes and resources, even those ones far away from the considered process.

1.3 Resource planning for IPS²: a multi-dimensional and multi-objective optimization problem

The resource planning of Industrial Product-Service Systems is an optimization problem such as classical scheduling problems or the travelling salesman problem. When starting the planning all process-resource-combinations are chosen best regarding costs etc., so reducing transition times is the main possibility of optimization. But when there are delayed processes or additional processes to be executed in short time, the resource planning can make use of the specific variances to solve this problem under real time conditions.

There are several parameters to be adjusted within the resource planning's optimization according to the specifics and variances of Industrial Product-Service Systems. The numerous variances each induce possibilities to solve a problem. In addition these variances can be applied to several processes and resources. Due to this wide scope of variables the IPS² resource planning is a multi-dimensional optimization problem, becoming even more complex by the interrelations and dependencies between the variables.

Based on that, there are multitudinous possible solutions for an optimization problem. Applying variances or combinations generates various solutions concerning costs, efficiency, and so on. So solutions have to be compared regarding the current aims of the planning.

The three main objectives of the IPS² resource planning are:

- delivery reliability (towards the customer);
- costs;
- work load of the resources;

The quality though has to be kept on the original level by using only the variances specified during the development of the IPS².

There are at least three objectives and depending on the planning horizon the priorities of the planning are changing; hence the resource planning is multi-objective.

Additionally it is an optimization problem that cannot be assessed by mathematical methods: The relationship between two planning solutions can be described by applying the IPS²-specifics, but the relation between planning changes and solution improvements (if → then) cannot be modelled mathematically. Thus a heuristic approach was chosen.

2 ANALIZIS OF RELATED ALGORITMS

When looking at the details of the IPS²s planning it can be seen that it is a combination of several optimization problems.

The underlying basic problems of the combinatorial optimization are, among others:

- bin packing;
- travelling salesman;
- resource allocation;
- vehicle routing;
- course timetabling;
- job shop scheduling;

All these basic problems cannot be easily assessed by mathematical optimization techniques. For complex real cases of these problems mainly randomized search heuristic are applied, as they are able to cope with problem specifics and constraints [9-14].

The IPS²s planning features several objectives, many constraints and a multi-dimensional solution space. Thus no directly applicable optimization algorithm exists and the application of an individual hybrid metaheuristic is essential.

Metaheuristics refer to a class of optimization techniques including stochastic optimization and black-box optimization. They are able to cope with complex problems that cannot be assessed by mathematical optimization as there is too less knowledge about the solution space. On the other hand they can be used for large scale problems where brute-force search does not work. If the quality of a random solution can be quantified by a fitness function, it is possible to compare solutions and to move towards the optimal one.

A hybrid metaheuristic furthermore is a combination of several metaheuristics [15].

2.1 Basic metaheuristics and algorithms for the optimization of real problems

In the following the relevant basic metaheuristics / algorithms are characterized; according to their applicability for the IPS² resource planning the main advantages and disadvantages are shown. For details about the general algorithms' principles please refer to [16-20].

Evolutionary Algorithm

As a main characteristic of Evolutionary Algorithms the quality of the solution depends on the topology of the search space. If no exact solution is needed, it is a very fast algorithm, as the near-optimal point can usually be reached in a very short time; the longest time is spent in the evaluation of all chromosomes. Evolutionary Algorithms are stochastic and mostly there are no guarantees to reach an optimum. They can be applied to problems of various natures, and are adaptable for hybrid metaheuristics; e.g. the combination with Simulated Annealing (see below) allows passing local maxima in the process of evolution. [21, 22]

Genetic Algorithm

Genetic Algorithms are a particular class of Evolutionary Algorithms using the mutation of chromosomes in addition to the evolutionary recombination. They mainly feature the same advantages and disadvantages. The solution quality and speed can be better than with Evolutionary Algorithms, although the optimal solution is usually determined by going through a number of generations. The application to the IPS² resource planning is not easy, as the chance for circular movements probably outweighs the faster covering of the search space. [23]

Simulated Annealing

Simulated Annealing helps to improve the performance of simple search algorithms. As with other metaheuristics there are no guarantees to reach an optimum. Especially with noisy fitness functions Simulated Annealing helps to find the global optimum. [24, 25]

Tabu Search

In applying a tabu search technique to the problem, neighbourhood structure and search strategy are elaborated to improve solution quality and to reduce computation time. They generally find pretty good solutions very early in the search, but must be combined with another algorithm to find a first solution from where the optimization could start. Tabu Search heuristics are capable of integrating constraints and boundary conditions by declaring tabus in a short-term memory of the search (tabu lists). They only apply well on discrete problems. [26]

Greedy Algorithm

A Greedy Algorithm creates a small amount of interim solutions to be compared by choosing the best variables. That is not applicable for the IPS² resource planning, as there is no causal relationship between the costs etc. of a variance and the quality of the referring solutions. [27]

Ant Algorithm

The Ant Algorithm or Ant Colony Optimization uses the historical quality (pheromones) of components to create new solutions. It works well on complex problems and is quite established on large Travelling Salesman Problems. However it is a totally different approach, difficult to hybridize, and normally requires long calculation times. [28]

2.2 Comparison of applicability

When comparing those basic metaheuristics (see table 1), the Evolutionary Algorithm fulfils the most requirements; the second evolutionary approach (Genetic Algorithm) features problems with the application on the IPS² resource planning, as the mutation of solutions easily causes circular movement.

The next compatible approach is Simulated Annealing; the combination with an Evolutionary Algorithm is purposeful. In case of the IPS² resource planning the fitness function abruptly increases if an additional process becomes realizable. Therefore Simulated Annealing enhances the possibility to cope with local optima of this discontinuous (noisy) fitness function.

	Implementation of restrictions	cope with noisiness	initial solution	speed	solution quality	possible hybridization	applicability
Evolutionary Algorithm	o	o	+	+	o	++	++
Genetic Algorithm	o	+	+	+	o	+	o
Simulated Annealing	+	++	--	o	+	++	++
Tabu Search	+	o	--	+	+	+	+
Greedy Algorithm	o	o	-	++	+	+	--
Ant Algorithm	++	+	+	-	+	-	+

++ very good, + good, o moderate, - bad, -- very bad

Table 1: Comparison of basic metaheuristics

Another alternative would be the integration of Tabu Search techniques, as they are easily implementable and work well on discrete, combinatorial problems. In order not to complicate the hybrid metaheuristic to be developed, the Tabu Search was not implemented additionally, but that could be done easily when larger problems justify an extensive hybrid metaheuristic.

3 THE HEURISTIC RESOURCE PLANNING APPROACH FOR IPS²

The Heuristic Resource Planning Approach for IPS² (HRPA-IPS²) consists of a hybrid metaheuristic (Figure 1) structuring the variances' application and defining the exit conditions. Within this metaheuristic the variances are applied independent from each other while including the intelligent use of the variances' specifics.

3.1 Hybrid metaheuristic

The optimization of an existing scheduling to integrate an additional job makes use of the IPS²-specific variances. The reasonable way to generate solutions for evaluation is the selective application of these variances consecutively to the relevant resources and processes.

These variances have to be structured according to their effectiveness and efficiency. Therefore the strategy of application ranks the variances according to the caused costs, preferring low cost variances. Additionally it ranks the resources and processes according to their optimization potential; those directly linked to a problem are preferred.

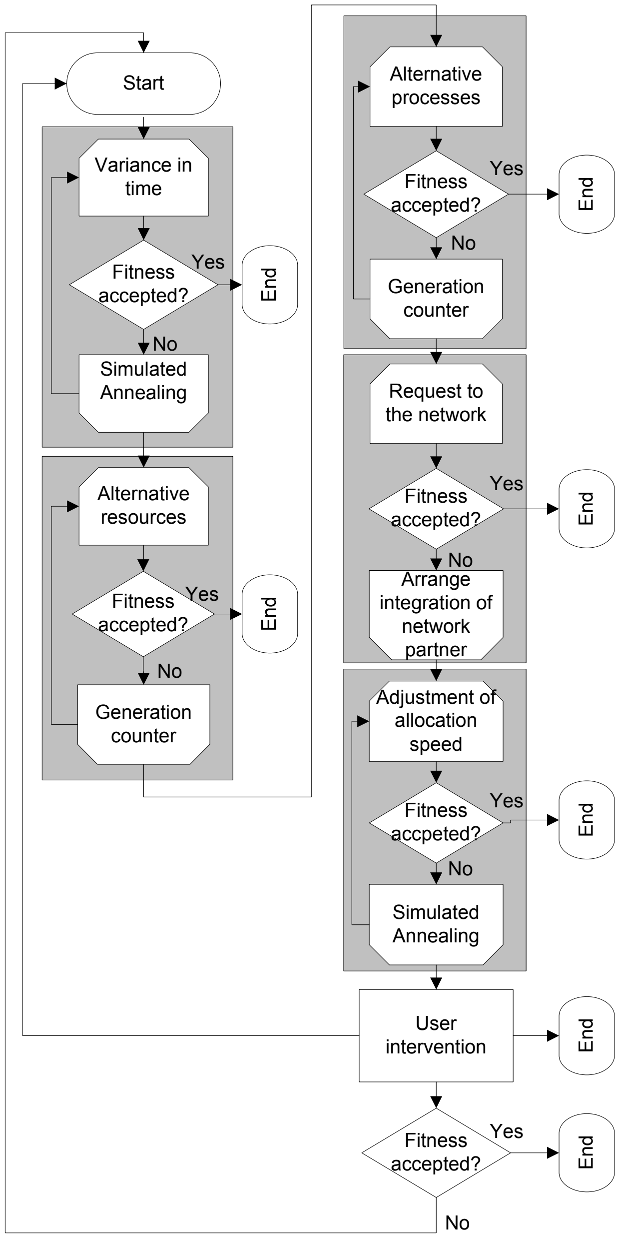

Figure 1: Structure of the hybrid metaheuristic

The variances are mainly categorized by the direct costs they cause. The application of the **variance in time** (i.e. postponement of processes) does not cause any direct costs. The use of **alternative resources** also causes no direct costs, if only unused, existing resources are considered; however it will cause some indirect costs, because e.g. an alternative worker is not as familiar with the job and thus takes longer. The use of **alternative processes** might cause some direct and indirect costs, as during the development already the most cost effective process was chosen for each task. To **request necessary resources to the network** will cause a significant amount of costs, as the external partners have to be included, coordinated and supported as well; also it is a very direct but slow way to replace a necessary resource. At least the **adjustment of the allocation speed** is considered; it often causes direct costs by using faster but more expensive means of transportation.

After each variance's application the fitness is checked to finally stop the complete optimization if the necessary fitness is reached.

Additionally break conditions are added to the inner loop of each variance to switch over to the next one. According to the complexity of the variances' application, these break conditions consider how broad and how deep one variance is used: how many applications of this variance are executed consecutively and up to which level of complexity (range of alterations) an improvement of the solution is supposable.

The application of the variance in time is easy to apply on the one hand, but comprises two degrees of freedom: the selection of the process to be rescheduled and the amount of time it is postponed. The consecutive postponement of several processes will be more effective in many cases, but along the variance's application the improvement of the solution becomes less supposable over time while making the overall scheduling more and more inefficient. Thus an evolutionary algorithm is combined with simulated annealing (see next chapter); the HRPA-IPS² makes use of the advantages of consecutive evolutionary algorithms but allows for passing local optima by a dynamic adjustment of the exit condition.

The same applies to the alteration of the allocation speed which keeps two more degrees of freedom besides the selection of the resource to be accelerated: resources can be accelerated by several means of transportation, additionally that can be applied to each journey of this resource. Again the consecutive acceleration of several resources might be more effective. Thus also an evolutionary algorithm is combined with simulated annealing. Nevertheless it is a much more cost-intensive variance and thus it is not evaluated as deep as the variance in time.

The last part of the hybrid metaheuristic includes the request to the user as a kind of interactive optimization. The user in some cases can decide beyond the initially planned variances and thereby enable a kind of optimization the approach itself cannot achieve. For example the user can phone to a customer to arrange an exceptional increase of the time variance and enable the further postponement of this process. Moreover he can raise the available maximum capacity for a resource (i.e. instruct overtime).

Then the user can abort the optimization, make use of his new variances by starting the same metaheuristic again, or switch over to the extended one. If there has not been found a solution yet, the metaheuristic is started again but extended by implementing the next stages of deepness in the variances' application. Therefore the intended number of generations is increased, the simulated annealing is slowed down and the Resource Identifying Heuristic (RIH, see next chapter) additionally examines one more degree of relationship.

3.2 Identifying the source of the problem

For the application of the variances within the hybrid metaheuristic (see next chapter) the sources of the planning problem have to be identified first. Therefore two heuristics are used:

The Process Identifying Heuristic (PIH) defines the search space for process related variances. It selects the critical processes as follows (pseudocode):

```
procedure PIH
    if resourceRequirement > resourceCapacity
    then resource ← "critical"
    if processEnddate > processDuedate
    then process ← "critical"
    if resource ∈ critical process
    then resource ← "critical"
    if process ∈ critical resource
    then process ← "critical"
end PIH
```

In that way it tags all delayed process, those processes using one or more critical resources, as well as the connected processes that also use a resource involved in a delayed process. To step over to the next degree of relationship to the initial problem source, this procedure can be applied twice (see recent chapter).

The search space for resource related variances is defined by the Resource Identifying Heuristic (RIH):

```
procedure RIH
    if resourceRequirement > resourceCapacity
    then resource ← "critical"
    if resource ∈ alternatives (critical resource)
    then resource ← "critical"
    if processEnddate > processDuedate
    then process ← "critical"
    if resource ∈ critical process
    then resource ← "critical"
end RIH
```

It selects the overloaded resources, their direct alternatives and all resources involved in critical processes. If a resource is less related to the critical resources, its replacement or acceleration has too low chance to solve the problem. To step over to the next degree of relationship to the initial problem source (see recent chapter), this procedure can be applied after the PIH.

3.3 Variances' application

All variances' applications are large scale optimization problems themselves, as each application step includes a whole scheduling (see chapter 1.1) and thereupon impacts all other processes and resources. So the search within each step also needs for individual metaheuristics.

Variance in time

The Process Identifying Heuristic (PIH) defines the search space. Afterwards an evolutionary algorithm optimizes this scheduling: For candidate solutions it chooses one of these processes and shifts it for a certain amount of time (within its variance in time). The EA stops if the necessary fitness or a predefined number of generations is reached. After this single optimization, the overall scheduling and thus the critical resources have changed. To deal with this the application of the variance in time is started again (inner loop). The break condition for the inner loop is modified by simulated annealing (SA), as ongoing shifting of processes becomes less effective during calculation but without SA the EA would not be able to pass local optima. Therefore the allowed fitness worsening is decreased by degrees. In addition the inner loop stops, when the delivery reliability or the overall efficiency becomes unacceptably bad. (Figure 2a)

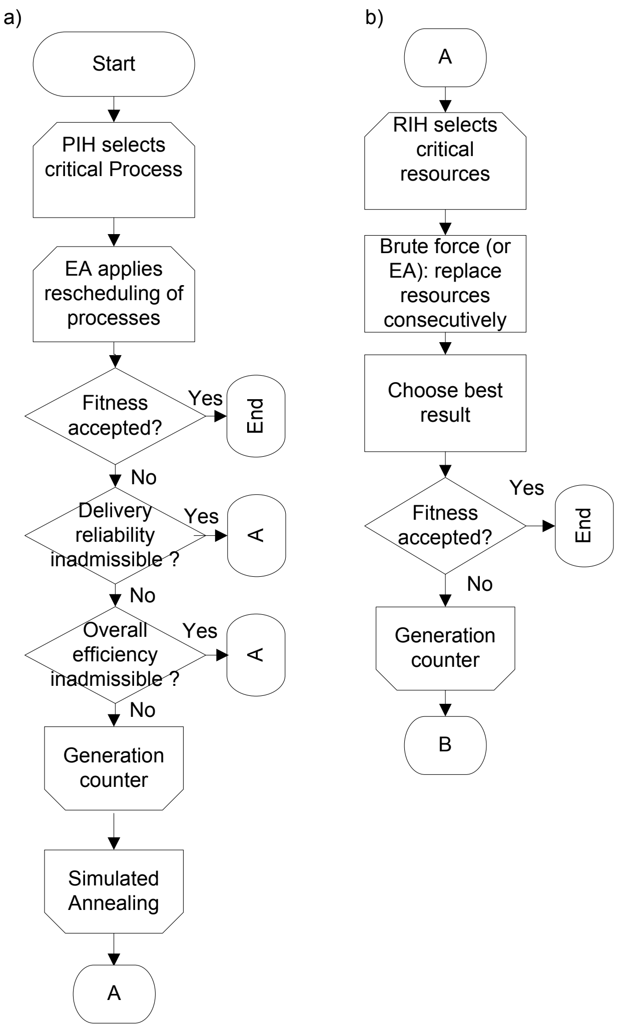

Figure 2: Application of the variance in time and the variance of resources

Variance of resources

Following to the search space definition by the Resource Identifying Heuristic (RIH) the combinations of replaceable resources are checked according to the achievable fitness. For normal scale problems and few available calculation time (of the overall optimization) the possible combinations are examined consecutively (brute force). If the main loop was already executed unsuccessfully and more alternatives have to be evaluated in depth, as well as for very large scale problems, that is done by an evolutionary algorithm instead.

After this single optimization, the overall scheduling and thus the critical resources have changed and the application of the variance of resources is started again (inner loop). The break condition for the inner loop is a predefined number of generations, as ongoing replacement of resources carries the risk of moving in a circle during calculation. (Figure 2b)

Variance of processes

In this case the PIH again defines the search space. Thereafter all combinations of alternative processes are checked according to the achievable fitness (brute force).

That is repeated for a small number of generations only (inner loop) as it has a wide and complex impact on the whole planning, and deeper analysis would cause extremely long calculation times without necessarily improving the result. (Figure 3a)

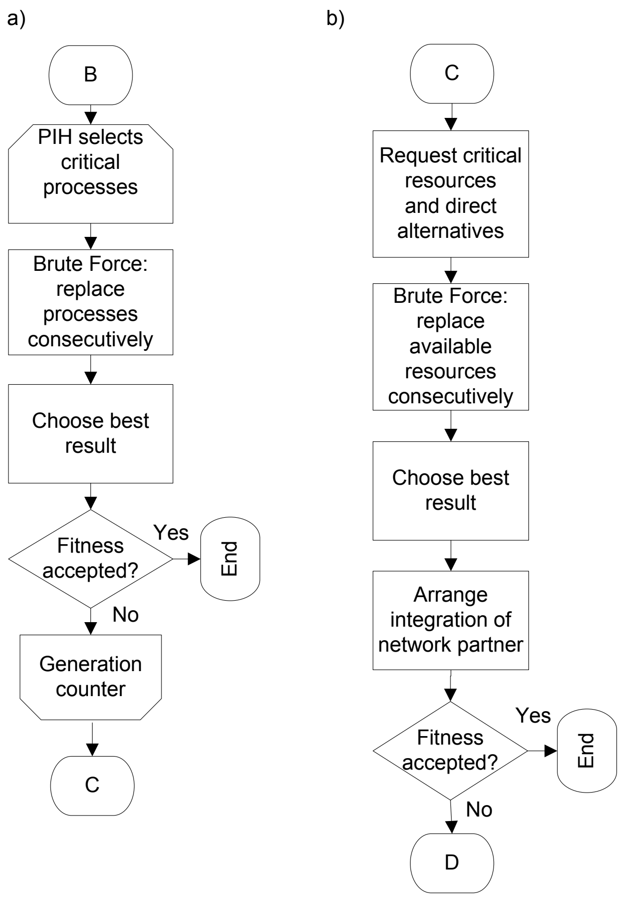

Figure 3: Application of the variance of processes and the service distribution

Service distribution

Here again the RIH is applied. Then all critical resources and their direct alternatives are requested to the network which includes e.g. customers, suppliers or sub suppliers. Further on all combinations of available resources are examined (brute force).

Requesting more resources less related to the critical ones would involve too much coordination effort while being to slow to enable the required real-time solution. Also this variance is not started again afterwards (no inner loop), as this would cause too long response time, too. (Figure 3b)

Variance of allocation time

Finally the adjustment of the allocation speed is executed for a reasonable calculation time.

The RIH at first tags the promising resources for acceleration. Afterwards an evolutionary algorithm optimizes the scheduling: For candidate solutions it chooses one of these resources, a journey between two processes and shifts it to another way of transportation. The EA stops if the necessary fitness or a predefined number of generations is reached. After this single optimization consequently the overall scheduling and the critical resources have changed. So an inner loop is implemented applying the variance of allocation time again. The break condition for the inner loop is modified by simulated annealing to pass local optima; therefore the allowed fitness worsening is decreased by degrees, whereas ongoing acceleration of resources becomes less effective but much more costly during calculation. (Figure 4a)

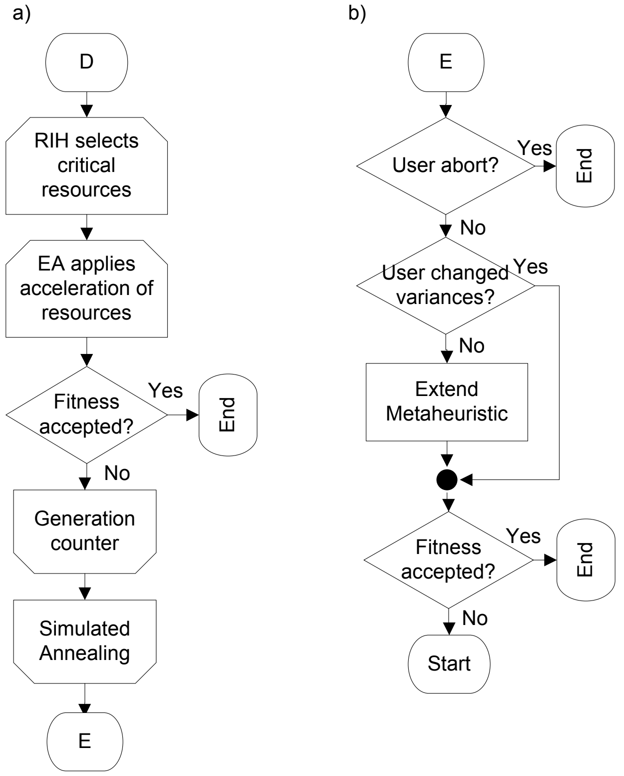

Figure 4: Application of the variance of allocation time and user intervention

After the application of all variances the user comes into action: He can abort the optimization manually or can modify some parameters / variances and start the same metaheuristic again. Alternatively he can start an extended metaheuristic on the same data. Therefore the intended number of generations is increased, the simulated annealing is slowed down; furthermore the PIH is applied before each RIH to additionally examine those resources involved in indirectly critical processes. (figure 4b)

3.4 Comparing optimization results

Basic requirement for every heuristic optimization is a calculable fitness function to compare solutions and move towards the optimum. Therefore the quality of a planning solution has to be measured by calculating key performance indicators (KPI). According to the three main objectives (delivery reliability, costs, work load, see chapter 1.3) at least three KPIs are needed.

Punctuality

The delivery reliability from the planner's point of view is represented by the punctuality. The punctuality z_p for each job is calculated by the ratio of process end date (end_p) and due date (due_p), each related to the current point in time t_i (equation 1a); in the best case z_p is 1, early finishing results in smaller, finishing too late in greater values. When combining these to the total punctuality ***z***, the single punctualities are weighted by an exponential function to put strength on large delays and reduce earliness effects (equation 1b). As $z_p>0$, the first term is between 1 and ∞ (Optimum=e). Thus the total punctuality ***z*** is greater than 0 and has the optimum 1.

$$z_p = \frac{end_p - t_i}{due_p - t_i} \qquad (1a)$$

$$z = \frac{1}{\left| \frac{\sum e^{z_p}}{n_p} - e \right| + 1} \qquad (1b)$$

Costs

As comparable relative costs the ratio of planned total costs ***c*** and the total costs of a new planning solution c_i are calculated (eq. 2):

$$ce = \frac{c}{c_i} \qquad (2)$$

Work load

The activity of all resources ***a*** is calculated by the ratio of cumulative process time (t_p) for all resources and the total possible resource working time (t_r), related to the current planning horizon and implying equal weighting of all resources. In the best case it is 100% (full use, no waiting); smaller values represent a lower work load. The overload of single resources is initially inadmissible; as an exception the planner can increase the maximum capacity of some resources and enable a work load > 1.

$$a = \frac{\sum t_p \forall r}{\sum t_r} \qquad (3)$$

Total fitness: weighted sum approach

After calculating the single KPIs they are combined to an overall KPI for the optimization result. The single terms normally tend to the optimum 1, while lower values represent worse KPIs.

$$f_i = w_1(t_i) \cdot z_i + w_2(t_i) \cdot ce_i + w_3(t_i) \cdot a_i \qquad (4)$$

The summation of the weights is 1. Furthermore the weights are adjusted dynamically according to the position within the planning horizon t_i: When the planning problem to be optimized is situated far in the future, so e.g. building up capacities is possible, costs are the main objective of the optimization. The absolute work load on the other hand has secondary importance, beyond costs, for the valuation of the optimization result, because the capacities can be adjusted to the workload. During the operative planning, which has to react on short-term tasks, e.g. due to a machine breakdown the delivery reliability for all jobs including the short-term tasks is much more important than costs or work loads.

Thus the planner can vary the focus of the planning between punctuality, costs and work load. The total fitness ***f*** is always > 0 and normally < 1; the greatest ***f*** represents the best solution. Only exceptionally a fitness > 1 can occur.

This situational combination of the three main KPIs allows reducing the optimization complexity as there is now only one objective: the optimization of the overall KPI.

4 SUMMARY

To deal with the multidimensional and multiobjective planning of service processes within Industrial Product-Service-Systems a real-time capable optimization strategy is needed. Therefore the related basic optimization problems and optimization metaheuristics were analyzed. This paper describes an approach of using an individual hybrid metaheuristic to optimize the resource planning. Therefore a combination of Evolutionary Algorithms, Simulated Annealing and Brute Force Search is used in conjunction with the structured application of the IPS²-specific variances.

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6 REFERENCES

[1] Levitt, T., 1969, The Marketing Mode, Pathways to Corporate Growth

[2] Cunha, P. F., Caldeira Duarte, J. A., 2004, Development of a Productive Service Module Based on a Life Cycle Perspective of Maintenance Issues, Annals of the CIRP, Vol 53/1, 13-16, ISSN: 0007-8506

[3] Tan, A. R., McAloone, T. C., 2006, Characteristics of strategies in Product/Service-System Development, International Design Conference – Design 2006, Dubrovnik – Croatia, May 15-18

[4] Matzen, D., Tan, A. R., Myrup Andreasen, M., 2005, Product/Service-Systems: Proposal for Models and Terminology, 16. Symposium "Design For X", Neukirchen, October 13-15,

[5] Arai, T., Shimomura, Y. 2005, Service CAD System – Evaluation and Quantification, Annals of the CIRP, Vol 54/1, 463-466

[6] Meier, H., Kortmann, D., 2007, Leadership – From Technology to Use, 14th CIRP Conference on Life Cycle Engineering, 159-163

[7] Meier, H., Krug, C. M., 2008, System for Planning of Resources in IPS²-Delivery, 41st CIRP Conference on Manufacturing Systems, Tokyo, Japan

[8] Meier, H., Krug, C. M., 2006, Strategische Kapazitätsplanung hybrider Leistungsbündel, PPS Management 11, 48-51

[9] Klamroth, K., 2009, Discrete Multiobjective Optimization, Evolutionary Multi-Criterion Optimization 5th International Conference, EMO 2009, Nantes, France, April 7-10, Proceedings ISBN 978-3-642-01019-4, 4

[10] Sathe, M., Schenk, O., Burkhart, H., 2009, Solving Bi-objective Many-Constraint Bin Packing Problems in Automobile Sheet Metal Forming Processes, Evolutionary Multi-Criterion Optimization 5th International Conference, EMO 2009, Nantes, France, April 7-10, Proceedings ISBN 978-3-642-01019-4, 246-260

[11] Datta, D., Deb, K., Fonseca, C. M., 2007, Multi-objective Evolutionary Algorithms for Resource Allocation Problems, Evolutionary Multi-Criterion Optimization 4th International Conference, EMO 2007, Matsushima, Japan, March 5-8, Proceedings ISBN 978-3-540-70927-5, 401-416

[12] Hutzschenreuter, A., Bosman, P., La Poutré, H., 2009, Evolutionary Multiobjective Optimization for Dynamic Hospital Resource Management, Evolutionary Multi-Criterion Optimization 5th International Conference, EMO 2009, Nantes, France, April 7-10, Proceedings ISBN 978-3-642-01019-4, 320-334

[13] Garcia-Najera, A., Bullinaria, J., 2009, Bi-objective Optimization for the Vehicle Routing Problem with Time Windows: Using Route Similarity to Enhance Performance, Evolutionary Multi-Criterion Optimization 5th International Conference, EMO 2009, Nantes, France, April 7-10, Proceedings ISBN 978-3-642-01019-4, 275-289

[14] Geiger, M. J., 2009, Multi-criteria curriculum based course timetabling - A comparison of a weighted sum and a reference point based approach, Evolutionary Multi-Criterion Optimization 5th International Conference, EMO 2009, Nantes, France, April 7-10, Proceedings ISBN 978-3-642-01019-4, 290-304

[15] Raidl, G. R., 2006, A Unified View on Hybrid Metaheuristics, Hybrid Metaheuristics, Third International Workshop, HM 2006 Gran Canaria, Spain, October 13-15, Proceedings ISBN 978-3-540-46384-9, 1-12

[16] Glover, F., Kochenberger, G. A. (eds.), 2003, Handbook of Metaheuristics, International Series in Operations Research & Management Science, Vol. 57, Springer, ISBN 978-1-4020-7263-5

[17] Blum, C., Roli, A., 2003, Metaheuristics in combinatorial optimization: Overview and conceptual comparison, ACM Computing Surveys 35(3), 268-308.

[18] Crescenzi, P., Kann, V., 1997, Approximation on the web: A compendium of NP optimization problems, Randomization and Approximation Techniques in Computer Science, International Workshop RANDOM'97, Bologna, Italy, July 11-12, Proceedings ISBN 978-3-540-63248-1, 111-118

[19] Talbi, E. G., 2009, Metaheuristics: from design to implementation, Wiley, ISBN 978-0-470-27858-1

[20] Vöcking, B.; Alt, H.; Dietzfelbinger, M.; Reischuk, R.; Scheideler, C.; Vollmer, H.; Wagner, D. (Ed.), 2008, Taschenbuch der Algorithmen, Springer, ISBN: 978-3-540-76393-2

[21] Zitzler, E., Laumanns, M., Bleuler, S., 2004, A tutorial on evolutionary multiobjective optimization, Metaheuristics for Multiobjective Optimisation, Springer, ISBN: 978-3-540-20637-8, 3-38

[22] Eiben, A. E., Smith, J. E., 2003, Introduction to Evolutionary Computing, Springer, ISBN: 978-3-540-40184-1

[23] Konaka, A., Coitb, D. W., Smithc, A. E., 2006, Multi-objective optimization using genetic algorithms: A tutorial, Reliability Engineering & System Safety, Vol. 91, Issue 9, 992-1007

[24] van Laarhoven, P. J., Aarts, E. H., 1987, Simulated Annealing: Theory and Applications, Springer, ISBN: 978-90-277-2513-4

[25] Martin, O. C., Otto, S. W., 1996, Combining simulated annealing with local search heuristics, Annals of Operations Research 63 (1), Springer Netherlands, ISSN 0254-5330

[26] Gendreau, M., 2003, An introduction to tabu search, Handbook of Metaheuristics, International Series in Operations Research & Management Science, Vol. 57, Springer, ISBN 978-1-4020-7263-5, 37-54

[27] Cormen, T., H., 2001, Introduction to algorithms, MIT Press, ISBN 0262032937

[28] Dorigo, M., Stützle, T., 2004, Ant colony optimization, MIT Press, ISBN 0-262-04219-3

Exploring Lightweight Knowledge Sharing Technologies for Functional Product Development

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Abstract

Moving away from offering just physical artifacts to becoming providers of functional products, or Product Service Systems (PSS), implies inevitable changes in the way engineering knowledge is identified and shared in a cross company environment. Capturing downstream knowledge assets and making them available to cross-functional teams becomes crucial to approach ill-defined problems in PSS design. The purpose of this paper is to investigate how Web 2.0-based knowledge sharing technologies may be used to support the design of functional products. The article, drawing on data from several industrial development projects in various segments, introduces the concept of “lightweight technologies” as a means to lower the threshold related to the sharing of downstream engineering knowledge assets. The paper points out potential benefits and challenges related to the adoption of a lightweight approach and provides examples of how tools like wikis, blogs or social bookmarking may be used to support functional product engineers.

Keywords

Product Service Systems, Functional Product Development, Knowledge Sharing, Engineering 2.0, Lightweight technologies, Cross-functional teams.

1 INTRODUCTION

In a traditional manufacturing situation, companies deal with the development, production and sales of goods in the form of physical products. When a product is sold, a company transfers its ownership to the customer and retains limited or no control over the later product life-cycle phases, except for sporadic maintenance interventions and for spare part replacement. In this context, production costs, timely delivery and technical quality are seen as main competitive factors. However, the emerging globalisation and the increasing market competitiveness are pushing companies to reconsider their business model, shifting from offering merely physical artefacts to introducing product-service combinations to able to satisfy increasingly sophisticated customer needs [1]. The basic principle of the Product Service Systems (PSS) [2] paradigm is to bring added value to the customer by offering the “functionality” or “performance” of the physical product as a mix of goods and services [3]. It also implies that the ownership of the physical product remains with the manufacturer or with the joint venture delivering the PSS [3], meaning that the function provider retains the extended responsibility of the product in the later life-cycle stages [4].

Brännström [5] defines functional products as combination of hardware, software and services. His study expressed a need for the companies integrating the development of hardware, software and services into complete offers, or functional products. In many discussions the least common denominator for the definition of a functional product is “improved performance through available ability” [6]. The current trend of offering this “functionality” leads to refer the development process as ‘Functional Product Development’ (FPD) [5-7].

Moreover, a single company rarely has all the knowledge required to deal with the development and supply of the mixed offer, therefore the development of functional products [7] is typically done in an Extended Enterprise (EE) [8-11] or Virtual Enterprise (VE) [8, 12-13] setting. Hence, FPD or PSS lead to a more complex organizational structure [14] with involvement of external stakeholders and multidisciplinary teams from the beginning of product planning to the development stage. This aspect radically changes the scope and objectives of the design activity [4,15]. Engineers and designers are requested to increasingly work in highly cross-functional, cross-disciplinary, cross-cultural, cross-located, and cross-organizational environments, thus these enterprise-wide teams have need of developing closer interactions with external stakeholders to gain a better understanding of the desired function to be developed. This new way of working demands engineers to make their knowledge available to a larger audience, as well as to use knowledge from more sources, compared to traditional product development situations. Such enterprise-wide teams, however, do not normally have a shared history of working together, neither a shared knowledge base nor methods/techniques to create, store and share information and experiences [15]. To provide effective support for knowledge identification, codification and sharing is a key objective to achieve successful PSS partnerships.

The design of functional products requires an enhanced understanding of the full range of life-cycle demands and needs in the earliest possible phases [7]. In this context, the availability of downstream knowledge, i.e. knowledge from the later life-cycle steps, becomes crucial to improve early-stage decision-making. This knowledge, however, is mainly tacit, owned by a wide range of people and dispersed in the extended organization. Making it available for the engineers, i.e. providing tools to capture, model, simulate and share this knowledge across organizational and departmental boundaries, represents a main issue in the design of PSS.

This continuously changing market context raises the interest of those companies participating in PSS development to create better knowledge sharing technologies that could allow them to stay ahead of the competition. A more lightweight, bottom-up approach to knowledge codification and sharing shows a serious potential for the creation of a collaboration environment where knowledge can flow smoothly and informally across functions and organizations [16-17], thus helping in building new communities, growing common understanding on the PSS concept and leveraging innovation capabilities and creativity across the corporate boundaries.

2 PURPOSE

Moving from the consideration that Web 2.0 technologies have shown to greatly enhance interactive information sharing and collaboration among communities on the World Wide Web, this paper aim to investigate how such methods and tools can complement existing knowledge engineering technologies and support better information management and knowledge sharing in an Extended or Virtual Enterprise context. The paper initially introduces the concept of “lightweight technologies” as a means to lower the threshold related to knowledge identification, codification and sharing of such downstream engineering knowledge. Further, it points out the potential benefits and challenges related to the adoption of this approach, providing examples of how tools like wikis, blogs or social bookmarking may be used to improve the knowledge flows across organizational and functional boundaries.

Although many contributions in literature describe how bottom-up lightweight technologies may be useful for education [18-19], human resource management [20, 35-36] innovation [21-22] and knowledge management [23-28] there are no clear statements about the benefits of using such technologies to support cross-functional teams designing functional products. The bottom-up approach shows potential in many domains; nevertheless no clear vision exists on how it may be beneficial for the design of e.g. an aircraft engine going to be sold as a function rather than merely a product. The following sections discuss principles, opportunities and challenges within the area of functional product development [7], thus outlining how a Web 2.0-based approach may enhance creativity and innovation in PSS or functional product design.

3 METHOD

This research is based on industrial case studies rather than in theory. The research strategy combines a case study approach [29] and ethnographic methods [30] to verify the approach close to technology and product development activities in industry. The paper draws on data from several industrial development projects related to products in various industry segments – ranging from the development of manufacturing tools and industrial drive systems, to aircraft engines and armoured terrain vehicles. The discussion has evolved in close collaboration with industrial companies and accessing empirical cases. A case study approach has been considered a good means to render a map of barriers, thus the key themes for the research. Several kinds of workshops, virtual meetings, and company visits have been performed during the data collection phase. Semi-structured interviews have been initially conducted with the scope of picturing the State-of-Practice in industry and to provide a solid context for the later data analysis stages. In the detailed data-gathering step, the researchers have explored the knowledge problems by means of in-situ observations, group interviews, in-depth interviews and through the analysis of working documents. The data gathering activity has involved about 50 people at different hierarchical levels, which include engineers, managers, and project leaders with knowledge on these projects, both from academia and from industry. The data collected from multiple sources allow the authors to integrate different perspectives and analyse the data under the lens of Web 2.0 to outline drivers and barriers related to the adoption of a more bottom up and lightweight approach in knowledge engineering to support functional product engineers.

4 KNOWLEDGE SHARING POTENTIAL OF THE LIGHTWEIGHT APPROACH

Traditionally, manufacturing industries have been using technologies like Product Data Management (PDM), Product Lifecycle Management (PLM), and Knowledge Based Engineering (KBE) systems for knowledge acquisition, knowledge sharing and intellectual property formalization. These technologies are characterized by a top-down structure, i.e. a centrally-controlled structure growing from a pre-defined concept that is refined in greater detail, adding additional subsystem levels, until the system is reduced to base elements. However, in a functional context, engineers are working to a lesser extent with pre-defined concepts and to a larger extent with ill-defined concepts, where they need to figure out what the “problem” actually entails. As they do so, they need to move back and forth between problem solving and prediction, collaborate with a multitude of actors across the value chain, and work in a network of loosely coupled companies and stakeholders that collaboratively interpret and define what customer value is and how it could most effectively be provided in the form of a PSS offer. A drawback of the “traditional” PDM/PLM approach when approaching this kind of issues may be found in these systems’ intrinsic rigidity and their relatively slow and resource-consuming development and deployment, partly due to the fact that the structure is defined “a priori” by the domain experts [31]. Furthermore, these tools normally lack support for the interaction process between the employees and are relatively ineffective in situations when instant feedback is needed during the knowledge creation process, thus not adequately supporting engineering teams when facing wicked design problems in a PSS situation.

For example, to design and produce an aircraft engine requires many organizations, customers, suppliers, research centres and external partners to collaborate and share each other’s knowledge, core competencies, and experiences in VE or EE settings. Typically, these geographically dispersed engineering teams operate in dynamic, multi-cultural, and highly unpredictable environments, using a diverse set of IT systems and collaborative technologies [15]. During the design and production stages, these virtual engineering teams need to collaborate consistently to share design information, know-how, and stakeholder feedbacks, etc. In the traditional way, the virtual engineering teams usually capture and store all the design information and knowledge in databases that are categorized by a predefined structure. These databases mainly cover formal (structured/explicit) communication such as internal corporate information, project documents, design drawings, lessons learned, best practices records, etc. However, they show limitations when a new engineer or another co-located team requires authentic information, expert help, or when there is a need to share ideas and knowledge for collective decision making, aggregate knowledge flows in the organization, search and retrieve quality information, and most importantly, capture informal (unstructured/tacit) knowledge that comes from the knowledge workers’ own experiences. This often leads to misunderstanding and ambiguities in facilitating knowledge sharing among global virtual engineering teams [32].

Hence in functional product development settings, it is fundamental to develop information systems with fully integrated and social interactive features that support collaboration and sharing of both formal and informal knowledge to provide added value for an organization [31]. The authors believe that lightweight technologies show a promising potential in this context with a focus on connecting people, synthesizing information, and supporting both formal and informal communications.

The shift towards the functional aspects of a product, seeing it as a value carrier as opposed to hardware, adds complexity and knowledge intensity to the design activity. The capabilities to make superior product development are derived from their ability to create, distribute and utilize knowledge throughout the product development process in a new and more efficient way [33].

Developing highly successful new products is possible through the integration of abilities of both upstream (e.g. innovation and design engineers) and downstream knowledge workers (e.g. manufacturing, maintenance, and field-service engineers) [33]. Here the issue is to capture the tacit knowledge that comes from the experiences of the individuals. This could be considered as the most powerful form of knowledge, but this kind of knowledge is difficult to articulate formally, difficult to communicate and share, shared only when individual are willing to engage in social interactions within the extended organization.

According to Bell [34], 80% of organizational knowledge is stored in people's heads, 16% is stored as unstructured data (Office documents, network folders, files and e-mail, internet sites) and only 4% stored as structured data (databases, data warehouses, cubes, XML data). These results indicate how important it is for an organization to capture and share tacit knowledge from their employees, and to deal with unstructured data in more effective ways.

This highlights the need for a different approach able to merge traditional technologies, with emergent social software technologies. These tools show completely different characteristics compared to corporate databases. Their structure evolves over time, they support a bottom-up approach and informal communication, they are flexible in nature and transfer the control to the users, and their development is quick and inexpensive [31,35]. These technologies with their underlying social features like co-authoring, people finding, tagging and community building, may provide easy and better conditions for knowledge sharing between virtual teams [32]. Furthermore they may support and encourage virtual engineering teams to engage [36], participate, cooperate and share their ideas, experiences, and feedback to simulate the knowledge flow and social networks across the organizations. Moreover, these technologies are relatively lightweight, if compared with the traditional ones, in terms of cost, time for implementation and maintenance.

External participation and knowledge sharing of corporate knowledge in virtual environments can yield benefits that include higher customer satisfaction, greater customer loyalty and reduced support costs, and continuous refreshment of knowledge [37]. Many organizations are starting to acknowledge the sharing potential of the lightweight approach, and believe that these technologies certainly support the traditional tools, like PDM, PLM and KBE systems, for effective virtual collaboration and knowledge sharing, and further they could help fill the social-technical gap in the organizations.

A recent initiative started by PTC to integrate a Social Product Development approach with PDM tools to be able to provide interaction and collaborative features among global design teams [38]. Some other examples of adoption of lightweight methods come from IBM, using Dogear social bookmarking, and Microsoft, using the Quest internal communications system, which includes a wiki system for effective knowledge codification and sharing in the organization [31].

5 CONTEXT AND MEANING OF THE LIGHTWEIGHT PARADIGM

Lightweight technologies [15,18-28, 31-32, 34-45, 47-48, 51-54] are intended as systems that require little time and effort to set up, learn, use, and maintain, i.e. aiming to lower the threshold for adopting. Moreover, they are intended to let the structure evolve over time and to support informal communication also in absence of physical proximity [15]. Lightweight technologies are built on the basis of technologies such as blogs, wikis, tag clouds, mashups, RSS, and social networks. They are not intended as a replacement for traditional heavyweight technologies, instead they aim to complement them, dealing with new problems in new way as required in the development of functional products or PSS. The following sections describe some of the major terms in the "lightweight" domain, followed by a detailed discussion of Engineering 2.0 opportunities and challenges.

5.1 Web 2.0

Web 2.0 is a term coined by Tim O'Reilly of Tech publisher O'Reilly Media in 2005 [39]. Web 2.0 represents the second generation in the Web's evolution that shows a significant move in the way people engaged on the web can create, store, edit, access, share and distribute the content to larger audiences compared to the first generation of web, Web 1.0.

Web 1.0 refer to static web pages, written solely in HTML, that only allowed users to read, and there was an hierarchical organization of producer/user, and lack of support for two-way communications [40]. In contrast, Web 2.0 refers to dynamic web pages that allow users to write, contribute, add value and act as co-developers, and this approach further facilitates creativity, collaboration, and sharing between users.

The O'Reilly Radar team [41] formulates Web 2.0 as *"…a set of economic, social, and technology trends that collectively form the basis for the next generation of the Internet—a more mature, distinctive medium characterized by user participation, openness, and network effects.".* Some of the most common Web 2.0 applications are blogs, wikis, social networking, tagging, RSS, mashups, podcasts, bookmarking, media sharing and collaborative editing, etc. O'Reilly stated that Web 2.0 does not have hard boundaries, but relatively have a gravitational core which specifies seven core characteristics of Web 2.0 [39]. These characteristics can be grouped into three areas: the use of the Web as a platform, the Web as a place to read and write rich content, and the social and collaborative use of the Web [42]. Web 2.0 is revolutionizing the World Wide Web in favour of a bottom-up and collective sense-making approach to knowledge sharing. Functional product or PSS design also require a more open approach to knowledge sharing, hence these tools are particularly interesting to be implemented in an industrial setting.

Strengths	Weaknesses
Facilitate virtual collaboration,co-ordination, co-operation. Capture “unstructured data” across the organization. Allow informal (tacit) knowledge capturing and sharing. Easy access to experts and network building. Leveraging open and bottom-up innovation. Simplified store, search, retrieval and access information. Allow for exchange of ideas with control access. Cost-effective, easy to set-up, use and maintain. Collective intelligence approach to knowledge creation.	Older workforce could resist adopting new technology. Ambiguity and misunderstanding in knowledge modelling. Proper maintenance is required, otherwise become vague. Demands active participation. Consistency on regular usage of tools. Management policies and organizational control. Possibilities for making mistakes in social interaction. Ineffectiveness in case of lack of consensus. Degree of transparency.
Opportunities	**Threats**
Collaboration among multi-disciplinary virtual teams. Shared knowledge base in enterprise-wide teams. Facilitate innovation practices and promote innovation. Build long term relationships and community building. Lightweight knowledge enabled engineering system. Incorporate social collaborative features to traditional systems. Improve knowledge baseline for new PSS projects.	Privacy of organizational knowledge assets. Losing control of intellectual property. Sharing confidential information with unauthorized persons. Security. Espionage.

Table 1: SWOT analysis of lightweight technologies adoption in an engineering context.

5.2 Enterprise 2.0

Many organizations have started to use Web 2.0 technologies in their working environment. McAfee [43] summarizes the rising interest in the use of these 2.0 tools for generating, sharing and refining information in the companies with the term Enterprise 2.0 [43]. Enterprise 2.0 is defined as “*the use of emergent social software platforms within companies, or between companies and their partners or customers”* [43]**.** McAfee uses the acronym SLATES to specify the six underlying components of Enterprise 2.0 technologies that guide the creation of Enterprise 2.0 software: Search, Links, Authoring, Tags, Extensions and Signals [43]. SLATES forms the basic framework for Enterprise 2.0, however it does not deny the higher level of Web 2.0 design patterns and business models [44] since it takes some of the prominent ideas of Web 2.0 like user generated content and peer production. The most common Enterprise 2.0 platforms are blogs, wikis, social networking, instant messaging, and mashups.

Several organizations are driving towards Enterprise 2.0 to enhance real time communication, community building, collective intelligence, and knowledge management. The major differences with new social tools from the traditional ones are that they can change enterprise knowledge flow by making it more open to public and more sociable [44]**.** It can create value by extracting the knowledge from various sources in the organization. A recent survey from McKinsey reported that 69 % of 1,700 executives perceived that their organizations gained measurable business benefits, including more innovative products and services, more effective marketing, better access to knowledge, lower cost of doing business, and higher revenues [45]. Another report on enterprise adoption of Web 2.0 tools in the workplace shows that between a third and one half of businesses are either already using or will soon be deploying Enterprise 2.0 tools in the workplace for better communication and collaboration practices [44].

5.3 Engineering 2.0

Functional product development is something different from traditional engineering and product development: The organization is different, the team composition is different, the objectives are different, and the responsibilities are different, since it is done in a virtual enterprise setting involving many industrial partners and external stakeholders. A major challenge is how to support knowledge workers to collaborate across the many boundaries of the virtual enterprise. The traditional CAD/PDM/PLM technologies, although playing a strong role in virtual enterprise collaboration, show some inefficiency in terms of time, cost and quality of knowledge sharing.

Larsson et al [15] coined the term Engineering 2.0 to indicate the use of Web 2.0 technologies in the fields of engineering and functional product development. These technologies specifically target globally dispersed engineering teams working in business-to-business situations of the VE kind where the available technology support for knowledge sharing still centers heavily on comparably heavyweight technologies like CAD, PDM, and PLM systems [15]. In this paper authors like to explore a set of Engineering 2.0 tools that could potentially enhance better knowledge sharing in functional product development. Blogs, wikis, social networks, RSS feeds, tagging, microblogs, instant messaging, discussion forums, social bookmarking, and mashups are few examples of these technologies. Some of these technologies might be positioned in between Web 1.0 and Web 2.0, but authors consider them because they believe that these technologies can help cross-functional virtual engineering teams in the context of functional product design. For example, microblogging can provide combination of synchronous and asynchronous communications, while instant messaging could provide an effective channel for immediate assistance, and a quick way of sharing files and triggering video/audio meetings.

5.4 Opportunities and Challenges of the Lightweight Approach

Lightweight technologies can provide easier platforms to connect virtual engineering teams through sharing their ideas, know-how and corporate knowledge with the support of existing enterprise artefacts. But achieving the benefits of these technologies will require cultural and behavioural shifts within an organization as described earlier. Hence, the adoption of a lightweight approach could create both pros and cons in internal and external environments of the enterprise. The authors use SWOT analysis to explain and summarize the opportunities and challenges of such an approach in a cross-functional engineering context. There are many different interpretations of a SWOT analysis, and in this paper authors considered Strengths and Weakness as a Now (or As-Is) situation and Opportunities and Threats as a Future (or To-Be) situation of a lightweight approach in an engineering context [46]. Table 1 below shows the outcome of the SWOT analysis on the application of lightweight tools in an engineering context.

6 ENGINEERING 2.0 FOR FUNCTIONAL PRODUCT DEVELOPMENT: A SCENARIO COLLECTION

This section discusses some of the most common Web 2.0 technologies from an engineering perspective, trying to outline how such technologies can be adopted in a PSS development context to support engineers in the knowledge sharing activity within the above-mentioned constraints and barriers. The main scope of this section is to point out how these technologies can be useful in a PSS context presenting examples of To-Be usage scenarios coupled with the issues and challenges related to their utilization. These scenarios are drawn both from observing real industrial cases through case study approach and theoretical findings from the functional product development or PSS research.

One of the most common Web 2.0 technologies is the **blog**. From a PSS perspective they show potential to be used as a platform for early feedback from external stakeholders and employees and allow them to engage in the discussion [22] on product and service offerings. On one hand, new ideas and findings on innovation projects could be presented to a larger audience as an entry in the weblog. On the other hand, stakeholders may easily comment and express their opinions, in a very informal mode. Such a two-way communication channel may be developed in a way that could make it possible to network and exchange knowledge between the organization and a larger customer base, thus allow capturing customer usage patterns, their needs and demands. The low level of formality associated with the tool may possibly lower the threshold for the documentation of personal experiences, thus giving people a chance to codify and share their practical and tacit knowledge with others.

Wikis have gained popularity in recent times as a means to gather collective knowledge about a topic and to share it with a large audience. Wikis have demonstrated good potential regarding knowledge sharing in an enterprise setting [47] and successfully used in several parts of the organization as a platform for both internal and external collaboration. From a PSS perspective, the benefits of the open authorship approach can be further leveraged, e.g. as a supporting tool that allows the different PSS stakeholders to gather and collaboratively define and refine best practices and lessons learned from the different life-cycle phases. Wikis can also be used as a space to collaboratively grow ideas for future products, letting stakeholders propose innovations and changes directly building from the ideas of the others. Its asynchronous nature, bottom-up and informal approach [47] may facilitate idea and experience sharing among the stakeholders, building a sort of informal corporate memory [48]. An alternative usage scenario for the wiki is in the area of service provision. They may be used as a shared platform to collect and manage knowledge on customer use, requirements, maintenance demands, know-how and more.

Social networks. Within a single company it is rare to find all the competences needed to develop real PSS combinations, since it requires a deep investigation of topics that are typically outside the technical horizon of the engineers [49]. As far as the complexity of the problem space increase, it becomes more important to involve people with different expertise in design, i.e. knowing who knows [50]. Very often, in fact, the problem related to the lack of specific knowledge in a given topic is addressed by networking with experts working in different enterprise contexts to raise the knowledge baseline and this is often done by merely relying on the “social ties” people in the PSS design team may have developed in their carrier. Social networking, in particular, may support newcomers in exploiting the network of connections that typically distinguish more experienced engineers, finding expertise inside and outside the company or, alternatively, stakeholders with similar interests across the organizational and functional boundaries, thus giving the possibility to form a work group and discuss ongoing issues and learn from each other [22]. It can ultimately foster collaboration among staff and external stakeholders allowing sharing of new ideas, needs, opportunities and updates on products and services.

RSS feeds allow employees to subscribe to their choice of content resources to get regular updates in a standardized format, which facilitates the pulling of relevant information to the employees instead of pushing it to them [51]. Organizations in a PSS context include many geographical dispersed teams functioning simultaneously and updating key information from projects, themes, and discussions into various databases, blogs, wikis, and forums. This may lead to information overload and difficulties to overlook and consolidate the updates from several vital sources. RSS feeds, with its Interactive and dynamic nature, can help employees in getting the right information at the right time in the right place [51]. Organizations of the VE kind may create RSS pages to accumulate all updates from various databases that are specifically customized for the employees’ needs and can help them to get an overview of the hot topics in the organizations. Alternatively, they could allow updating of stakeholders on issues of their interest that can enhance decision-making in between organizations. In addition, it can potentially reduce email overload [51] and save time by speeding up the dissemination of information among staff and external stakeholders.

Tagging enables the generation of user-generated taxonomies (i.e folksonomies) that basically categorizes the content with keywords or tags for easy searching and retrieval. In a typical PSS environment, different organizations have different ICT policies and databases, forcing engineers to store documents in a formal and restrictive hierarchical system that does not allow flexibility in modelling complex information and knowledge [31]. This can cause misinterpretations and ambiguities when other staffs tries to retrieve the information from traditional databases since they neither have the same technical background, nor a shared history of working together. Using tagging practices, PSS engineering teams can organize their content or documents in the most comfortable way for the teams likely per customers, competitors, projects, product types, maintenance and service offerings. This can help other engineering staff and business partners to locate and fetch information or documents easily by referring their tags or by a tag search function. Additionally, it is possible to retrieve specific content from different sources tagged in the same way. Tags can be used in internal blogs, wikis and collaborative portals of the organizations for easy retrieval and sharing of information. From a PSS perspective, this practice can leverage the collective wisdom of engineers and improve the way information and knowledge sharing takes place among employees and external stakeholders. Further, organizations can consistently update their taxonomies based on the popular tags from tag clouds, hit ratios and context [52].

Social bookmarking is a method to store, organize and share bookmarks of web content with the help of metadata in the form of keywords or annotations. Engineers in a PSS context often deal with complex problems, and functional related research topics. They frequently require saving their search information for easy access and retrieval in the future. Furthermore, they need a shared platform for collective knowledge sharing among multi-disciplinary teams to come up with innovation solutions. From a PSS perspective, social bookmarking enables global engineering teams to possibly search and find the experts on specific product related topics based on informal browsing of bookmark collections for external help in problem solving. It also facilitates to locate the people with similar interests in the projects, enabling them to group as a team, and outline shared bookmarks by a group tag. In a PSS context, engineers may get informed of significant new content with RSS feeds that allow easy subscription of a bookmark collection belonging to a specific tag, keyword or individual. Research engineers from various organizations can share their research with peers that allow others to rate and review to decide on usefulness of resources [19]. All these practices nurture communities of practice [53] between enterprises, thus could improve information and knowledge sharing in functional product development.

Microblogs allow users to share brief text updates, web links, photos or audio clips to a restricted group by the user choice. As mentioned earlier, engineers in the PSS context take part in multi-disciplinary teams working at different locations around the world. Engineers with similar interest in a specific subject can group together and share innovative sources of ideas, quotes, and links that may allow others to give focused and concrete feedback. From a PSS perspective, microblogging may act as an informal communication channel for collaborative work that can yield communication productivity and lower the threshold for knowledge sharing compared to email, instant messaging and forums [54]**.** Its people-centric nature can facilitate virtual discussion on ongoing issues or functional requirements among business partners that possibly nurture the relationships among employees, customers and partners. On the other hand, it can help engineers to locate and follow experts in a VE setting, to allow them to ask questions and get answers that can create a learning experience and foster professional connections.

Instant messaging is a text-based communication medium for connecting users in real-time. The PSS context includes different organizations and external stakeholders, and since engineers in a PSS context deal with complex problems in their everyday work, they often need to engage in real-time communication to get quick access to help, suggestions or feedbacks. From a PSS perspective, engineers in the virtual enterprise network can use instant messaging for short one-to-one conversations and to escalate immediate queries and clarifications [54] on technical difficulties, functional needs, etc. It can enhance the sense of community and accessibility that facilitate collaborative learning environments [19] across PSS engineering teams. Moreover, it can helpful for coordinating unstructured group meetings and scheduling tasks of engineers within a company or with external parties. Although microblogging provides both synchronous and asynchronous ways of communication, instant messaging, by adding more enterprise features, can enhance virtual collaborative learning environments among PSS engineering teams.

Discussion forums allow users to post questions for debate to find helpful answers. PSS engineering teams require long-term commitments throughout the product lifecycle. They need easy-to-use platforms where to discuss certain issues over a prolonged period. From a PSS perspective, forums could allow engineers to discuss on certain critical issues among business partners in the early stages of product development, and they could also be useful for heavily moderated topical conversations over a prolonged period [54] for the internal and external arguments. Using forums in the PSS environment can create opportunities to come up with new solutions to the problems or get feedbacks from technical experts in the various life phases of the product. Furthermore, forums may be helpful for bottom-up innovation with regard to new products and services that can possibly build cooperation and association among organizations and business partners to enhance collaborative knowledge exchange [28].

7 CONCLUDING REMARKS AND FUTURE WORK

This paper has taken an important step towards exploring the application of Web 2.0 technologies in the area of Functional Product Development, introducing and exemplifying the concept of Engineering 2.0, intended as a more bottom up and lightweight knowledge sharing approach, able to complement CAD/PDM/PLM systems in the early product development stage when dealing with the design of a product-service combinations in a cross-functional and Virtual Enterprise setting.

The research work has outlined that existing knowledge sharing systems are not supporting in an adequate way the capturing, codification and sharing of cross-functional knowledge in PSS design. The authors believe, therefore, that adding social features to these technologies may improve the knowledge sharing potential of existing “heavyweight tools”. Lightweight technologies can add further support to the heavyweight systems, hence leveraging global communication and collaboration in a functional product development or PSS context.

Although such technologies, methods and tools look promising to leverage the knowledge baseline of functional product innovation projects, their uptake in industry is limited. The discussion with the industrial partners has outlined several issues that have to be addressed both from a process and tool perspective before a wide adoption of such tools may be achieved:

Active user participation. Web 2.0 tools are intended as spaces where people may grow their knowledge and understanding through interaction with other people sharing the same interests on a topic (rating, commenting, replying to feedbacks). The lack of user participation in the discussion will eventually spoil the innovative power of the technology.

Leakage of proprietary knowledge. Letting the information flow across the organization in such an open mode can have negative consequences on a company’s proprietary and core knowledge, thus strict policies concerning dissemination of sensitive, proprietary information outside the company may be required. Using RSS feeds, for instance, confidential information can be pushed to unknown subscribers.

Information quality. One of the major problems relates to information quality. Web 2.0 tools are typically dominated by the loudest and most persistent voices, leaning towards personal opinions and interpretations rather than verified facts.

Lightweightness. Over time, as far as the information and knowledge managed by the lightweight platform increases, noise and spam increases as well, leading to a situation where the system is no longer lightweight, but rather cumbersome to navigate and poorly reliable. The risk of duplicated information is also relevant and may generate confusions and errors if not accurately managed.

From a process perspective, future research need to consider the importance of lightweight technologies in PSS or FPD context in considerations to industrial obstacles and defining the kind of working modes that these technologies able to support cross-functionality.

One of the advantages related to the bottom-up approach is that it can allow to overcome the traditional symptoms – a corrective actions working mode – moving towards an approach where problems can be avoided by recognizing in advance the root cause of the problems.

Eventually, the capability to turn tacit knowledge into explicit, and to make it available across functions and projects is still to be assessed. At this point, an Engineering 2.0 demonstrator is under development, in collaboration with the Swedish manufacturing industries, to collect feedbacks on the use of bottom-up and lightweight technologies for cross-functional knowledge sharing in a cross-company design situation.

8 ACKNOWLEDGMENTS

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9 REFERENCES

[1] Oliva, R., Kallenberg, R., 2003, Managing the Transition from Product to Services, International Journal of Service Industry Management, Vol. 14, No.2, pp. 160-172.

[2] Mont, O., 2002, Clarifying the Concept of Product-Service System, Journal of Cleaner Production, Vol. 10, No.3, pp. 237-245.

[3] Baines, T.S., Lightfoot, H.W., Evans, S., et al., 2007, State-of-the-art in Product-Service systems, Journal of Engineering Manufacture, Vol. 211, pp. 1543-1552.

[4] McAloone, T.C., Andreasen, M.M., 2002, Defining Product Service Systems, Design for X, Belträge Zum 13 Symposium, Neunkirchen, 10-11 October.

[5] Brännström, O., 2004, Market Offer Development: Industrial Experiences in a Business-to-Business Context, Ph.D. thesis, Luleå University of Technology, Luleå, Sweden.

[6] Löfstrand, M., Larsson, T.C. et al, 2005, Demands on Engineering Design Culture for Implementing Functional Products, International Conference on Engineering Design (ICED), Melbourne, 15-18 August.

[7] Isaksson, O., Larsson, T.C. et al, 2009, Development of Product-Service Systems: Challenges and Opportunities for the manufacturing firm, Journal of Engineering Design, Vol. 20, No.4, pp.329-348, August.

[8] Browne, J., Zhang, J., 1999, Extended and Virtual Enterprises - similarities and differences. International Journal of Agile Management Systems, Vol. 1, No.1, pp. 30-36.

[9] Kanter, R.M., 1999, Change is everyone’s job: Managing the extended enterprise in a globally connected world, Organization Dynamics, Vol. 28, No.1, pp. 7-23.

[10] Ericksen, P.D., Suri, R., 2001, Managing the Extended Enterprise, Purchasing Today, Vol. 12, No.2, pp.58-63, February..

[11] Boardman, J.T., Clegg, B.T., 2001, Structured engagement in the extended enterprise, International Journal of Operations & Production Management, Vol. 21, No. 5/6, pp. 795-811.

[12] Davidow, W.H., Malone, M.S., 1992, The Virtual Corporation: structuring and revitalizing the corporation for the 21st century, Harper Business, New York, NY.

[13] Hardwick, M., Bolton, R., 1997, The Industrial Virtual Enterprise, Communications of the ACM, Vol. 40, No.9, pp. 59-60.

[14] Matzen, D., Tan, A.R., Andreasen. M.M., 2005, Product/Service-Systems: Proposal for Models and Terminology, 16.Symposium, Design for X” Neukirchen, 13-14 October.

[15] Larsson, A., Ericson, Å., Larsson, T., Randall, D., 2008, Engineering 2.0: Exploring Lightweight Technologies for the Virtual Enterprise, Proceedings of the 8th International Conference on the Design of Cooperative Systems, COOP 08, Carry-le-Rouet, France, 20-23 May.

[16] Björk, J., Magnusson, M., 2009, Where Do Good innovation Ideas Come From? Exploring the Influence of Network Connectivity on Innovation Idea Quality, Journal of Product Innovation Management, Vol. 26, No .6, pp. 662-670.

[17] Surowiecki, J., 2004, The Wisdom of Crowds: Why the Many Are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies and Nations, Doubleday, New York.

[18] Anderson, P., 2007, Whats is Web 2.0? Ideas, Technologies and Implications for Education, JISC Technology and Standards Watch, February.

[19] Grosseck, G., 2009, To use or not to use Web 2.0 in higher education?, Procedia Social and Behavioral Sciences, Vol. 1, No.1, pp.478-482.

[20] Martin, G., Reddington, M., Kneafsey, M.B. et al., 2008, Web 2.0 and Human Resources: A Discussion Document, CIPD, Research Insight, June.

[21] Schreuder, M., 2009, Using Web 2.0 to support the innovation process, Vrije Universiteit Amsterdam.

[22] Radziwill, N., Duplain, R., 2008, A Model for Business Innovation in the Web 2.0 World, In Lytras, M.D. et al. Eds., Web 2.0: The Business Model, Springer, pp.75-88.

[23] Levy, M., 2009, Web 2.0 Implications on Knowledge Management, Journal of Knowledge Management, Vol.13, No.1, pp.120-134.

[24] Hawryszkiewycz, I.T., 2007, Lightweight Technologies for Knowledge Based Collaborative Applications, The 9th IEEE International Conference on E-Commerce Technology and the 4th IEEE International Conference on Enterprise Computing, E-Commerce, and E-Services, pp. 255-264.

[25] Shimazu H., Shinichi K., 2007, KM2.0: Business knowledge sharing in the Web 2.0 age, NEC Technical Journal, Vol. 2, 13 February.

[26] Bibikas D., Kourtesis D., Paraskakis I., Bernardi A., Sauermann L., Apostolou D., mentzas G. and Vasconcelos A.C., 2008, A socio-technical approach to knowledge management in the era of Enterprise 2.0: The case of Organic.

[27] Sotirios. P., Alya A.S., 2009, Determinants of Knowledge Sharing Using Web 2.0 Technologies, Journal of Knowledge Management, Vol. 13, No. 4, pp.52-63.

[28] Scherp A., Schwagereit F., Ireson T., 2009, Web 2.0 and Traditional Knowledge Management Processes, In: KSM2009 1st Workshop on Knowledge Services & Mashups, at 5th Conference Professional Knowledge Management, Solothurn, Switzerland.

[29] Yin, R.K., 1994, Case study research: Design and methods, 2nd edition, Sage, Thousand Oaks.

[30] Blomberg, J., Giacomi, J., Mosher, A. and Swenton-Wall, P., 1993, Ethnographic Field Methods and their Relation to Design, In Schuler, D. and Namioka, A. (Eds.) Participatory Design: Principles and Practices, Hillsdale, NJ: Lawrence Erlbaum, pp. 123-155.

[31] Patrick, K., Dotsika, F., 2007, Knowledge Sharing: developing from within, The Learning Organizations Journal, Vol. 14, No.5, pp. 395-406.

[32] Lewkowicz, M., Wijnhoven, F., Draghici, A., 2008, Misunderstandings in Global Virtual Engineering Teams: Definitions, Causes and Guidelines for Knowledge Sharing and Interaction, In Bernard, A., and Tichkiewitch, S. Eds., Methods and Tools for Effective Knowledge Life- Cycle –Management, Springer, pp.145-157.

[33] Hong, P., Doll, W.F., Nahm, A.Y., Li, X., 2004, Knowledge Sharing in Integrated Product Development, European Journal of Innovation Management, Vol.7, No.2, pp.102-112.

[34] Bell, S., 2006, Lean Enterprise systems: Using IT for continuous improvement, John Wiley & Sons, Hoboken, New Jersey, USA, pp.271.

[35] Payne, J., 2008, Using Wikis and blogs to improve collaborations and knowledge sharing, Strategic HR Review, Vol.7, No.3, pp.5-12.

[36] Martin, G., Reddington, M., Kneafsey, M.B., Sloman, M., 2009, Scenarios and Strategies for Web 2.0, Journal of Education + Training, Vol.51, No. 5/6, pp.370-380.

[37] Apostolou, D., Sakkas, N., Mentzas, G., 1999, Enabling Knowledge Sharing in Supply Chain Management: A Case Study in the Wood Furniture Sector, Proceedings of the 5th International Conference of the Decision Sciences Institute, Athens, Greece, 4-7 July.

[38] Shoemaker, T., 2009, Social Networking and Product Development, Cadalyst, 23 July, browsed on 17 September.

[39] O'Reilly, T., 2005, What is Web 2.0: Design Patterns and Business Models for the Next Generation of Software.

[40] Cormode, G., Krishnamurthy, B., 2008, Key Differences between Web 1.0 and Web 2.0, AT&T Labs-Research, 13 February.

[41] Musser, J., O'Reilly, T., 2006, Web 2.0 principles and Best Practices, O'Reilly Radar, http://oreilly.com/catalog/web2report/chapter/web20_report_excerpt.pdf, November.

[42] Platt, M., 2007, Web 2.0 in the Enterprise, The Architecture Journal, Journal 12, July.

[43] McAfee, A., 2006, Enterprise 2.0: The Dawn of Emergent Collaboration, MIT Sloan Management Review, Vol. 47, No. 3, pp. 21-28.

[44] Hinchcliffe, D., 2009, The Year of the shift to Enterprise 2.0, Enterprise Web 2.0 blog, ZDNet, http://blogs.zdnet.com/Hinchcliffe/?p=382, 15 May.

[45] Bughin, J., 2009, How Companies are benefiting from Web 2.0?, McKinsey Global Survey Results, June.

[46] Swinton, L., 2004, How to do a SWOT Analysis, CSM Group 2004-2005, http://www.customerservicemanager.com/swot-analysis.htm.

[47] Grace, T.P.L., 2009, Wikis as a Knowledge Management Tool, Journal of Knowledge Management, Vol. 13, No.4, pp.64-74.

[48] Kalny, O., 2007, Enterprise Wiki: An Emerging Technology to be considered by the AEC Industry, AECbytes Viewpoint, Issue. 31, http://www.aecbytes.com/viewpoint/2007/issue_31.html, 19 March.

[49] Morelli, N., 2006, Developing new product service systems (PSS): methodologies and operational tools, Journal of Cleaner Production, Vol. 14, No. 17, pp. 1495-1501.

[50] Groth, K., 2004, On knowing who knows – An alternative approach to knowledge Management, Ph.D. thesis, Royal Institute of Technology, Stockholm.

[51] Kreutz, C., 2007, An Email alternative: Four dimension of feeds (RSS) in organizations, Crisscrossed blog, http://www.crisscrossed.net/2007/08/10/an-email-alternative-four-dimension-of-feeds-rss-in-organizations/, 10 August, browsed on 16 November 2009.

[52] Ramamoorthy, A., 2007, Corporate Tagging for Information Management through Work Place Democracy, The Satyam & Microsoft Synergy, 30 October.

[53] Millen, D., Feinberg, J., Kerr, B., 2005, Social Bookmarking in the Enterprise, ACM Queue, Vol. 3, Queue.3, 9 (Nov.2005), pp. 28-35.

[54] Mayfield, R., 2009, Enterprise Microblogging Whitepaper, Socialtext, September.

A Reference Model for Analysing Automotive Service Formats

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Abstract

In recent years, the automotive service sector has been affected by various trends. In order to stay successful companies that offer automotive services have to consider these developments by adapting their existing service formats. Therefore, a situation analysis and the derivation of future requirements resulting from trends are necessary.

This paper introduces a reference model for the description and analysis of automotive service formats. The reference model is divided into five dimensions: organisation, product, process, resource and market. On that basis possible strategic fields of action are derived. Finally, the application of the reference model is demonstrated for the automotive service format of a so called Fast Fitter.

Keywords

Automotive Service Formats, Service Analysis, Automotive Service, Service Reference Model

1 INTRODUCTION

Services in the automotive industry include all activities that create benefits for customers over the life cycle of cars [1]. Within the automobile value chain, automobile services can be situated between the car manufacturer and the consumer [2]. Thus, automotive service companies act as important intermediaries between them.

With a view on the life cycle stages automotive services can be divided into “pre-sales”-, “sales”-, and “after-sales”-services [3]. The two former categories are focusing on sales-promotional and sales-supporting activities, e.g. financing, advice for the product choice or configuration. The latter category (“after-sales”) includes all activities ranging from the usage phase to the end-of-life-stage, such as maintenance, spare part (management) or recycling.

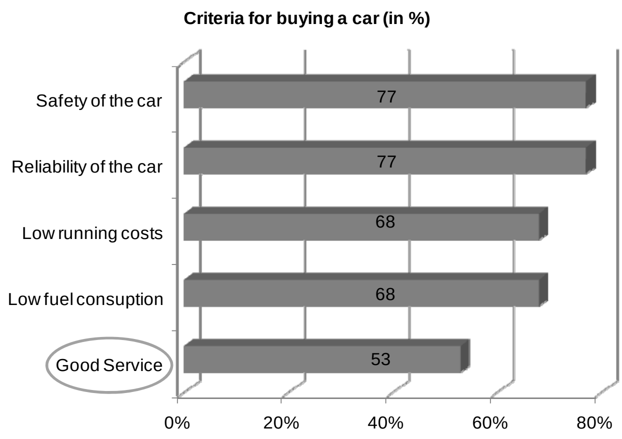

Figure 1: Criteria for buying a car [4]

With an average of twelve years, the usage phase of cars is the longest stage within an automotive life cycle [5]. Thus, services have a high relevance for the customer satisfaction and loyalty. For instance, for more than half of the people owning a driving license, a good service offer is an important reason for buying a brand-name car (Figure 1). Furthermore, services are important for the differentiation from competitors [4, 6].

The economic success of the automotive industry is crucially determined by after sales services due to decreasing turnovers and margins for the sale of new cars in consequence of high competition as well as substitutable cars. Even if the major turnover of car dealers is inducted by the selling of new and used cars, after sales services (e.g. maintenance, retail and car accessory sales) contribute the most to the results (Figure 2).

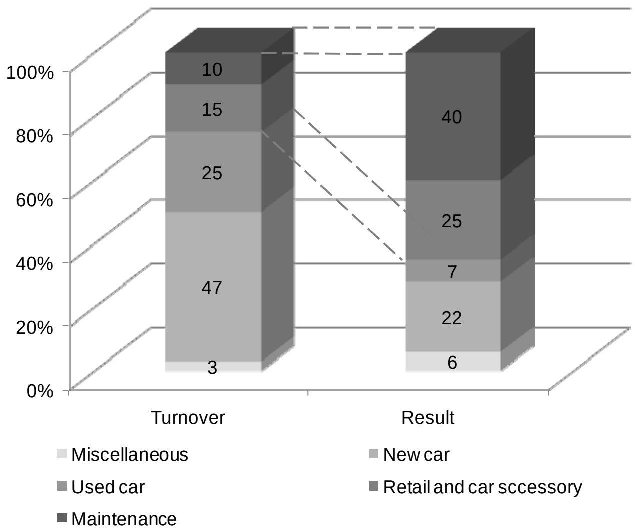

Figure 2: Relevance of after sales service in the automotive industry [7]

The automobile service sector is influenced by a variety of trends, which have to be considered. These trends are shown in Table 1. Thereby, various interdependencies are inherent.

Economic: Increased competition, decreasing service market volumes due to increased car quality and thus extended service intervals, price sensitivity due to increased living and car costs as well as a heightened savings rate, etc.
Political: Liberalisation of the service market by the group exemption regulation (GVO) 2002 and thus changed market conditions for independent car dealers and car workshops as well as component suppliers by changed basic conditions, e.g. concerning the multi-brand service, the location clause, the spare parts supply and the supply with technical car information. All these factors lead to increased competition, etc.
Socio-cultural: Changed purchase and customer behaviour (e.g. online-shopping, heightened demand on quality), shifted priorities (e.g. holiday and health is more important than car ownership, individuality), altered mobility behaviour (e.g. car sharing as a concept for using instead of buying a car), ageing society resulting in the shortage of skilled workers, changed way of life and working, etc.
Technological: New engine technology, increasing electronic components, shorter product life cycles lead to an increasing variety and an increasing car complexity, etc.
Ecological: Increasing environmental impacts caused by world traffic, increasing ecological awareness of car drivers, increasing political and legal measures for the reduction of environmental pollution by car, etc

Table 1: Relevant trends for the automotive service sector

In order to stay successful automotive service companies have to consider the depicted challenges and changes by adapting existing or developing new service strategies and service formats. Thereby, a service format comprises a group of service companies with the same business objectives. These are determined by the needs of their selected target group. A service format covers the structure, dimension and objective of an automotive service company [3].

As automotive services are provided within a socio-technical system and influenced by such manifold trends as shown in Table 1, its analysis requires an interdisciplinary approach. Some of the mentioned trends affect each other; some of them are mutually exclusive. Thus, a partial view on one trend or a local analysis and optimisation focussing only on one trend is not helpful. Equivalent to the planning and development of a physical product, a systematic and holistic situation analysis of existing service strategies and formats is essential. Requirements resulting from trends and future challenges need to be identified in the first step of a systematic planning process. In the second step, these requirements are to be analysed with regard to the structure, dimension and objective of existing automotive service companies. On this basis, strategic fields of action within service formats can be derived (see chapter 4).

Alongside this multi-disciplinary background, the main question is how to process a holistic situation analysis efficiently in order to ensure high-quality service strategies and formats. The planning and development process for the automotive service sector – and therefore also its analysis – are lacking in formalized processes, models and methods. Thus, adequate approaches and models are necessary in order to improve this procedure, resulting in more professional services.

A reference model for the systematic and efficient description and analysis of automotive service formats is required. Such a reference model should provide the input

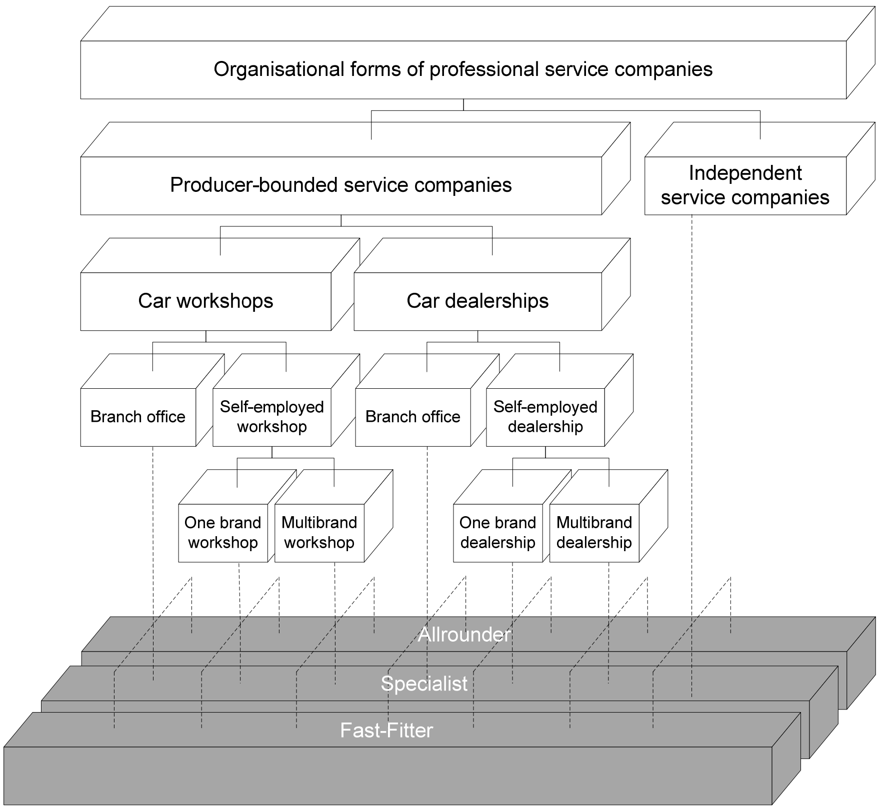

Figure 3: Form of organisation for service formats in the automotive industry

for an effective and goal-oriented adaptation of service formats and serves as a productive method for analysing automotive services.

2 PROVIDERS IN THE AUTOMOTIVE SERVICE SECTOR

Automotive services are provided by service companies which are mostly car dealerships ("pre-sales", "sales" and "after-sales") and car workshops (only "after-sales"). In general, these service providers can be divided into commercial and private providers.

Private providers include those repair- or maintenance operations that are done by oneself or by friends and acquaintances (Do-it-yourself: DIY). Illegal employment is ascribed to this group, too. In summary it makes up a market share of 8% [8].

The focus of this paper is on commercial providers that can be subdivided into producer-bound service companies (authorized dealers and car workshops) and independent workshops. This means that producer-bound companies are integrated into a super-ordinated distribution, marketing and service system of a car, component or retail manufacturer. Currently, the market is still dominated by producer-bound service companies, which have a market share of 55 % [8].

In a further step, producer-bound service companies can be divided into car dealerships and car workshops as shown in Figure 3. Both could be distinguished by their ownership. Either the service company is a branch office of the manufacturer or a self-employed service company. The latter one can also be divided into service companies that serve only one or multiple brands [2]. Finally, service formats can be differentiated in:

- *Allrounder:* This service format must cover full service in order to realise the promised performance and warranty bounds as well as goodwill gestures of the manufacturer. The strengths of the Allrounder can be found in the possibility to handle more complex and car-specific components such as the power train and electronics. Continuously, increasing technical complexity make high demands on the equipment and qualification of workshops. Here, authorized car workshops can draw upon full support and the know-how of the manufacturer.
- *Fast Fitter:* The target groups of Fast Fitters are all car classes and brands with an age of 4 to 15 years as well as price-sensitive customers who own cars of this segment by majority. Fast Fitters focus on selected car brands, as a general rule high-volume brands, and the operation areas are low-tech-workings that are easy to calculate, e.g. brakes, shock absorbers, tires and aluminium wheels or oil change. These need fewer resources, e.g. expensive equipment or specialized staff. Due to better cost structures Fast Fitters can often offer these services at a cheaper rate than *Allrounders*. One disadvantage is that less common cars as well as more complex maintenance workings of the engine, electrics or gear unit can possibly not be handled.
- *Specialists:* Mechanical service operations, such as repair of shock absorbers or exhaust systems, are increasingly conducted by Specialists. In contrary to *Allrounders*, *Specialists* focus on one or several car components for mostly all car classes, brands and segments. Often, the provider is a component manufacturer or a (specialised) dealership group. The advantage of this concept is the concentration on a few individual car components, so that high margins can be reached due to highly-standardised processes. As it is the same with Fast Fitters, overalls works concerning the whole car can oftentimes not be conducted due to their highly specialised knowledge. The different ranges of service offers for the introduced service formats are illustrated in a portfolio (Figure 4).

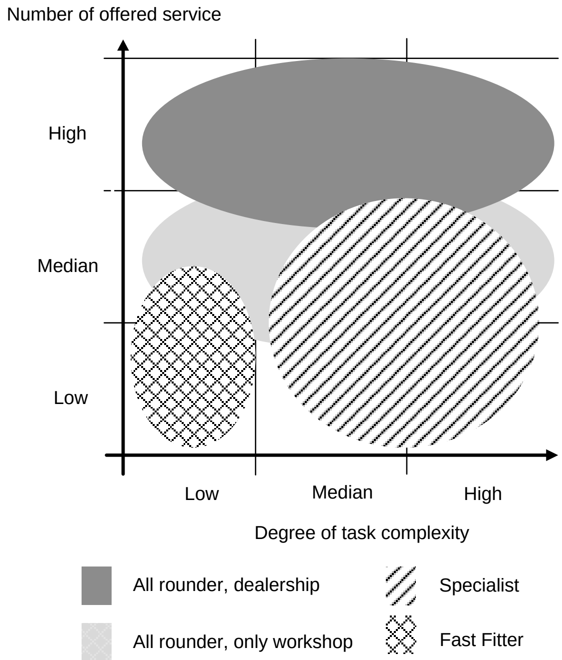

Figure 4: Range of service offers for different service formats

The abscissa indicates the degree of the task complexity, from low to high. Hereby, tasks, such as changing wheels or exhausts, link to low complexity. Tasks with medium complexity are jobs on brake systems, air condition, or simple car body repairs (smart repair), for instance. Works on the engine or electronics are tasks with high complexity. The ordinate indicates the number of offered services, from low (only few, selected services) to high. Examples for low and medium number of services are *Fast Fitters* offering only a few, selected services with low complexity or *Specialists* offering services for selected car components. In contrary, *Allrounders* with their wide range of service offers have a high number of services.

3 REFERENCE MODEL OF SERVICE FORMATS

In order to enable a systematic analysis of different service formats a reference model has been developed aiming at the illustration and description of all possible service formats. The reference model focuses on automotive sales and after-sales services and has the following objectives:

1. *Systematic and comprehensive modelling* of any kind of automotive service formats
2. Provision of a *basis for a situation analysis* of automotive service formats
3. Provision of a *basis for an impact analysis* of future changes (e.g. maintenance of new engine technology)

The reference model is an important input for an effective, goal-oriented adaptation or development of service formats

3.1 Dimensions of a service format

The reference model is based on the concept of model-based service systems engineering [9] as it provides multiple methods and techniques for the modelling as well as institutional background knowledge for the understanding of service formats. Thereby, the concept refers to the system theory.

According to the purpose of used sub-models in the reference model, it can be differentiated between models focusing on the illustration of the structure or the allocation of objects. Structure models refer to the structure of an examined object type. For instance, an organisation chart illustrates the hierarchical structure of the object type employee. Against this, allocation models focus more on relationships between different object types. For example, the object type employee can be allocated to the object type resource, if an employee is specialised in using e.g. a specific software tool. Furthermore, hybrid models exist, combining structure and allocation models.

The concept of model-based service systems engineering relies on the constitutive, phase-oriented service definition. According to diverse scientific research activities [10] this approach gives the most distinct definition of services as these are defined on the basis of service-specific characteristics. Thereby, it is differentiated between a market, result, process and potentiality dimension.

For the modelling of an automotive service format, the service dimensions have been considered as well as their inter-dimensional connections. Moreover, these are completed by a comprehensive, fifth dimension, the organisational dimension. The organisational dimension of service formats comprises the modelling of the structural organisation. This implies the consideration of organisational connections to adjoining companies, too. Their constitution and structures, however, are neglected as these are not in the focus of the reference model.

In the following, the five dimensions of an automotive service format are described in more detail. Starting point is the depiction of the organisational dimension. In the following step, their market-, result-, process- and potentiality dimensions are presented.

Organisational dimension (What kind of service format is regarded and what is its internal and overall organisational structure?)

The organisational dimension includes the different types of service formats on the service market as depicted in Figure 3. It also implies its embedding in a super-ordinate service company, e.g. Pit Stop [11] or Volkswagen Services [12]. In addition to this, the organisational dimension refers to the structural organisation, i.e. the hierarchical constitution of employees, e.g. within a car workshop.

Market dimension (To whom is the service offered?)

The market dimension of the reference model contains information about the customer and car target groups, suppliers as well as potential competitors. Target groups of a service format can be differentiated in terms of their characteristics and requirements, e.g. demographic or socio-economic characteristics of customers. Thus, the market dimension implies a segmentation of target groups and their allocation to different markets, e.g. national or international markets. This allocation to markets is also part of the competitor view on service formats. Moreover, the connections between services of a competitor can be related to those of the modelled service format in terms of complementary or rival relations.

Product dimension (What kind of service is offered?):

Within the product dimension, the reference model differentiates between an internal and an external view. The internal view comprises the product portfolio of a service format from an internal point of view, whereas the external view combines the market dimension with the product dimension by allocating services to potential customer and car target groups.

Process dimension (*How is this service offered?*)*:*

The process dimension of the reference model considers management-, support- and business processes of a service format. Thereby, the focus is on the illustration of business processes, e.g. the process of arranging appointments or repair processes. Thereby, the implemented process modelling method service blueprinting enables the explicit consideration of the external factor of automotive after sales services within the process dimension. This means that the reference model allows for differentiating between customer processes and internal processes.

Potentiality dimension (Which objects are necessary in order to offer a service?):

The potentiality dimension refers to the necessity of available resources if service formats are able to offer automotive after sales and sales services. The resources contain employees, equipment, materials and the knowledge that is existent within a service format. Regarding the potentiality dimension the strong relationship between resources and suppliers of a service format is emphasised as suppliers are, for example, required to provide spare parts to a service format.

3.2 Frame of the reference model

The reference model of service formats has been developed on the basis of a system perspective and with respect to the introduced service format dimensions in chapter 3.1. In the reference model, the mentioned dimensions are depicted by different sub-models with the help of the corresponding, suitable modelling methods. For the determination of the sub-models, the focus is put on the information required for a market analysis. The reference model is illustrated in Figure 5. Its elements and interrelations will be explained from inside to outside.

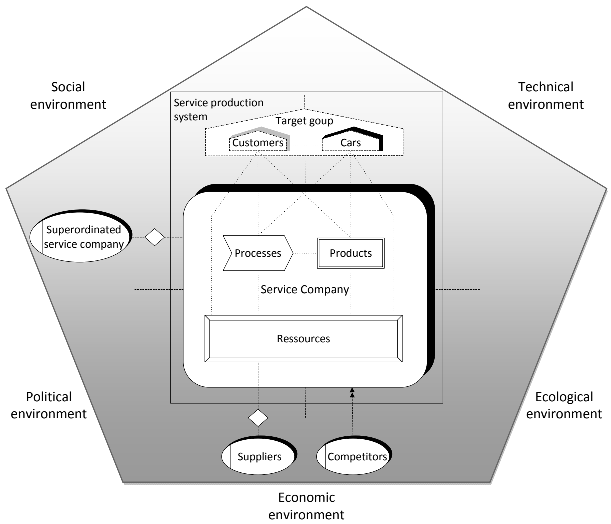

Figure 5: Reference model of service format

In the centre of the reference model is the organisational system of the *service company* with its three sub-systems *products*, *processes* and *resources*. The sub-systems correlate with each other and their configurations determine the complexity of the service format.

The *service production system* is a system that is dependent on the *customers* of a service format on the one hand and their *car* on the other hand. The customers and cars are integrated into the structure *target group.* Thus, the depicted relations refer to the market orientation of a service format on the one hand; on the other hand, it demonstrates the dependence of its internal processes and resources on the target group. Thus, the integration of the external factor is explicitly respected. Within the context of service formats, the external factor comprises the service customer and his car as well as relevant information about car characteristics.

The outer shell of the reference model illustrates the *environment* of a service format containing the social, technical, political, ecological and economic environment. Therein, *suppliers*, *competitors* as well as *super-ordinate companies* are situated.

As stated above, the reference model aims at the illustration and description of all kinds of possible service formats. The service dimensions described in chapter 3.1 are depicted by sub-models in order to enable a detailed view of a service format. This is done with the help of corresponding, suitable modelling methods of the concept of model-based service systems engineering (Figure 6). Thereby, structure and allocation models as well as hybrid models are applied. When modelling a specific service format, e.g. a fast-fit company (see chapter 4) or an authorised workshop, the individual configuration of the reference model is required.

3.3 Detailing the reference model

A more detailed view on the reference model shall be demonstrated using the example of a sub-model within the product dimension. It contains the general internal product sub-model shown in Figure 7.

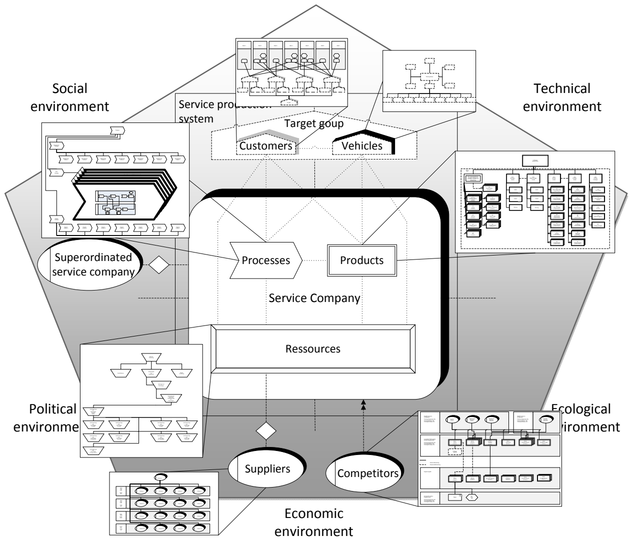

Figure 6: Sub-models of the reference model

The internal product sub-model is a structure model (cf. chapter 3.1) allowing for the illustration of the hierarchical structure of all possible services which can be offered by a service format. Within this sub-model it is differentiated between different categories such as technical services (e.g. repair and maintenance) as well as automotive sales services (e.g. new and used car trading, spare part dealing, accessory dealing) and other services (e.g. financing). Depending on the necessity for further detailing, the hierarchy is divided into further sub-categories, e.g. different degrees of complexity (cf. Figure 4) within technical services (i.e. complexity level).

In order to achieve the allocation of relevant aspects to separate services allocation models (cf. chapter 3.1) are used. This allows for exemplifying inter-dimensional

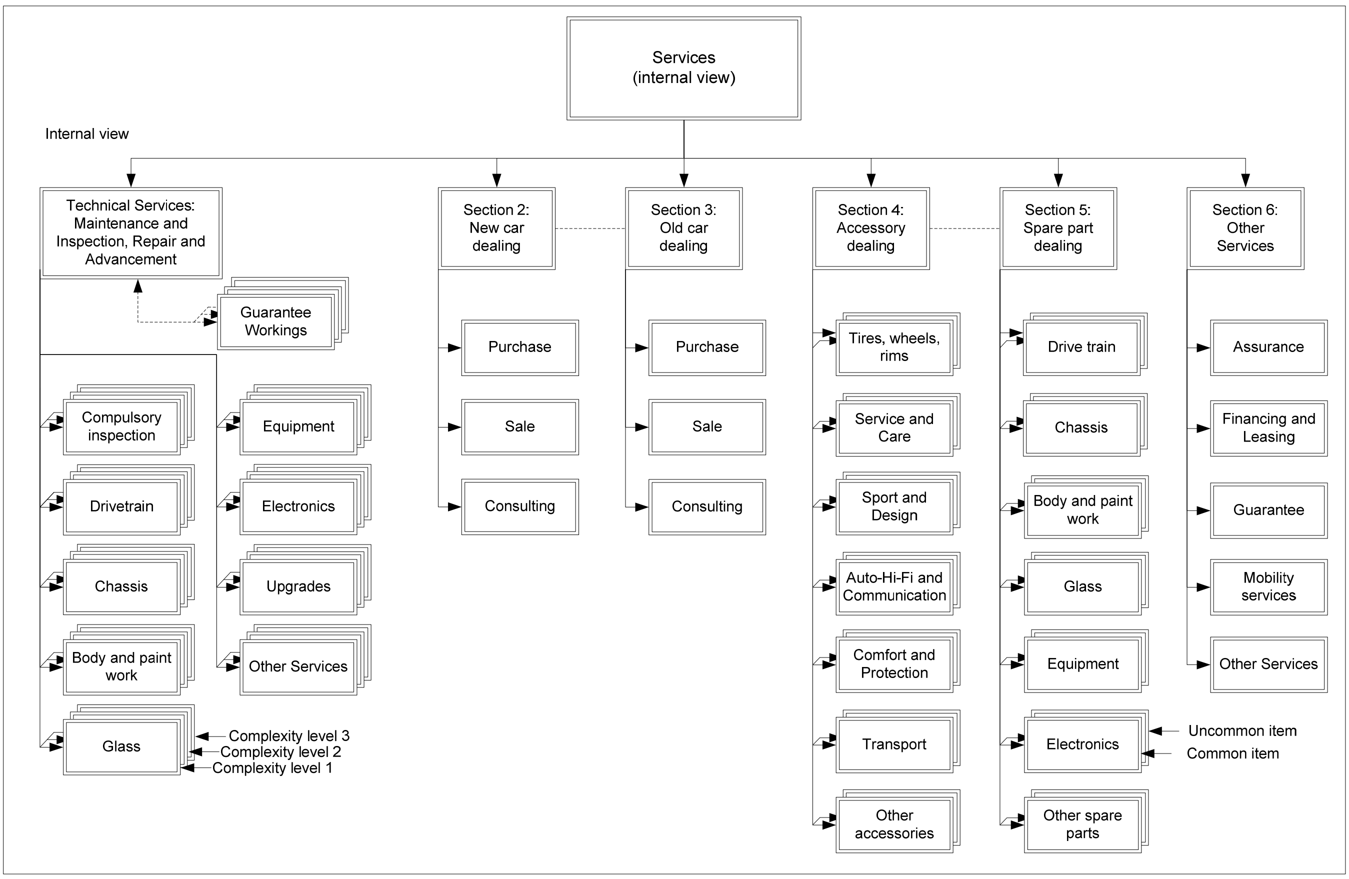

Figure 7: Internal product sub-model

relations as it is done in Figure 8 for the example of an oil-change.

Within the internal product model the oil-change can be located in the category drivetrain, sub-category low complexity level. Exemplarily, the potentiality dimension is represented by the object types *oil pan* and *employee*, the market dimension by the customer *requirement promptness*, as well as *customer* and *car target group*. Further aspects like potential *laws* can also be included.

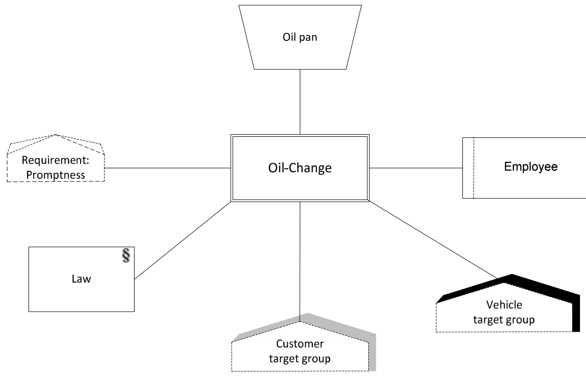

Figure 8: Allocation model for the service oil change

In the course of a project the reference model was applied to the service format Fast Fitter. Every sub-model was specified according to the available data concerning the Fast Fitter. As an example the internal product model of this service format is shown in Figure 9. In analogy to the explanations in chapter 2, the Fast Fitter mostly focuses on technical services with low complexity. Thus, the number of business units is low in the shown sub-model.

4 TRENDS INFLUENCING SERVICE FORMATS

Starting from the specified service format as it was shown for a Fast Fitter in chapter 3.3, further analyses are possible. In order to stay successful in the future, investigations concerning the following aspects are to be conducted:

- Future demands on the workshop caused by a new technologies
- Importance of target groups and their needs in the future
- Required services which have to be offered in future.
- Future process and resource requirements

Therefore, one objective of the reference model is the estimation of impacts and their consequences on a single automotive service format caused by the mentioned trends (cf. Table 1). On this basis possible strategic fields of action can be deducted for the adaptation of service formats. The required procedure steps are as follows:

- Step 1: In the first step *relevant trends* and challenges for the future service business (cf. Table 1) are *identified*. These trends have to be analysed and described in order to achieve transparency and a good understanding of their impact
- Step 2: For every trend, meaningful key factors are elaborated on the basis of step 1. This enables an efficient identification and measurement of the impact of each trend.
- Step 3: Using the key factors, a systematic analysis of the specified service format is conducted. Therefore, every sub-model is checked and evaluated (from high to low) regarding the influence of every single trend. Based on the analysis results, important fields of

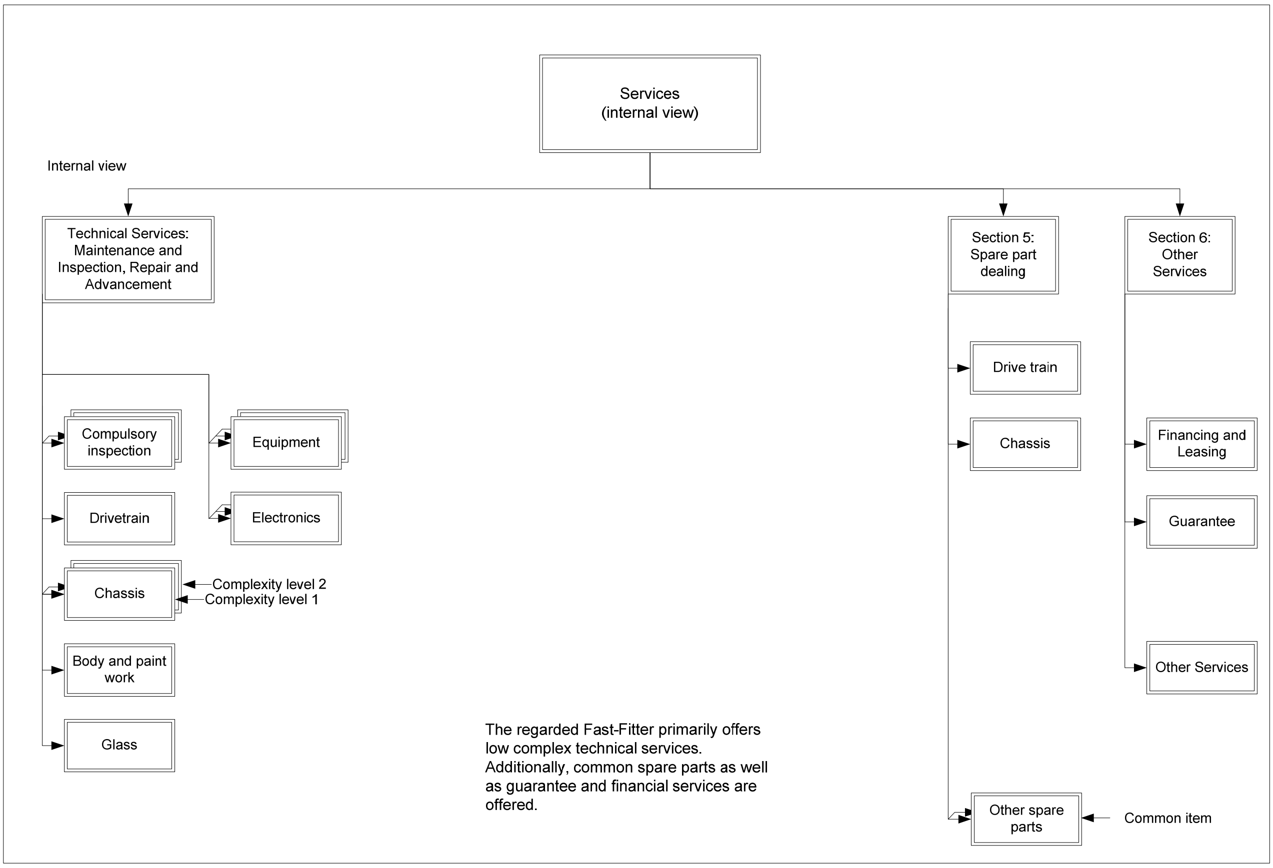

Figure 9: Internal product model for the service format “Fast Fitter”

action are identified and prioritised.

- Step 4: A catalogue of measures is worked out for the high prioritised fields of action

In Figure 10 the impacts of the trend increasing car complexity are depicted for the service format Fast Fitter. Thereby, only the adaptation of the service format Fast Fitter with cost-sensitive customers is considered.

In step 1 the trend increasing complexity has been identified on the basis of a survey representing an important technical trend.

Step 2 then refers to the identification of meaningful key factors pointing at the impact of increasing car complexity. The trend is in large part caused by an increasing share of electronic components [3]. Thus, a key factor for rising complexity is the share of electronics in cars. Furthermore, the increasing individualisation and customisation results in an increasing car variety as well as increasing equipment rates adding to car complexity [3]. Thus, car variety and the number of additional features have also been identified as key factors for the trend increasing complexity.

In step 3 suitable measures have been derived for each of the affected service dimensions on the basis of the reference model. Thus, in order to stay successful the structures of the considered Fast Fitter need to be adapted within the following service dimensions:

- Resources: Within the resource dimension highly complex cars require highly qualified employees and know-how. Additional, suitable technical equipment is necessary. Examples for suitable adaptation measures are shown in Figure 11 such as adaptation of information infrastructure to improve the provision of car or maintenance instruction information, or new diagnostic tools for a safe and quick maintenance. Further on, the employees have to be educated and the know-how needs to be acquired to cope with the new requirements.
- Processes: Increasing car complexity results in more extensive, detailed and heterogeneous processes with increased interfaces. Thus, the objective for the process-model is the aggregation and standardisation for service processes. Accordingly, processes need to be clustered and implemented by a supporting IT-system.
- Super-ordinated companies: In order be able to handle the increasingly complex cars extensive information and maintenance instructions are required. Hence, the access for updated data has to be established in cooperation with the car and spare parts manufactures.

In analogy to the depicted procedure, the service format Fast Fitter has to be analysed for all trends listed in Table 1. Finally, the measurements for all trends, need to be clustered and prioritised in order to get a holistic measurement catalogue for the effective adaption of Fast Fitters.

5 CONCLUSION

In recent years, the automotive service sector has been affected by radical structural changes. Trends in social, political, technological and economic areas force automotive service companies to change their market position. Hence, a systematic analysis of their service format is needed.

Within this paper a reference model for the holistic and systematic analysis of specified automotive service formats was presented. On the basis of the reference model, an approach for an impact analysis of future trends was proposed and detailed, using the example of the service format Fast Fitter. Thereby, essential key factors and affected parts of the service format were identified with respect to future developments. After that, suitable measures for the adaptation of the service format Fast Fitter were compiled for the influence of the trend increasing car complexity.

The advantage of the reference model is the provision of a systematic and comprehensive description and analysis of all kinds of automotive service formats. Thus, it enables a situation and impact analysis concerning all relevant future trends and changes.

Nevertheless, more detailed (quantitative) evaluations are necessary. Thereby, key figures, e.g. cost or environmental parameters, could be integrated in the reference model for a more extensive decision-support.

6 REFERENCES

[1] Torney, M., Kuntzky, K., Herrmann, C., 2009, Service Development and Implementation - A Review of the State of the Art, in: Proceeding of the 1st CIRP IPS2 Conference, Cranfield, 24-30.

[2] Diez, W., Reindl, S., 2005, Das Management der automobilwirtschaftlichen Wertschöpfungskette, in: Diez, W., Reindl, S., Brachat, H. (Ed.), Grundlagen der Automobilwirtschaft. 4 Edition, Auto Business

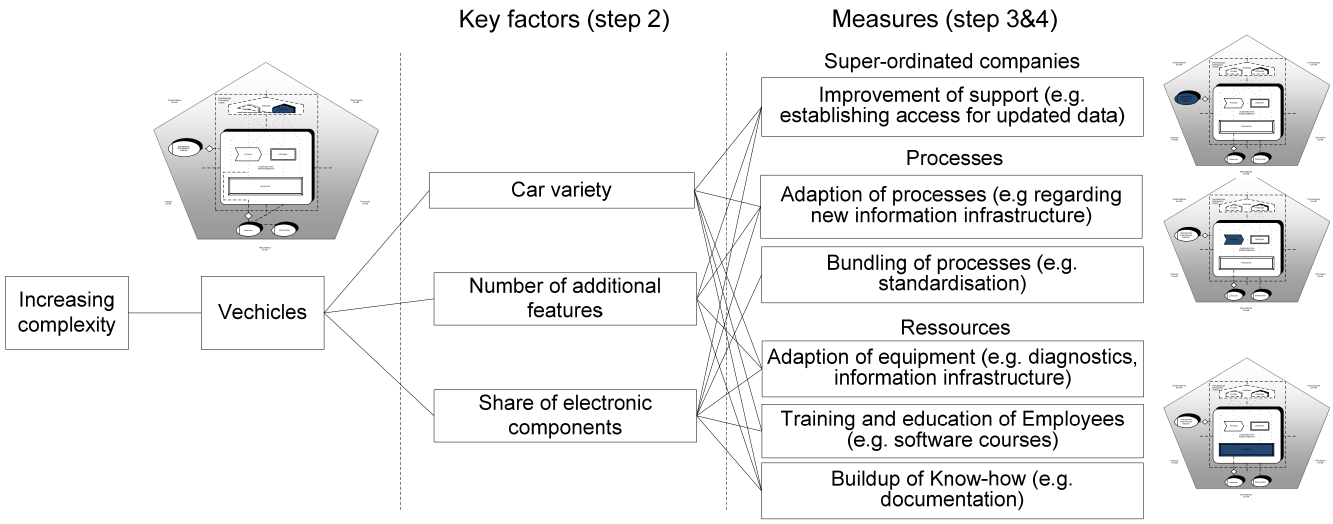

Figure 10: Internal product model for the service format “Fast Fitter”

Verlag, München, 71–104.

[3] Juehling, E., Torney, M., Herrmann, C., Droeder, K., 2009, Framework of the Integration of Service and Technology Strategies, in: Proceeding of the 1st CIRP IPS2 Conference, Cranfield, 132-139.

[4] Communication Networks 12.0, 2008, Studie „Der Markt der Mobilität", http://www.medialine.de/CN.

[5] C. Herrmann, S. Thiede, T. Luger, A. Zein, J. Stehr, P. Halubek, M. Torney, 2009, Automotive Life Cycle Engineering, in: Proceedings of the 16th CIRP International Conference on Life Cycle Engineering, Kairo, 157-164.

[6] Hesselbach, J.; Dombrowski, U.; Bothe, T.; Graf, R.; Wrehde, J.; Mansour, M., 2004, Planning Process for the Spare Part Management of Automotive Electronics, Production Engineering Vol. XI / Issue 1.

[7] Reindl, S., 2005, Mobilitätsdienstleistungen in der Automobilwirtschaft, in: Diez, W., Reindl, S., Brachat, H. (Ed.), Grundlagen der Automobilwirtschaft, Auto Business Verlag, München, 423–466.

[8] Brachat, H. (Ed.), 2009, AUTOHAUS Extra « DAT Report », Deutsche Automobil Treuhand GmbH (Ed.), 7/2009, Springer Transport Media, München

[9] Klein, R., 2007, Modellgestütztes Service System Engineering – Theorie und Technik einer systematischen Entwicklung von Dienstleistungen, Gabler Verlag, Wiesbaden.

[10] Bullinger, H.-J., Fähnrich, K.-P., Meiren, T., 2003, Service engineering – methodical development of new service products, International Journal of Production Economics, Vol. 85, Number 3, 275-287.

[11] PIT Stop Germany http://www.pit-stop.de/

[12] Volkswagen Service Germany http://www.volkswagen.de/vwcms/master_public/virtualmaster/de3/kunden___service/Volkswagen_Service.html

Session 5A:
Knowledge and Information Management

Managing Information Flows for Product-Service Systems Delivery

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Abstract

The delivery phase is an integral part of the product-service system (PSS) approach that requires interactions involving the external and internal flow of information. Managing information flows for a company that adopts the PSS approach is therefore important to understanding interactions between manufacturers and customers during the delivery of a PSS.

The purpose of this paper is to use literature to identify the main approaches for managing information flow during PSS delivery. This paper plans to contribute to knowledge by: analysing the main approaches for managing information flow during the delivery phase and, making recommendations for future research.

Keywords

Product-service systems, information flow modelling, communication, organisation, collaboration

1 INTRODUCTION

According to a widely accepted definition by Baines *et al*. [1], a product-service system (PSS) is 'an integrated product and service offering that delivers value in use'. For the supplier, value is realised in the PSS approach which supports minimising inputs and maximising outputs during delivery. For the customer, value is realised in PSS propositions that centre on closely linking services to delivered products in configurations based on function provided by products, availability of product or the result required from the product (or service).

Interactions are required during the delivery phase by suppliers to manage internal and external flows, including the flow of information [2]. Internal information flows centre on interactions within company departments, projects, divisions and so on. External information flows centre on interactions between the supplier and the customer for managing the delivery of products and services. External information flows also involve interactions within trans-organisational partnerships and alliances that could be formed to manage aspects of the delivery phase [3]. Consequently, information flows for a company that adopts the PSS approach is important to understanding interactions between manufacturers and customers during the delivery of a PSS.

This understanding of information flow can assist PSS adopters to improve delivery performance.
This paper reviews the current state of research of information flows for PSS delivery. The aim of the paper is to identify the main approaches for managing information flow of during PSS delivery. This paper plans to contribute to knowledge by: analysing the main approaches for managing information flow during the delivery phase and, making recommendations for future research.

The paper begins with an overview on information flow in terms of its dimensions and main attributes. Next, the review methodology is presented followed by a review of PSS delivery in literature. The main approaches for managing the flow of information flow during PSS delivery will then be analysed and used to make recommendations in terms of future research needs and challenges for product-services systems.

2 INFORMATION FLOW OVERVIEW

2.1 Information flow dimensions

The flow of information is determined by three main dimensions: information access, information exchange and documentation [4] as shown in Figure 1.

Information access (or accessibility of information) relates to the presence of data and the ease with which information can be retrieved. It also describes how information is readily available for use in activities. The accessibility of information is dependent on the reliability of the source, convenience of the channel and ease of use of the contents [5]. In terms of information and communication technologies, accessibility of information is also required for remote systems, databases, files transfers and advanced work station facilities [6] and varies in terms of urban vs. rural contexts [7].

Information exchange is concerned with data flow, team interactions and the generation of knowledge [4]. It is required for the dissemination of information through avenues such as gatherings and forums [8] and is closely related to information sharing [9]. Team briefing, management meetings and the cascading of information are also useful means for communicating and disseminating information in organisations such as the social services and health care as noted by Blackburn [10]. Wamba and Boeck [11] identified information sharing as a dimension of information flow that is required for the communication of critical and proprietary information. Furthermore, information sharing between two entities could be generic (inventory control policies) or specific (weekly manufacturing schedule) [12].

Documentation refers to facilities to record and to store data [4] and also offers a useful avenue for the dissemination of information by means of newspaper articles, surveys and so on [8]. Stapel *et al*. [13] identified document flow as means of information flow achieved exclusively by the use of documents. In this form of information flow, documents (letters, memos etc) are considered inputs / outputs of activities. Documentation also involves developing models for describing the technical and non-technical elements of a system [14]. According to the Internet Engineering Task Force (IETF) [15], an information model is a protocol neutral tool used by designers and operators to give conceptual and abstract representations used for the creation of data concrete/detailed data models for use by implementers. Considerations and modelling for information flow is one aspect of an information model. Other aspects that could be captured by an information model include information structure and integrity.

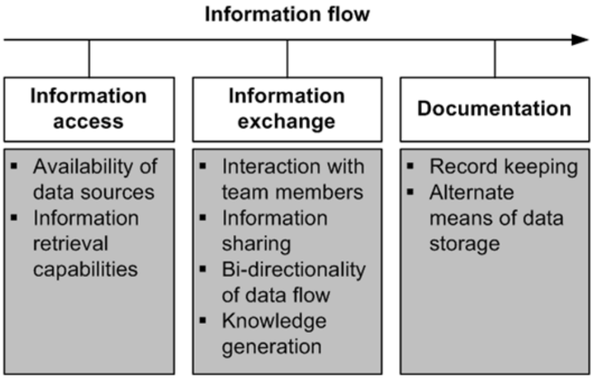

Figure 1: Dimensions of Information Flow [4]

2.2 Information flow attributes

According to Smith, Stoker and Maloney [16] the main attribute of information flow is quality**.** *Information flow quality* describes the free flow of information within an organisation or business [16]. Tarhule [17] noted that the quality of information flow in organisations is aided by the prioritisation of feedback paths and the channelling of efforts for making information available to stakeholders and team members. Manecke and Schoensleben [18] argued that the quality of information in an organisation directly translates to the efficiency of an organisation's business processes. Their argument is based on linking effective communication and information flow with the ability of an organisation to coordinate activities and processes. Citing the 'garbage in garbage out' (GIGO) concept in computer technology, Kehoe, Little and Lyon [19] suggested that information without quality is useless. This means that qualitative characteristics defined during the input of information must be met to ensure outputs are useful.

Information flow format is another aspect of information flow that describes the standardisation of communication to support interaction between processes [20]. Berente, Vandenbosch and Aubert [5] also identified *timeliness*, *transparency* and *granularity* as attributes associated with information flow. Transparency relates to how understandable information is for users whereas granularity refers to the level of detail of information. Timeliness describes the availability of information when it is needed.

3 REVIEW METHOD

A search for literature (journal articles and conference papers) on SCOPUS an online digital library using keywords 'information flow', 'delivery' and 'product-service systems' produced no results. 'Information flow' and 'product-service systems' produced 1 article that dealt with lifecycle management and only used the term 'information flow' in the abstract.

A search for literature based on keywords 'product-service systems' and 'delivery' produced 7 articles (3 relevant). Focusing on these articles this paper plans to examine the approaches for managing information flow that the article authors have highlighted and to use them to make recommendations for improving delivery performance of a PSS.

The main contribution to knowledge will be an analysis of the main approaches for managing the flow of information during PSS delivery.

4 PRODUCT-SERVICE SYSTEM DELIVERY

The delivery of 'value bundles' (made up of services and physical goods) by a PSS is closely linked to the emphasis placed on business, operations management, service sciences management and engineering (SSME), information systems (IS) and engineering [21]. From the business perspective, the delivery of a PSS is driven by marketing needs so as to define value propositions and business models for meeting customer needs. Operations management emphasises cooperation to maximise efficiency in operations and to better analyse customer needs. SSME emphasises service design and delivery especially involving the co-creation of value between supplier and customer. IS emphasises the need to model, analyse, propose and aid information flow. Within the context of PSS delivery, the discipline of IS emphasises the need for managing business processes that deliver value bundles for customers. Within engineering, the focus is on a clear split between the engineering of products and services.

Focusing on IS research, Becker *et al*. [21] argued for conceptual models aimed at PSS delivery for supporting value networks (value-nets). This is because in industry, companies have continued to move from sequential processes for creating value during production (value-chains) to a collaborative process that emphasises partnerships with customers, and among suppliers (value-nets) [22]. Becker *et al*. identified a conceptual model as 'a (re-)construction of a reality' and discussed the benefits of conceptually modeling PSS delivery. These benefits include: support for integration of processes and ICT, interdisciplinary communication among team members and complexity management during design.

In a study of battery-powered drill suppliers, Mont [23] investigated how a PSS can be delivered as a business model that emphasises services and value creation. The study involved an online survey of 618 households combined with interviews conducted with 10 producers, 20 retailers, 20 customers of rental services, 10 community-based sharing systems, 5 caretakers and 2 housing companies. Based on interactions with participants Mont analysed a PSS as a 'value system' made up of actors and scenarios required for the delivery of a PSS. The main actors include producers, rental companies, retailers, households, real estate companies, local organisations and caretakers that maintain community buildings. For the battery-powered drill business, possible scenarios for a PSS proposed include: (1) manufacturer retains drill ownership scenario, (2) sharing a drill between 2 or 3 neighbours, (3) a system for sharing drill(s) within a community of about 25, 50 and 100 households and (4) drill renting services. In an economic and environmental analysis of the delivery scenarios, Mont demonstrated that sharing a product within a community significantly reduces life-cycle environmental impacts, but requires a wide range of considerations for factors such as solution cost, product availability, travelling distance and customer comfort.

'Technology insertion' is a concept used in the defence industry to describe 'the utilization of a new or improved technology in an existing product' [24]. It involves researching new technologies (new service development) for supporting exiting products. Technology insertion is in principle a special case of product-related services – an orientation for the delivery of a PSS [25]. In this orientation, products are supplied or sold to customers, and the supplier also opens service channels for additional services such as upgrades, maintenance and repairs. In terms of technology insertion (PSS delivery for defence), Kerr [24] identified and discussed two main delivery considerations focused on end-users (air force, army and naval personnel), defence departments and industrial providers. Firstly, the need for planning how technology can be inserted at platform-, systems-, equipment and component-levels of a product hierarchy. This planning requires addition considerations for service needs, customer requirements and market/end-user needs. The second consideration involves the adoption of open system architectures and the use of commercial-of-the-shelf (COTS) technologies for technology insertion. Whereas the use of COTS is recommended for reduced costs (as a result of avoiding new specifications), open system architectures offers benefits of accessibility, evolvability, interoperability, maintainability, modularity, portability and scalability [24].

5 MANAGING THE FLOW OF INFORMATION DURING PRODUCT-SERVICE SYSTEMS DELIVERY

5.1 Managing communication for community and interdisciplinary access/exchange of information and for life cycle management

To support accessibility of information during delivery, PSS adopters can identify and implement suitable networks for aiding community communication. Two forms of networks are associated with the flow of information: soft networks that involve gathering knowledge by social interactions; and hard networks that make use of the internet to exploit ubiquitous technologies such as computing, telecommunications and information media [26]. Both networks can be combined for flexibility in communication and interactions with internal and external actors during PSS delivery.

Similarly, to aid information exchanges, PSS delivery can be based on suitable means for communication that take into account factors that affect PSS actors and scenarios such as travelling distance, available resources, customer preference and available resources. Examples of means for communication include electronic mail, facsimile, reports and letters. However, communication by social interactions such as face-to-face contact, word of mouth and meetings remain the richest form of communication. This is because social interactions are natural and informal forms of information exchange for businesses [27].

In a PSS, the ability to manage the flow of information during the life of a provision enables a business to continuously review and improve its operations. This is because information gathering is an internal function that supports PSS delivery and is a life cycle long process [28]. The process of managing information flow may also be standardised for compatibility and continuity in business operations.

5.2 Information systems for defining configurations during delivery

Information systems for managing interactions are important avenues for configuring a PSS. This is because a PSS could be based on centralised or decentralised configurations depending on the type of PSS partnership (or collaboration). PSS configurations may be decentralised to facilitate interactions between customers and manufacturers [29]. PSS configurations may also be centralised for monitoring resources and capabilities of manufacturers. In centralised configurations, main decisions are typically made by upper or senior management as a means of ensuring uniformity in applying policies and procedures.

In terms of improving PSS performance, feed-back and feed-forward paths of information flow for a PSS are also useful avenues for promoting innovation and competitiveness in a PSS. This is because feedback paths based on product market and customer requirements could capture key life-cycle information that could assist service designers in proposing new and cost-effective means for the delivery of a PSS. Similarly, feed-forward paths from the design process centres on the realisation of conceptual models for realising a PSS. Consequently, life-cycle information could drive innovation in a PSS based on the conceptual thinking process during the design phase. The competitiveness of a PSS could also be driven by life-cycle information during the delivery phase for maintaining profitable operations and affordable customer solutions [2].

5.3 Information flow models for conceptual design

Information flow during PSS delivery can be modelled by diagrammatic tools such as data flow diagrams, Integrated DEFinition (IDEFØ) technique, Graphes à Résultats et Activités Interreliés (GRAI) grids and nets, Petri nets, Input-Process-Output (IPO) diagrams and Design Structure Matrices [30]. Data Flow Diagrams analyse information flow within and between organisations or systems. IDEFØ illustrates information flow along with constraints and mechanism which affect system functions. GRAI grids and nets support information flow in decision communication, feedback and review. Petri nets represent automated and event-driven information flow in systems. IPO diagrams describe and document the organisation and logic of information flow. Design Structure Matrix depicts dependency, independency, interdependency and conditionality of information flow for systems and organisations. Morelli [31] recommended that for the conceptual design of a PSS, information flow models such as the IDEFØ technique must be complemented with additional representations for envisioning the scenarios and the use cases in a PSS.

Consequently, modelling information flows for the delivery of a PSS can serve as an enabler for realising PSS objectives and goals. This is because models present depictions of system components or subject area in order to understand, analyse or improve a system [26].

Some important features of a model that are required to define the quality, timeliness, transparency and granularity of information flow during PSS delivery include: interfaces and interconnections of business processes, business inputs and outputs, business functions and processes, and independency, collaboration and distribution within an organisation. When understood, these features can be improved or redesigned for enhanced organisational productivity [30].

A model of information offers a partial view of a PSS. Other models of PSS characteristics required to create a 'complete view' of a PSS include process and cash flow. Formal product/process models support standardisation of operations and must be used in cases where they are mandatory.

In other cases, trade-offs between creativity and conformity during the modelling of information flow in businesses [27]. Creativity in modelling information flow may be individual-focused i.e. designers and engineers are allowed to make use of intuitive and individual approaches for managing information flow. Conformity in modelling information flow on the other hand could be based on the use of a common modelling technique to support collaboration among different working groups.

6 FUTURE RESEARCH FOR INFORMATION FLOW

Figure 2 summarises the main approaches for managing information flow during PSS delivery. It also shows the motivators for PSS delivery (competiveness and innovation, life cycle impact, and value creation) and the benefits of PSS delivery. Focusing on the particular needs of PSS delivery a supplier could manage the flow of information based on:

- A comprehensive approach to capture key customer requirements and PSS needs. This could involve collaboration of technical personnel specific to a domain as well as marketing and distribution staff.
- An exploratory approach that allows flexibility in information access, information exchange and documentation.
- A methodical approach with well defined information access and communication. The flow of information in this case is based on established or pre-defined links and networks.
- A dynamic approach for which information flow modelling could be applied to cope with changes in stakeholder behaviour and non-deterministic characteristics of component lifetime distribution.

For a PSS, these approaches for managing the flow of information could also be considered in terms of their contribution to competiveness and innovation, life cycle impact, and value creation in a PSS. Further considerations could also be made for how replacing one strategy with another may impact a PSS and rationales for strategy selection.

6.1 Capturing Information Flow

Capturing information flow is an activity that offers opportunities to understand a PSS and the information needed during PSS delivery. This is because the design and delivery of a PSS requires the exchange of information so as to understand customer needs and the means to deliver them. Information flow research could focus on capturing information across industry sectors and developing ontology and frameworks for information flow that meet specific customer and manufacturer needs during PSS delivery.

Research in this area could also consider the role of factors such as timeliness, transparency and granularity of information flow for PSS delivery. This is because capturing information flow can require a deal of analysis since a unit of information may present useful information; but when information cumulates to form fragments, this piece, as part of a set, may offer a different meaning. For instance a reported faulty product may suggest a problem in a manufacturing process but a Pareto analysis may reveal a specific faulty tool in a fabrication process. The item of information can serve as an indicator for scope, frequency, source, timing and even accuracy whereas the cumulative or 'grouped' information, much like a system, can identify significance and wholeness for consideration.

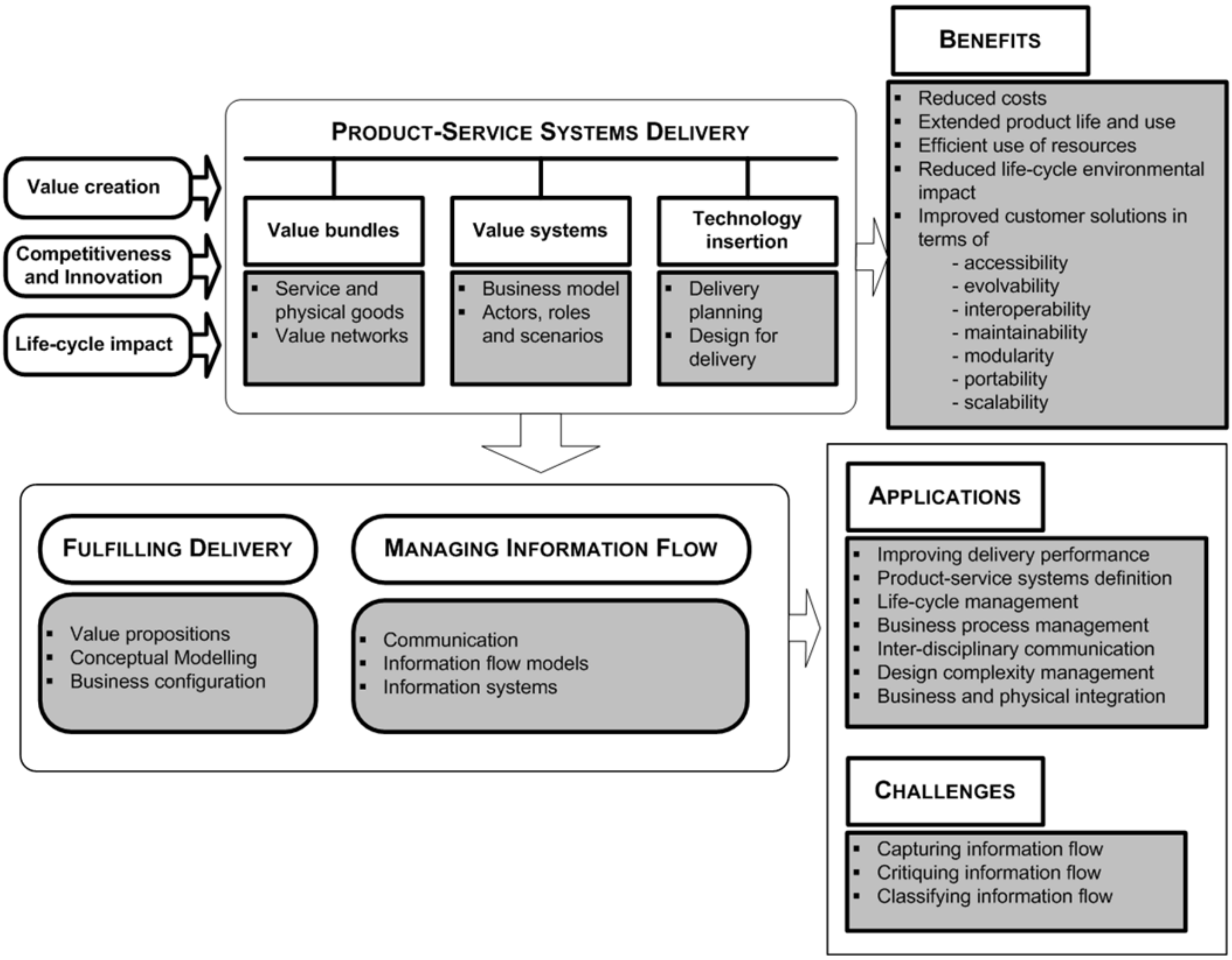

Figure 2: Managing information flows for product-service systems delivery

6.2 Classifying Information Flows

The focus of these research activities may centre on segmenting information flows during PSS delivery or exploiting related flows of information. Further considerations could also be made for the nature of information flow in terms of alternate classifications and orientations of information flows during PSS delivery. Classifications may be based on content (technical, social and economical), access (high-level versus low-level), channels (formal versus informal), direction (upstream versus downstream) and so on.

6.3 Critiquing Information Flow

For this area of research the focus could be to examine the necessity and requirements of information flow in a PSS. This examination may offer clues as to the presence of irrelevant, misinterpreted and redundant information in a PSS. Research in this area could also focus on understanding the interactions in a PSS so that information systems could be designed around communications and interactions.

Studies could also be conducted to examine how reconfiguring a PSS could improve delivery performance. Possible areas for studies include the impact of: standardising the flow of information, outsourcing information flow management or assigning an organisation (or personnel) to manage information flow. Further research could also consider the optimum level and timing of information audits to update and improve the flow of information. Information audits are measures designed to periodically evaluate the flow and processing of information by organisation [6]. This ensures redundant or repeated flows are minimised and inefficient flows are improved.

7 SUMMARY

This paper has attempted to identify approaches for managing information flow during the delivery of a product service system (PSS) with a view to improving PSS delivery performance. A literature review was carried out to examine the approaches for managing information flow during PSS delivery.

The main approaches for managing information flow during PSS delivery were then analysed in terms of: managing communication for community and interdisciplinary access/exchange of information and for life cycle management, information systems for defining configurations during delivery, and information flow models for conceptual design.

Future research challenges for managing information flow during PSS delivery were also highlighted with regards to investigating approaches for capturing, classifying and critiquing information flows.

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9 REFERENCES

[1] Baines, T., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J. R., Angus, J. P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I. M., Wilson, H., 2007, The state-of-the art in Product Service Systems, Proceedings of the I MECH E Part B Journal of Engineering Manufacture, 221(10), pp. 1543-1552.

[2] Durugbo, C., Tiwari, A., Alcock, J.R., 2009, An Info-dynamic Engine Approach to Improving the Efficiency of Information Flow in a Product-Service System in Proceedings of the 1st CIRP IPS2 Conference, 107-112.

[3] Braman, S., 1989, Defining information: An approach for policymakers, Telecommunications Policy, 13(3), pp. 233-242.

[4] Demiris, G., Washington, K., Oliver, D.P., Wittenberg-Lyles, E., 2008, A study of information flow in hospice interdisciplinary team meetings, Journal of Interprofessional Care, 22 (6), pp. 621-629.

[5] Berente, N., Vandenbosch, B., Aubert, B., 2009, Information flows and business process integration, Business Process Management Journal, 15 (1), pp. 119-141.

[6] Howells, J.R., 1995, Going global: The use of ICT networks in research and development, Research Policy, 24 (2), pp. 169-184.

[7] Aoyama, Y., Ratick, S.J., Schwarz, G., 2005, Modeling the impact of business-to-business electronic commerce on the organization of the logistics industry, Geographical Analysis, 37 (1), pp. 46-68.

[8] Mash, B.J., Mayers, P., Conradie, H., Orayn, A., Kuiper, M., Marais, J., 2008, How to manage organisational change and create practice teams: Experiences of a South African primary care health centre, Education for Health: Change in Learning and Practice, 21 (2), art. no. 132.

[9] Dawood, N., Akinsola, A., Hobbs, B., 2002, Development of automated communication of system for managing site information using internet technology, Automation in Construction, 11 (5), pp. 557-572.

[10] Blackburn, N., 2001, Building bridges: towards integrated library and information services for mental health and social care, Health information and libraries journal, 18 (4), pp. 203-212.

[11] Wamba, F., Boeck, H., 2008, Enhancing Information Flow in a Retail Supply Chain using RFID and the EPC Network: A Proof-of-Concept Approach, Journal of Theoretical and Applied Electronic Commerce Research, 3(1), pp. 92-105.

[12] Gavirneni, S., Kapuscinski, R., Tayur, S., 1999, Value of information in capacitated supply chains, Management Science, 45 (1), pp. 16-24.

[13] Stapel, K., Schneider, K., Lübke, D., Flohr, T., 2007, Improving an industrial reference process by information flow analysis: A case study, Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 4589 LNCS, pp. 147-159.

[14] Loos, P., Allweyer, T., 1998, Application of production planning and scheduling in the process industries, Computers in Industry, 36 (3), pp. 199-208.

[15] Pras, A., Schönwälder, J., 2003, On the Difference between Information Models and Data Models, IETF RFC 3444, Jan. 2003; online at: www.rfc-editor.org/rfc/rfc3444.txt . accessed 15 August 2009

[16] Smith, G., Stoker, G., Maloney, W., 2004, Building social capital in city politics: Scope and limitations at the inter-organisational level, Political Studies, 52 (3), pp. 508-530.

[17] Tarhule, A.A., 2007, Climate information for development: An integrated dissemination model, Africa Development, 32 (4), pp. 127-138.

[18] Manecke, N., Schoensleben, P., 2004, Cost and benefit of Internet-based support of business processes, International Journal of Production Economics, 87 (3), pp. 213-229.

[19] Kehoe, D.F., Little, D., Lyons, A.C., Measuring a company IQ (1992) IEE Conference Publication, (359), pp. 173-178.

[20] Iskanius, P., Helaakoski, H., Alaruikka, A.M., Kipinä, J., 2004, Transparent information flow in business networks by using agents, IEEE International Engineering Management Conference, 3, pp. 1342-1346.

[21] Becker, J., Beverungen, D.F., Knackstedt, R., 2009, The challenge of conceptual modeling for product-service systems: status-quo and perspectives for reference models and modeling languages, Information Systems and e-Business Management, pp. 1-34.

[22] Cherbakov, L., Galambos, G., Harishankar, R., Kalyana, S., Rackham, G., 2005, Impact of service orientation at the business level, IBM Systems Journal, 44 (4), pp. 653-668.

[23] Mont, O., 2004, Reducing life-cycle environmental impacts through systems of joint use, Greener Management International, (45), pp. 63-77.

[24] Kerr, C.I.V., Phaal, R., Probert, D.R., 2008, Technology insertion in the defence industry: A primer, Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 222 (8), pp. 1009-1023.

[25] Tukker A, 2004, Eight types of product-service system: eight ways to sustainability? Experiences from SusProNet, Business Strategy and the Environment, 13(4), pp. 246-260.

[26] Malecki, E.J., 2002, Hard and soft networks for urban competitiveness, Urban Studies, 39 (5-6), pp. 929-945.

[27] Durugbo, C., Tiwari, A., Alcock, J.R., 2010, Survey of Media Forms and Information Flow Models in Microsystems Companies in Camarinha-Matos, L. M., Pereira, P., Ribeiro, L., (eds.) Emerging Trends in Technological Innovation (IFIP Advances in Information and Communication Technology Book Series) AICT 314, 62-69.

[28] Aurich, J. C., Fuchs, C., DeVries, M. F., 2004, An Approach to Life Cycle Oriented Technical Service Design, CIRP Annals - Manufacturing Technology, 53(1), pp. 151-154

[29] Mont, O. K., 2002, Clarifying the concept of product-service system, Journal of Cleaner Production, 10(3), pp. 237-245

[30] Durugbo, C., Tiwari, A., Alcock, J.R., 2010, A Review of Information Flow Diagrammatic Models for Product-Service Systems, International Journal of Advanced Manufacturing Technology (Accepted for publication)

[31] Morelli N, 2006, Developing new product service systems (PSS): methodologies and operational tools, Journal of Cleaner Production, 14(17), pp. 1495-1501.

Introducing PSS in product-based organizations. A case study in the manufacturing industry

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Take the knowledge path to support knowledge management in product service systems

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Abstract

Product/Service-Systems (PSS) strategies are a part of an overall movement towards a service-based society that is increasingly knowledge and information based. Knowledge sharing for cross-company innovation and development projects has been recognized as troublesome, since disparate knowledge domains must be brought together in a cohesive way to support both creativity and innovations. Stage-Gate process models are widely used in collaborative development projects but they do not suggest how to assess the degree of understanding of the produced information and the results in projects. A successful assessment of knowledge should be used for designing the next development steps in form of work methods and tools. This paper describes an approach for supporting Knowledge Management and Knowledge Sharing in the development of PSS. Finally, a concept for supporting knowledge assessment is proposed, based on designing and visualizing knowledge paths.

Keywords

Knowledge Management, Product Development Process, Knowledge path, Knowledge maturity, Technology Readiness Level

1 INTRODUCTION

Globalization, increased competition, dynamic and constantly changing business demands are some of the factors that industrial manufacturing companies have to deal with. These demands require the companies to improve the performance in their product development, which primarily are achieved by focusing on reduction of cost, reduction of lead-time and improvement of quality [1]. The activities to follow during product development can be formalized in a Product Development Process (PDP) wherein work methods, tools and practices can be described. The results when following the PDP depends on the methods and tools that are prescribed, as well as on the knowledge and skills of the people doing the work.

To achieve an improved performance many industrial manufacturing companies have adopted a Stage-gate process [2, 3] as the foundation of their Product Development Process, and the benefits of using such a model have been well documented. Johansson [4] explains this choice with *'In industry, a popular way of formulating a process based on the gate-milestone model, because it makes the process more natural to manage and you have natural decision points in the gates where everyone converges to take decisions about the process'*. Stage-Gate is a process that moves projects from idea to launch of product. It is based on a process model called Phased Review [3] implemented by NASA during the 1960s to manage the development projects by breaking the process into clearly defined stages with reporting in-between them.

The main structure of Stage-Gate is that you have a series of Stage and Gates, typically named Scoping, Business Case, Development, Testing and Launch. The Stage (see Figure 1) is where the development work takes place and within each Stage, activities are normally undertaken in parallel. The Stage can also be seen as information gathering activities that after an integrated analysis produce deliverables as input to the Gate [3]. After a Stage there is a Gate (also known as a decision point). The role of the Gate is to assess results, evaluate what has been done in the previous Stage and to decide the way forward; what should be done in the next Stage, how that path forward should be undertaken and how much resources should be allocated for creating new deliverables during the next Stage [3].

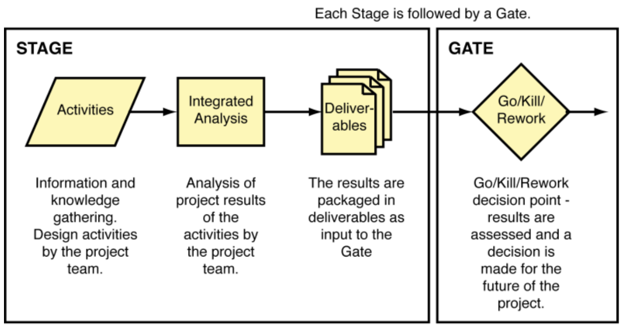

Figure 1: Stage-Gate structure with a Stage followed by a Gate (adapted from Cooper [3])

Stage-Gate models prescribe that the gate keeping team focuses their reviews on the results that has been developed during the Stage. Particularly, Stage-Gate models do not provide any solutions for assessing the degree of understanding of the produced information in the process. Furthermore, it is not apparent how such solutions should support the assessment of infomation in the PDP in the existing Stage-Gate context of industrial manufacturing companies. A successful assessment of knowledge should be at the centre of support methods and tools to be used by the project team.

Moving towards a development of a Product/Service Service system, depicting an integration of a diverse set of knowledge areas with the integration of hardware and services in a total offer with a lifecycle perspective [5], managing uncertainties and ambiguities by assessing knowledge and information [6] will be even more important to be able to deliver a PSS that the manufacturer can "live with" for the duration of the its life cycle.

Thus, the purpose of this paper is to describe different views on knowledge assessment in the Product Development Process in industrial manufacturing companies and to suggest how this can be supported in the development of PSS.

Following this introduction, a theoretical framework within the area of Knowledge Management is summarized. The data generation and results of the case study are presented in the following chapters and finally, a concept for supporting knowledge assessment in the Product Development Process is proposed, based on designing and visualizing knowledge paths.

2 THEORETICAL FRAMEWORK

2.1 Knowledge and Knowledge Management

There are many ways to define Knowledge Management. One of them is *'…the systematic processes by which knowledge needed for an organization to succeed is created, captured, shared and leveraged.'* [7]. Knowledge Management greatly focuses on organizational aspects and how knowledge can be managed for the benefit of the organization, stopping it from leaving with i.e. employee turnover [8].

As with Knowledge Management, there are also many ways to define knowledge. Knowledge can be distinguished from information and data by using the knowledge hierarchy (also known as the DIKW-hierarchy reflecting the terms Data, Information, Knowledge, and Wisdom), see Figure 2.

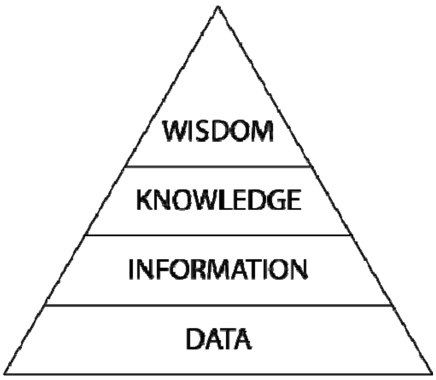

Figure 2: Knowledge hierarchy, relating data, information, knowledge and wisdom (adopted from [9])

Johansson [4] summarizes the knowledge pyramid as:

- Data is about the raw numbers.
- Information is about adding meaning to the data, for instance by relating it to other sets of data.
- Knowledge is when predictions can be made and actions can be taken, you start to see patterns in the data and information. You no longer look back in the past on what has been, but can start to look ahead and take decisions and act for the future, based on what you know, in real time.
- Wisdom is yet one more step forward, where you forecast implications of decisions and actions.

Understanding and context aids the transition from one stage of the hierarchy to the next. Clark [10] states that *"one gains knowledge through context (experiences) and understanding'*.

Knowledge can also be broken down into tacit and explicit knowledge [11]. Tacit knowledge is the type of knowledge that is residing in people's minds [12] and cannot be written down and codified in an easy manner. In contrary, explicit knowledge is the knowledge that can be communicated with others.

2.2 Technology Readiness Level

TRL is developed by NASA [13] and prescribes the development of a technology that, in the case of NASA, will feature on products that are used for space missions. The TRL is a 9-level scale that has criterions that describes necessary developments for every step, see Figure 3. TRL is intended to be used as a flight of stairs that are climbed one by one as the technology is developed and thus matured. It begins, on the first level (TRL 1), with basic principles being observed often in research or laboratory environments. At this stage the technology is as far away from implementation as is possible. Thereafter the developers can develop and mature the technology, through different stages of validation and integration in larger systems. At the end of the scale (TRL 9) the technology and its systems are 'flight proven' in space environments and various bugs have been ironed out. The further up the scale the technology matures, the more expensive it is to move to the next level. Therefore, technologies and systems that are not 'mission critical' will not move through the whole scale. TRL has been widely adopted in the aerospace community and is now a feature in many companies to measure technology maturity.

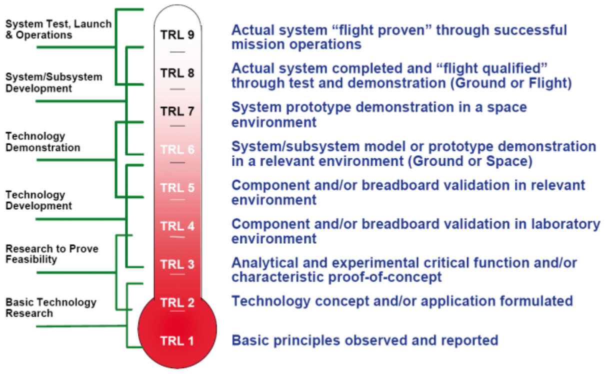

Figure 3: Technology Readiness Level (TRL) chart with criterion descriptions (from Mankins [13])

2.3 Knowledge Maturity

Knowledge Maturity [4] is an approach based on the idea of assessing the state of the current knowledge at any point in a development project. Essentially, it is about comparing the amount of knowledge that a company considers to be needed to feel confident (i.e. good enough) that a product or service will perform as intended, with the knowledge that is available to the company about that product or service at any time in a project. Based on maturity and readiness ideas borrowed from the Technology Readiness Level [13] concept and the Capability Maturity Model (CMM/CMMI) [14, 15] concept from software engineering, the Knowledge Maturity idea was born as a way to assess knowledge in a similar way as performance measures and indicators are assessed at decision points (i.e. gates). It is developed to support a gated process where there is a prescriptive dimension to it as well as the gate-assessment dimension. The maturity of the knowledge is assessed on three dimensions; input data, methods/tools used, and experience/expertise of the people doing the work. A generic scale of the criterion is presented in Figure 3 below.

5	EXCELLENT	*The content and rationale is tested and proven. It reflects a known confidence regarding, for instance, risks. *The procedure to produce the content and rationale reflects an approach where tried out methods are used and where workers continually reflect and improve. *Lessons learned is an important element.
4	GOOD (between 3&5)	
3	ACCEPTABLE	*The content and rationale is more standardised and defined. *There is a greater extent of detailing and definition. *The procedure to produce the content and rationale is more stable with an element of standardisation and repeatability.
2	DUBIOUS (between 1&3)	
1	INFERIOR	*Content and rationale is characterised by instability. *The procedure to produce the content and rationale is dependant on individuals and formalised methods are non-existent.

Figure 4: Knowledge Maturity criterion
(adopted from Johansson et al [4])

Input data is a label for all information and data that flows into the process (mainly from outside the company). How well can the company trust that the information is accurate? Is further research and development into the subject needed? Such questions should this dimension be able to address. The method/tool dimension is basically about assessing the refinement and development (of the input data) that goes on in a project. How good are the processes and methods used? How accurate are the simulation models that are used? And so on. These types of questions should be taken care of by this dimension of the Knowledge Maturity concept. Experience and expertise is about people, it is about the people who do the work, the experts that contribute, etc. Who has delivered this result? Which experts were involved? What experience from similar projects can be utilised? Such questions could be answered by addressing this dimension.

Since sharing tacit knowledge is one of the basics for enabling knowledge creation [16], knowing what experience and expertise conclusions can be based upon can be the deciding factor of whether a project is a success or a failure.

This concept with the criterion scales is also working in a prescriptive manner, where project leaders can assess what areas of knowledge creation and acquisition efforts should be focused on.

2.4 Lessons Learned

There are many different definitions of Lessons Learned. Secchi et al [17] provides a definition that is used by American, European and Japanese space agencies:

'A lesson learned is a knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned. A lesson must be significant in that it has a real or assumed impact on operations; valid in that is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result.'

3 DATA GENERATION

The data presented in this paper has been gathered during both formal workshops and semi-structured follow-up interviews with some of the participants of these workshops.

Three workshops where held between April and September 2008 with development teams of three different product development projects in the aerospace sector. The participants were introduced to the workshop method with this information:

'For many corporations, 'thinking-outside-the-box' means detaching yourself from current market needs and demands, and the term is often filled with frustration for the development teams that are supposed to turn these unconventional ideas into engineered reality. In a two-day immersive workshop format, we are using visual facilitation methods to enable highly cross-functional teams to explore a wide range of critical issues concerning product and service innovation, to create new ideas for how to address these issues, and to develop practical solution proposals for how to bring these ideas to market.'

In these workshops, the development teams consisted of competencies representing all phases of the product lifecycle. Researchers who actively have participated and thus influenced both process and results have facilitated the workshops. The workshop process and the results have been thoroughly documented in internal reports.

In addition, to follow-up the workshops, semi-structured interviews were held with a selection of the participants. Based on the results from the workshops, the following themes were discussed during the interviews;

Application of:

- Stage-Gate processes
- Knowledge Management
- Knowledge Maturity
- Technology Readiness Level
- Lessons Learned

The intention to focus on different views on knowledge assessment in the Product Development Process have evolved during of the implicit analysis of the workshops and interviews, which have highlighted specific challenges about the current practice, thus evolving to become a main focus of this paper.

Given the use case driven nature of this study, the research can be seen as case study oriented.

4 KNOWLEDGE ASSESSMENT CHALLENGES IN THE PRODUCT DEVELOPMENT PROCESS – 'AS-IS'

The three development projects are described as:

- Project A: Process Development – Development of the company's PDP
- Project B: Product Development – Developing a new physical aerospace component
- Project C: Technology Development – Developing a new technology in order to be able to take on new product development projects

In all of the three development projects a company-specific version of the Stage-Gate is implemented. During the workshops we find that this process is well communicated and understood amongst the participants.

However, in both project A and B the gate reviews are seen as very important, but poorly used as an opportunity of knowledge assessment.

'…they (the gate reviews) are important but why aren't we using them for educational purposes? Why aren't other development projects participating in order to learn something new?'

Another participant comment was:

'…and our review process isn't that good today. A lot of deliverables (between 40-50 reports) and a total of 6000 pages. Everything wasn't read or understood by the gate keeping team…'

In project A, knowledge is primarily identified as a resource challenge. As one respondent puts it:

'We only have a limited amount of staff with a certain competence. This implies that the number of experts isn't enough to cover the total needs of the company's project portfolio.'

In project C, two companies are involved; the first is an experienced actor within the aerospace community; the other has no previous knowledge of aerospace development projects. Several times during the workshop communication issues are discussed. Lack of communication and lack of usage of tacit knowledge are seen as some of the major risks for this project.

'…things that we (the experienced company) take for granted, is news for the others in the project…'

'We should immediately start a knowledge exchange program where we continuously send people to each others offices'

The idea of the exchange program was developed in order to assess new and tacit knowledge to and from both organizations.

In all three projects, participants are comfortable with using the TRL scale. Especially in project A is it obvious that the intense focus on reaching a higher TRL is seen as an important challenge.

'…our focus on TRL is always of highest priority. It doesn't work – we will reach TRL9 and go bankrupt at the same time…'

In project B, Lessons Learned is the topic of the workshop. During the workshop, 8 positive and 12 negative Lessons are identified as the most important.

In all projects, Lessons Learned are prescribed in the Stage-Gate process description. They are supposed to be identified and documented (as a deliverable) at the end of the project.

'…we should identify other development projects that can use the lessons we have learned – and then arrange a road show and 'push' the lessons to them…'

All projects also mentioned the challenge of finding relevant Lessons Learned from other development projects.

In none of the three projects are the term knowledge maturity discussed or related to during the workshops.

In Table 1 below, some of the main points from the workshops and interviews are summarized to enable the reader to get an overview of the results from the case study.

5 KNOWLEDGE PATHS IN THE PRODUCT DEVELOPMENT PROCESS

The concept is based on the knowledge path framework introduced by Murray [18]. The term knowledge path is defined as the path a firm takes to explore the knowledge that expands and add value to its current knowledge base and product offerings. A knowledge path has two dimensions; the first part is how the firm searches for new knowledge and the second part is the assembly of the new knowledge with the existing knowledge base.

Murray [18] suggests that a firm's decision about where to search for knowledge and how to assemble it should be based on cost of search and assembly, organizational requirements, and likelihood of success. Further, Murray [18] states that a better understanding of the knowledge paths and their underlying processes will be at the heart for sustainable competitive advantage for knowledge-based firms.

5.1 The concept idea

As found in the in the results section there seems to be a need to better support knowledge assessment in the PDP. In the context of the PDP, the Stage-Gate models prescribes a way of performing product development activities, as well as prescribing the search and assembly of information in order to meet both the deliverables during the Stages and make correct decisions at the Gates. However, the knowledge assessment dimension is still missing in Stage-Gate models, as the main focus is about delivering and reviewing the results, not on a learning perspective. Engwall [19] concludes that Stage-Gate needs to be applied correctly, to allow for both flexibility and learning.

The main idea behind the concept presented here is to combine the approaches of TRL and Knowledge Maturity and relate them to the Stage-Gate process. See Figure 6

	Project A	**Project B**	**Project C**
Type of project	Process Development – Development of the company's PDP	Product Development – Developing a new physical aerospace component	Technology Development – Developing a new technology in order to be able to take on new product development projects
Workshop focus	PDP Development	Lessons Learned	Risk Management
Usage of Stage-Gate processes	Yes. The Gate reviews aren't used to assess or distribute knowledge.		
Usage of Knowledge Management	Resource planning is a knowledge challenge	-	Lack of usage of tacit knowledge is an identified risk for this project
Usage of Technology Readiness Level	Yes		
Usage of Knowledge Maturity	No		
Usage of Lessons Learned	Hard to find usable from other projects.	Hard to find usable from other projects. Pushing their own lessons to other development projects.	Hard to find usable from other projects.

Table 1: Summary of workshop and interview results

for a schematic overview of the idea. Work in the PDP is aimed at and governed by increasing the TRL of the product. Knowledge maturity is about supporting the learning and knowledge utilization in the PDP. High knowledge maturity reflects a high level of knowledge about the product and the process. The use of a scale depicts that it is an evolutionary process, where you climb the scale while developing and learning about the product and process.

The knowledge path can be seen in this figure as the journey that the development team needs to make in terms of knowledge acquisition and technological evolution to meet the objective with the product, depicted as an increase in Knowledge Maturity and TRL respectively.

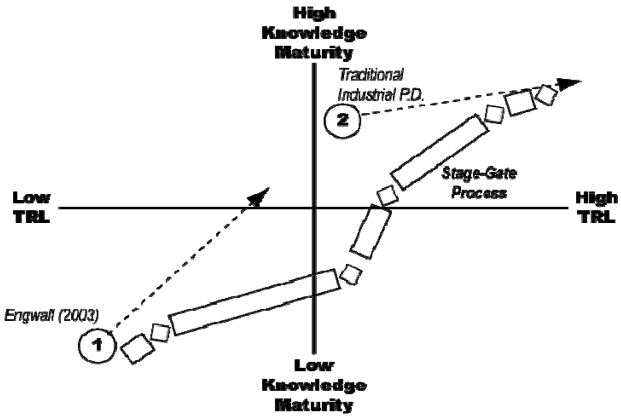

Figure 6: 2-by-2 that show the Knowledge Maturity in relation to TRL.

The knowledge path looks different for different product development projects, depending on the amount of learning. As the team learns, the amount of knowledge is improved and therefore the maturity of the knowledge in the project improves. This learning is depicted as moving along the y-axis in this figure. As a consequence of the learning, the technology is also developed. For instance, testing and simulating materials moves it closer to being ready for implementation in a product. This technological development is depicted as moving along the x-axis in the figure.

Figure 6 also depicts two examples, where the dashed arrows indicate the knowledge paths taken in the respective cases. The first has been described by Engwall [19], where the project team discarded the standardized Stage-Gate based process that the companies usually work by, in favor of processes that are more flexible and allows for uncertainty and learning. In this case there were essentially no prior knowledge about the problem they were solving and therefore the knowledge maturity began at a low level. Discarding the Stage-Gate did not only bring positive results as the integration with the organization and industrialization of the project proved difficult.

The second example depicts a more traditional product development project in the aerospace industry. There is very little uncertainty as contracts have been written with customers before the development effort begins, as well are their demands clearly defined in the contracts. This means that little learning takes place and the TRL level of the technologies is relatively high when beginning the project.

5.2 Designing the process

This line of thinking will also make it possible to design the process and knowledge path that should be taken. When will leaps in knowledge be made during the project? When will more staffing and resources be needed to make these leaps? And naturally, when can these resources be afforded to some other projects? Further, adding a time dimension to this reasoning could also help in planning of utilization of resources, such as when external consultants or experts are necessary to bring the project forward. In Figure 7 below, the dashed line exemplifies a typical knowledge path developed in advance of a project as a part of the resource allocation plan. Here stages with high workload can be identified and thus knowledge-intensive resource can be allocated. Conversely, Stages with need for less knowledge-intensive resources can also be planned for, so that they can be released to other projects in the organization. The same approach can be made for the gate keeping team who probably needs to invest more time and effort into Gate five due to the high increase in knowledge maturity during the Stage leading up to Gate five.

In a PSS scenario it is about making sure that you can deliver and be profitable for the duration of a product's lifecycle. Signing up for the risk that a total offer contain, means that a company cannot take any risks in terms of not knowing how the product will perform or that the business case will not hold. Therefore, being able to balance the technological leaps that need to be made from time to time to have an attractive PSS offering, with knowing about the unknowns will be imperative. The idea is to "design" this with this kind of representation.

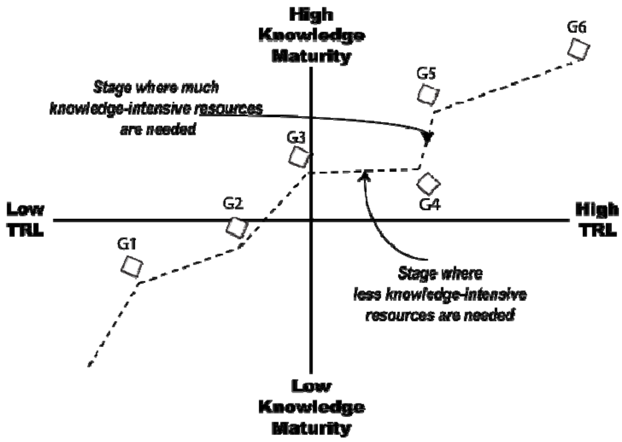

Figure 7: 2-by-2 that show the planning of a knowledge path.

5.3 Visualizing the progress

Cooper [3] says that the role of the gate meeting is, apart from deciding if the project should be allowed to pass, to decide how the path forward should look and how many resources should be allocated for the next Stage. The example in Figure 8 reflects one arbitrary gate in a product development project, where the dashed line depicts the knowledge path that should be taken during the stage. However, in this case the actual result of the work during the stage is similar in terms of TRL but too low in terms of the progress made in the knowledge maturity dimension. Therefore, more learning is needed in the following Stage to take the knowledge base to the correct level.

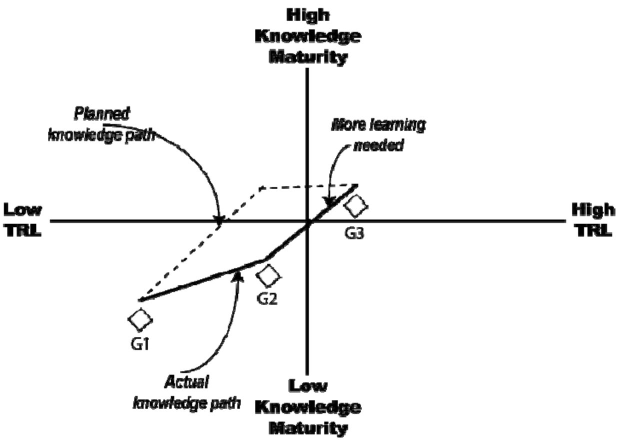

Figure 8: 2-by-2 that shows progress made in relation to what was prescribed in terms of learning and technological maturity.

6 CONCLUSIONS

The purpose of this paper was to describe different views on knowledge assessment in the PDP in industrial manufacturing companies. The result from the case study shows that both Stage-Gate process and TRL is already used in several types of development projects. However, there is an identified need of developing knowledge assessment methods, as learning and knowledge is not a focus in today's Stage-Gate driven development projects.

From a PSS perspective, the dimensions of learning and managing ambiguities and uncertainties will be even more important for successful executions of development projects.

Our conclusions are that the area of knowledge assessment in the PDP in industrial manufacturing companies is an interesting approach to facilitate learning in the development process. It is in need of further research and initially with a focus on the descriptive part in order to gain a better understanding. Thereafter, the intention is to move on with a prescriptive study, where and intervention, i.e. tool, method or other form of support, will be designed to aid in overcoming the problems identified.

The presented concept of creating knowledge paths in the PDP can be a valuable contribution as it combines two existing and implemented concepts (Stage-Gate and TRL) with a new method of assessing knowledge, the knowledge maturity approach. This concepts also fits very well into the development of PSS with the focus on managing a disperse knowledge base.

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8 REFERENCES

[1] Ulrich, K.T. and Eppinger, S.D., 1995, Product Design and Development, (McGraw-Hill Book. Co. Boston, MA, USA).

[2] Cooper R.G., 2001, Winning at New Products: Accelerating the Process from Idea to Launch, 3rd ed. 2001, (Perseus Books, Reading, MA).

[3] Cooper R.G.,2008, Perspective: The Stage-Gate® Idea-to-Launch Process-Update, What's New, and NexGen Systems*, Journal of Product Innovation Management, 25(213-232).

[4] Johansson C., 2007, Knowledge Engineering in the Virtual Enterprise: Exploring a Maturity-Based Decision Support, Licentiate Thesis, Department of Applied Physics and Mechanical Engineering, Luleå University of Technology, Luleå, p. 39.

[5] Tukker, A. and Tischner, U., 2004, New Business for Old Europe. Suspronet.

[6] Johansson, C., 2009 Knowledge Maturity as Decision Support in Stage-Gate Product Development: A Case From the Aerospace Industry, Doctoral Thesis, Department of Applied Physics and Mechanical Engineering, Luleå University of Technology, Lulep, p. 68.

[7] Rumizen, M.C., 2002, The Complete Idiot's Guide to Knowledge Management, (CWL Publishing Enterprises, Madison, WI, USA).

[8] Kreiner, K., 2002, Tacit Knowledge Management: The Role of Artifacts. Journal of Knowledge Management, 6(2), pp. 112-123.

[9] Hey J., 2004, The Data, Information, Knowledge, Wisdom Chain: The Metaphorical link, (Intergovernmental Oceanographic Commission, Berkley, CA).

[10] Clark, D., 2004, The Continuum of Understanding. URL: http://www.nwlink.com/~donclark/performance/understanding.html. Accessed: 2009-01-15.

[11] Nonaka, I., 1994, A Dynamic Theory of Organizational Knowledge Creation. Organization Science, 5.

[12] Polyani, M., 1966, The Tacit Dimension (Routledge & Kegan Paul Ltd., London, United Kingdom)

[13] Mankins J.C., 1995, Technology Readiness Levels, (NASA Advanced Concepts Office)

[14] Paulk M.C., et al., 1993, Capability Maturity Model SM for Software, Version 1.1, (Software Engineering Institute, Carnegie Mellon University, Pittsburgh, PA).

[15] CMMI Product Team.,2007, CMMI for Acquisition. Technical Report. URL: ftp://ftp.sei.cmu.edu/pub/documents/07.reports/07tr017.pdf. Accessed: 2009-01-15.

[16] von Krogh G., Ichijo K. and Nonaka I., 2000, Enabling Knowledge Creation: How to Unlock the Mystery of Tacit Knowledge and Release the Power of Innovation, (Oxford University Press, New York, NY, USA).

[17] Secchi, P., Ciaschi, R. and Spence, D., 1999, A Concept for an ESA Lessons Learned System. In P. Secchi, Proceedings of Alerts and LL: An Effective Way to Present Failures and Problems, Technical Report WPP-167 (ESTEC: Noordwijk, The Netherlands).

[18] Murray, F.E., 2001, Following Distinctive Paths of Knowledge: Strategies for Organizational Knowledge Building within Science-based Firms. In Managing

Industrial Knowledge (Eds. Nonaka, I. and Teece, D.J.), (SAGE Publications, London, UK).
[19] Engwall M., 2003, Produktutveckling bortom kunskapens gränser: mot en osäkerhetens grammatik, (Studentlitteratur, Lund, Sweden).

Software Agents for Automated Knowledge Generation in IPS²

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Abstract

For a competitive (re)design, planning and usage of Industrial Product-Service System (IPS²), knowledge about the usage patterns of the customer, the IPS² system behavior and the remaining lifetime of products is needed. The data from the operation phase is the source to discover this knowledge. With the help of software agent technology product- and process data can be made locally available - data which are spatially and temporally distributed along the life cycles of IPS² in different media and formats. In a next step it will be processed with the help of data mining algorithms in an appropriate form to knowledge, as required by the application. The Virtual Life Cycle Unit (VLCU) is a concept for such an information system. It is an information technology network, which appears to humans or machines as a single unit to support the supply chain and communication processes in the complete IPS² life cycle.

In this paper the technology, data acquiring and communication concepts of the VLCU in the IPS² life phases is being discussed and presented.

Keywords

Industrial Product Service Systems, Virtual Life Cycle Unit, Knowledge Generation, Software Agents, Ontology

1 INTRODUCTION

In business-to-business and also business-to-customer markets there is a tendency towards combined offers of products and services, which are sold in one package to fulfill customer needs. These combinations of products and services are called product-service systems (PSS) or industrial product-service systems (IPS^2) in case of industrial application [1]. The use models of Industrial Product-Service Systems (IPS²) are based on the idea of selling functionality, availability or results instead of selling machines.

For a competitive design, planning and usage of IPS², knowledge needs to be generated about the usage patterns of the customer, the IPS² system behavior and the remaining lifetime of products in the IPS². The data from the operation phase is the source to discover this knowledge. With the help of information technology product- and process data can be made locally available, data which are spatially and temporally distributed along the life cycles of IPS² in different media and formats, and processed in an appropriate form - as required by the application. The Virtual Life Cycle Unit (VLCU) is a concept for such an information system. It is an information technology network, which appears to humans or machines as a single unit to support the supply chain and communication processes in the complete Industrial Product-Service System (IPS²) life cycle.

2 IPS² LIFE PHASES AND REQUIRED KNOWLEDGE

The idea of selling functionality instead of products is the core idea of Industrial Product-Service Systems (IPS²) [2]. To be competitive on the market the provider and manufacturer of IPS² have a strong interest in using a minimum of production resources, which means maximum utilization and usage of products and components. Therefore manufacturers of capital goods (e.g. machine tools) expand their business activity beyond selling physical products. Industrial customers make their day-to-day business by selling this kind of products (e.g. manufacture components) which means that they are interested in functionality over a time frame to achieve a result [3]. Therefore, with new business models manufactures of capital goods offer functionality, availability or results instead of selling products to meet the customer needs. Selling functionality means that the customer gets the physical products designed to its requirements. The customer is responsible for maintenance and the risk of breakdowns or in the case of selling availability or results, the risk for breakdowns, malfunctions and the execution of maintenance processes goes over to the provider.

To maximize the lifetime of components and to replace them at the time before it breaks – not too early, but to ensure the functionality not too late - a lifetime prognostic is required. It facilitates a minimum costs for spare parts due to enable the maximum use of resources and prevent an unseen production breakdown. Of course this implies that the exchange can be made within the time to the predicted breakdown. From the point of the planning, this might be not always economical. It might be cheaper to replace a part during an inspection, than sending a technician two days later again to replace the worn part. Lifetime prognostic allows a condition based scheduling for services. Finally the lifetime prognostic also enables the reuse of components. Combined with a condition diagnostic it is possible to decide if a used component can have a second life phase in another application. This saves further resources and so and leads to a more competitive IPS².

Assuming that the IPS² provider knows about the usage patterns of his customer, the design and planning would be made perfectly matching to the customer needs or the provider would give advises to his customer how to produce more economic. In the initial phase of the IPS² business relation, the customer tries to communicate his demands to the provider. He tries to design an IPS² which fits best to these requirements. However, most times the sold product or in our case IPS² has many chances to be enhanced. This is because the designer relies on ideal assumptions that differ from the real product behavior and use. Identifying these gaps would create the ability for a more efficient design and planning of the IPS².

To ensure the functionality, to enhance the design of the IPS² and to adopt the services the provider needs knowledge about the IPS² system behavior. The system behavior is knowledge about inferences between product and services, as well as services or products among each other.

If identified new system behaviors, e.g. for the early malfunction of machines under certain conditions, the question is for which IPS² in business this is effective. Usually every IPS² is a unique system, but certain conditions lead to a system behavior, which bases on design, usage etc. To identify similar IPS² classification are useful. Classification identifies groups or similarities.

In addition as mentioned before lifetime prognostics is required to prevent loosing of production functionality due to unplanned breakdowns and so to schedule services, like wear part exchange to optimize the service scheduling or to save resources.

This is called knowledge, as it leads to a competitive provision or design of IPS². Actually there are many definitions for the term knowledge, but the definition of [4] has become more and more popular within the last years. This defines knowledge as the appropriate linking of information. Knowledge results from the processing of data and information, acquired in certain situations. So data and information are the raw material for knowledge. The value of knowledge will be shown, when it is referenced to an application and the ability for acting is facilitated. The acting itself needs an intention and if acting correctly and original or inventive, the competitiveness is given, see Figure 1.

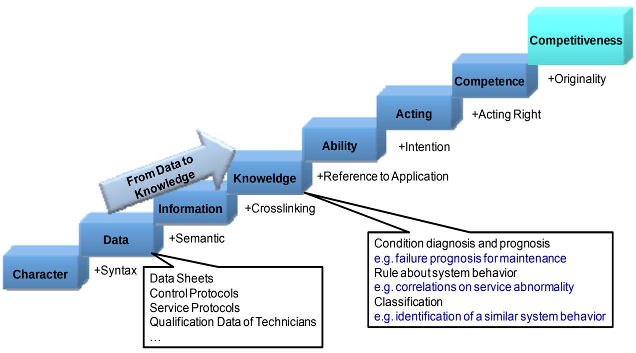

Figure 1: Knowledge in the context with as the foundation for competitiveness [4]

This means that automated generated knowledge set the foundation for a competitive business with IPS². Therefore the VLCU and its knowledge generation is an enabler for the competitive redesign, planning or delivery in the IPS² business model.

3 DATA SOURCES FOR KNOWLEDGE GENERATION

Due to the modern IT based engineering, business communication and documentation, most data along the life cycle of an IPS² are already digital available and via internet worldwide accessible, e.g. machine datasheets, service protocols or personal database. The challenge lies in the access, acquiring, communication and finally the processing to knowledge to support the decision-maker along the IPS² life-cycle.

The available data sources are in different formats and media. The VLCU access these data sources by the use of software agents. Agents are software modules acting independent, based on given rules. Those agents build the communication and processing platform for the knowledge generating information technology concept of the VLCU. Necessarily not every single source has to have an own agent, one agent could also handle different local sources. Each agent is responsible for a location of data sources. Finally this concept allows a database, file or company-based access.

The content of the data sources and their relations are described by an ontology, to select the relevant data for the knowledge generation process. In the context of computer and information sciences, an ontology defines a set of representational primitives with which to model a domain of knowledge or discourse. The term is taken from philosophy, where ontology is a systematic account of Existence. For Artificial Intelligence systems, what 'exists' is that which can be represented. [5]

4 EXAMPLE SCENARIO

As an example scenario there shall be electric wire discharge machines in micro-production, with the problem that the wire is sometimes not transported correctly and get tangled up along the transport wheels. The question for the designer is what causes this problem. Knowledge about under what conditions this happens facilitates an effective analysis of this problem and enables to develop the right therapy. This inference knowledge can be found by comparing the data of the usage of all machines of this kind. Influencing factors to this problem can be technicians, service procedures, special kind of used spare parts, production equipment, the process itself or production conditions. This means, that the VLCU needs to call data from the control protocols from the wire erode machines, the IPS² customer production, service protocols from service partners, datasheets or quality test reports about used production equipment and involved technicians personal and qualification data. Those are distributed digital available within the databases or computers of the partners in the IPS² supply chain. The technical access for the VLCU to these data is being done by using software agent technology.

5 SOFTWARE AGENTS FOR DATA ACQUIRING AND COMMUNICATING WITHIN THE VLCU NETWORK

In the VLCU Network the JADE (Java Agent DEvelopment Framework) [6] Software Agent system is used for acquiring and communicating the information that contains knowledge. The software agents work within a network in a flat hierarchal concept. A special designed agent - the so called DataAdministrator Agent - acts as the controlling unit for the VLCU Network; it sends out the requests for data delivery to the agents at the data sources and collects all communicated data into its connected database - the so called VLCU data warehouse. A data warehouse is a standardized, consistent, clean and integrated form of data sourced from various operational systems in use in the organization, structured in a way to specifically address analytic requirements [7]. This database is the source for the data processing step; the knowledge generating.

JADE is a software Framework fully implemented in Java language and based on the FIPA (The Foundation for Intelligent, Physical Agents) specifications for software agents and their message based communication [8]. The implementation in Java language makes it independent of the operating system where it is executed. The message based communication allows an asynchrony operation which ensures a robust system as well as that the agents cannot interfere with each other.

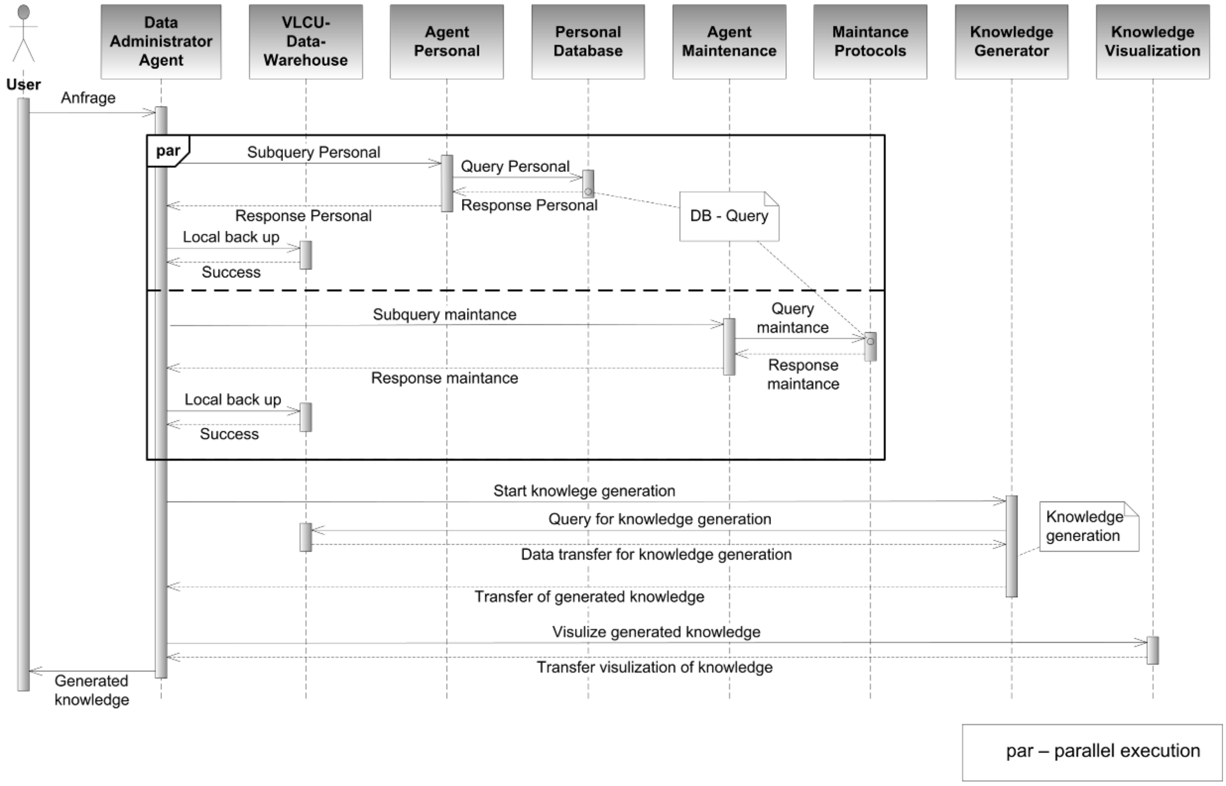

Figure 2: Communication Sequence Diagram of the Agents for the knowledge generation in the VLCU network

At the top of the JADE Agent hierarchy there are platforms that are composed of container, holding the individual agents. Each platform has one main container that holds two administrative agents – the Agent Management System (AMS) and the Directory Facilitator (DF).

The AMS agent could be called the white page of the network - it has the function to insure that each agent has a unique name and address within the platform. The DF agent can be referred to as yellow pages - it manages the available services from the registered agents within the platform. This means it tracks which service is provided by which agent and lists which agent has booked which type of services. So it informs all agents booked for a type of services when a new service of that type is available. The information flow is based on the pushing principle. A new agent sends which services it offers to the DF agent. In turn it informs all the agents that have booked that type of service about the newly available service. These two agents are the basis for a dynamically changing network, where agents can sign on and off. The IPS² network is growing dynamically with new service provider that only need to register with their own JADE agent to integrate into the VLCU network. A new agent in the network has to register with the AMS agent first, before it can register its services with the DF agent.

Via internet it is possible to connect distributed data sources in different locations, e.g. companies or data centers. Unfortunately security reasons within the internet demand that each location is protected by a firewall. The asynchronous communication in a single platform is difficult without reducing the effectiveness of the firewall by opening a communication port. Therefore each location has its own platform, which communicates with the help of the Message Transport System (MTS) [6]. This facilitates an easy connection of two or more platforms. That way the services from an agent in another platform can be used. In our example scenario three locations that are distributed but connected by internet have to be connected to the DataAdministrator Agent. Those are e.g. the customers' administration building with the personal database, the customers' factory with the usage and machine control protocol and the service provider 'maintenance' with the service and maintenance protocols, see Figure 3. A communication sequence diagram of the agents for the knowledge generation in the VLCU network is shown in Figure 2.

In the VLCU agent network the service 'data-service' provides a uniform connection to the data managed, stored or monitored by the agent, as well as its documentation by its partial ontology. The DataAdministrator Agent is looking for services of the type data-service. It requests each agent providing such service to transmit what kind of data it provides along with the partial ontology. The DataAdministrator Agent can then generate a comprehensive ontology of all the data available in the network and the agents providing it.

The DataAdministrator Agent analyses the requested enquiry to tasks the agents having access to the data which has to be considered in the knowledge generation process. Here the ontology helps to identify which data sources are relevant for the given knowledge processing, see Figure 4. In our example scenario the electric wire discharge machines are being used for micro-production. As micro production is sensitive for temperature changes, data from the production room´s air condition is required. The ontology holds this relation and refers to the air condition protocol as one of the required data source for the knowledge generation process.

The agents transmit the data back to the DataAdministrator Agent which stores it then in the central VLCU-Data-Warehouse database. The analysis is performed by the Knowledge Generator that operates on the data stored in the VLCU-Data-Warehouse. Further the processed knowledge will be archived in the IPS²-Life Cycle Management System (HLB-LM) [9]. This allows documentation and fast access to all kind of actors within the IPS² network.

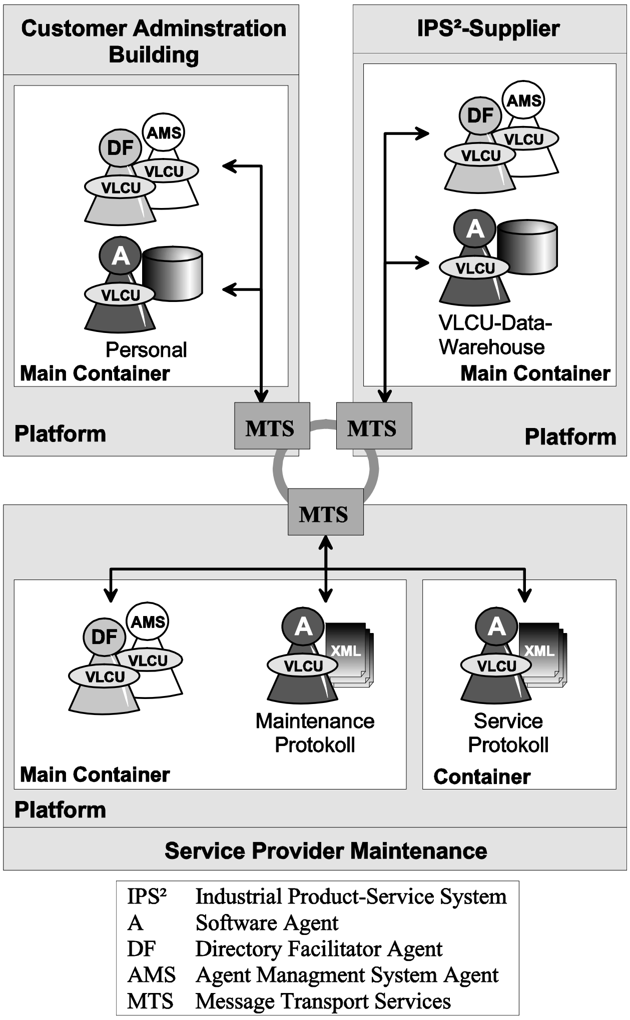

Figure 3: VLCU Agent Network

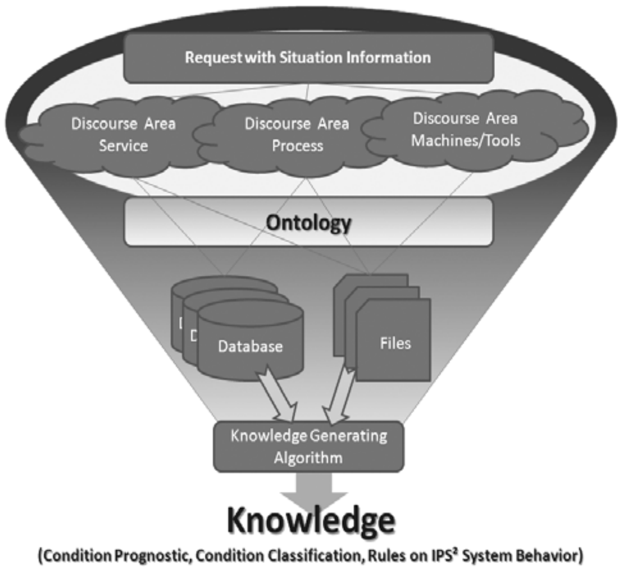

Figure 4: Ontology enables a request-based selection of relevant data sources

At the state of the research the distributed data is transferred as needed to the VLCU-Data-warehouse and the knowledge generation process is done centralized. As a perspective the knowledge generating process shall be done decentralized on the agents where the data is stored. The knowledge generation process would be executed on a VLCU-agent-mesh. This would lead to a network without the data warehouse, which is actually a storage, communication and processing demanding system. Further the access to the knowledge processing can be done via the software agents themselves, which gives access to all supply chain members, be connected in the VLCU network.

6 KNOWLEDGE PROCESSING

Knowledge is generated by linking IPS² operation information and describes the system performance within the IPS². This includes rules about the process flow of the IPS² and its operations, as well as prognoses and classification of ISP² health condition [10]. Rules about the IPS² workflow can be generated from the operation data. It is possible to classify the influencing parameters and variables to each parameter with e.g. the aid of the C4.5 algorithm, which is based on the ID3-algorithm, basing on the Bayes theorem. The hereby generated dependencies can be displayed in a decision tree structure. This decision tree can be used as a system of rules for the decision making processes within the IPS² development and supply chain.

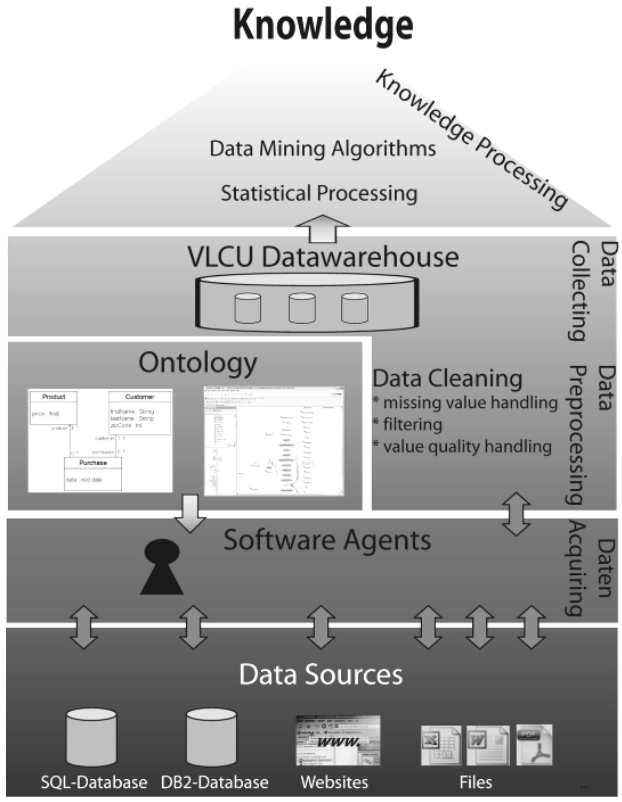

Figure 5: VLCU Concept Structure

Prognoses of the system condition are important knowledge, e.g. for the strategic planning. That way the service can be planned with the aid of a forecast for the time to failure, based on the actual condition of the machine. Controls act according given rules via fixed parameters - whereas the real lifespan is influenced by a multitude of influences, e.g. surrounding temperature, used tools or even the handling during the assembly. Via clustering algorithms like Statistical Pattern Classification it is possible to identify failure cluster and define or classify product health conditions.

By interpolation of the system conditions out of the IPS²-control, condition based prognostics is enabled – with failure mode statements. Prognoses also facilitate questions regarding the reuse of components, which stays in connection with the reconfiguration of IPS².

In the mentioned example scenario the C4.5 algorithm was able to identify a inference between the failure event and the used discharge wires. If an amount (length) of thicker wire (250um) has been used the transport of thinner wire (50um) failed. This knowledge leads to an investigation about the reason and it could easily identified, that the use of 'thick' wire lead to a wear on the transport rolls – which were actually not listed as a wear part. Roping avoid the needed contact for the correct transportation and so the 'thin' wire. The generated knowledge helps to locate the failure and enables a more focused problem search. The solution finding process is part on the level of planning and design.

This scenario leads to a result, which could be argued to be out of one data source, the control protocol. But this is not true. In dependence of the documented data of the machine control, the used length might be stored in the storage data base, where the available discharge wire is being listed. Then are already two sources minimum required. But as the inference is not identified at the time of the question, all data need to be investigated to identify the inference. The agent technology helped in the access of those data to process this in an automated network system.

The presented scenario based on a real problem with an AGIE electric wire discharge machine at TU Berlin, when the wire transport role was not declared as a wear part. Due to the research activities on this machine the wire has been unusual often being changed, why this problem occurred there first. Long and hard hand investigation identified the transport rolls in combination with the mentioned wire thickness. AGIE adopted this knowledge and declared the transport rolls as wear parts.

7 SUMMARY

The need of knowledge for the creation of competitive IPS² is essential. The available digital data along the IPS² life cycle are a source for an IT based knowledge generation to support the IPS² creation and design processes. The concept for an IT architecture has been presented in detail for the data acquiring and communication with the help of software agents, see Figure 5 – the so called Virtual Life Cycle Unit. Software agents enable a simple and adaptable way to access the data and also to give access to the knowledge generation for every partner within the IPS² supply chain. Further this technology allows and dynamic growing of the network, which is crucial for an effective and competitive supply chain network. The presented JADE implementation is widely used for software agents and allows an easy adaption and implementation for the most available computer systems.

In an example scenario the chances and needs of the IT based knowledge generation with VLCUs for supporting the design and creation processes to deliver a competitive IPS² has been shown.

8 ACKNOWLEDGMENTS

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9 REFERENCES

[1] Meier, H.; Uhlmann, E.; Kortmann, D.: Hybride Leistungsbündel - Nutzenorientiertes Produktverständnis durch interferierende Sach- und Dienstleistungen, wt Werkstatttechnik online, 95. Jahrgang, 7/2005, Springer-VDI-Verlag, ISSN-Nr.:1436-4980, S. 528-532.

[2] Tucker, A., Tischner, U., 2005, New Business for Old Europe – Product-Service Development, Competiveness and Sustainability, Greanleaf Publishing, Sheffield, UK

[3] Tan. A. R., McAloone, T. C., 2006, Characteristics of strategies in Product/Service-System Development, International Design Conference – Design 2006, Dubrovnik – Croatia, May 15-18.

[4] North, K.: Wissensorientierte Unternehmensführung. Wertschöpfung durch Wissen. 3. Aufl., Gabler, Wiesbaden 2002.

[5] Gruber, T., Ontology, 2009, Encyclopedia of Database Systems, Springer-Verlag, ISBN: 978-0-387-35544-3

[6] JADE Web page, http://jade.tilab.com, 2009

[7] Bau, A., Günzel, H.: Data-Warehouse-Systeme: Architektur, Entwicklung, Anwendung, dpunkt, 2008, ISBN 3-89864-540-1

[8] Bellifemine, F., Caire, G., Greenwood, D., 2007, Developing Multi-Agent Systems with JADE, Wiley-Verlag, ISBN: 978-0-470-05747-6

[9] Abramovici, M.; Schulte, S., Lifecycle Management für hybride Leistungsbündel (HLB), wt Werkstattstechnik online, 7/2006, Springer-VDI-Verlag, Düsseldorf

[10] R. Gegusch; G. Seliger: Knowledge Generation in the PSS Use Phase, International Seminar on PSS, 21-22 January 2008, Bochum, Germany

Key Challenges in Managing Software Obsolescence for Industrial Product-Service Systems (IPS2)

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Abstract

The defence industry is moving rapidly towards new types of agreement such as availability contracts based on Industrial Product-Service System (IPS2) business models. Obsolescence has become one of the main problems that will impact on a system during its life cycle. Most of the research carried out has been focused on electronic components, neglecting the impact of obsolescence in other areas such as software. This paper presents the concept of software obsolescence and highlights the key challenges and mitigation strategies to managing it, which was identified through a set of semi-structured interviews with experts in defence, aerospace and nuclear industries and literature review in software and obsolescence management. It is observed that there is a lack of understanding of the software obsolescence and the impact that it has on the systems.

Keywords

Software Obsolescence, Skills Obsolescence, Obsolescence Management, Industrial Product-Service Systems.

1 INTRODUCTION

Nowadays, companies are moving from a product-oriented towards a service-based business model in which customers purchase the services provided by products rather than owning the products themselves. Many new projects are started with through life planning principles from the earliest concept stages. Capability and availability based contracts are enabled by Industrial Product Service Systems (IPS2) that have progressively increased in scale and complexity through to major infrastructure projects and large defence projects. In sectors such as the defence, military and civil aerospace, transportation and railways, the life-cycle of an IPS2 can be extended over many decades. Due to the high costs and long life times associated with technology insertion and design refresh, these systems often fall behind the technology wave [1-3]. One of the main problems that definitely these systems will face during their life-time is obsolescence. A part becomes obsolete when the technology that defines it is no longer implemented and hence that component becomes no longer available from stock of own spares or being procurable or produced by its supplier or manufacturer [4-8]. IPS2 is also shifting risks from the customer to the prime contractors and their risk sharing partners. The prime contractors are increasingly expected to take responsibility of managing obsolescence impact and as a result there is strong motivation to study obsolescence and document it for later assessment and review.

Many authors [9-13] agree that the rapid growth of the electronics industry is making electronic components obsolete at a fast pace. This is the reason why most of the research carried out on the area of obsolescence is focused on EEE (electronics, electromechanical and electrical) components. However, the problem of the obsolescence is not restricted to EEE components. There are many other areas of an IPS2 that can become obsolete such as: (Figure 1)

- EEE components
- Mechanical components
- Materials
- Software and media
- Test equipment
- Processes and procedures
- Skills

Figure 1: The Holistic View of Obsolescence

These areas have interdependencies among themselves, so it is necessary to consider them following a holistic approach rather than analysing each one independently. The research presented in this paper focuses on the obsolescence issues affecting software, media and skills. The motivation is that these areas have not been explored in depth hitherto but it is acknowledged the big impact that

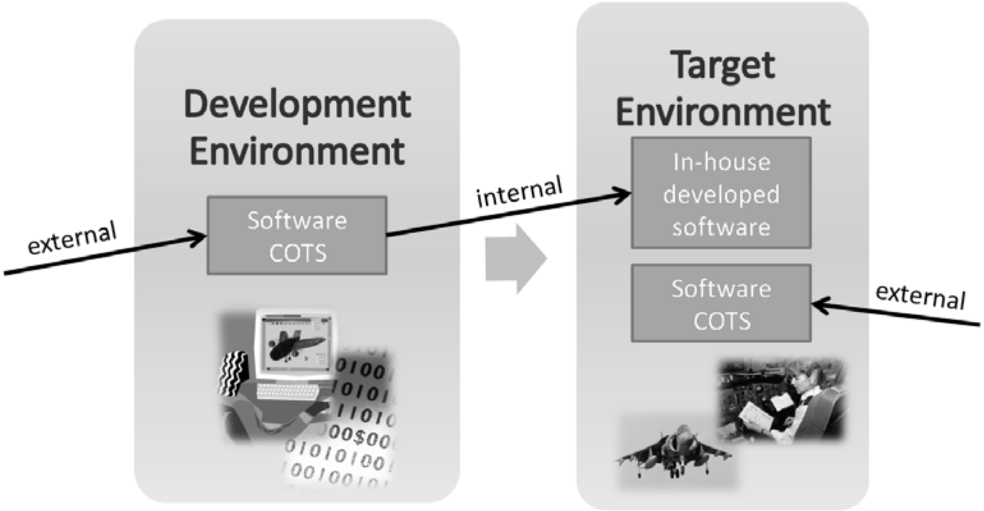

Figure 2: Software Environments

they have during the life cycle of an IPS2 in terms of availability, cost and sustainability.

The first step in this study was the review of existing literature related to obsolescence. It has been identified a growing number of publications in this area for the last 20 years. However, most of them are solely focused on the obsolescence of electronic components, disregarding the software obsolescence problem. During the last four years, a few authors [14-16] have recognised the importance of software obsolescence – especially related to Commercial off-the-shelf (COTS) Software – and hence there is a need for further research in this area to be able to manage and mitigate it properly. The Component Obsolescence Group (COG) at UK has also identified recently this necessity, and they have published a guide that gives an overview about the software obsolescence problem and provides a starting point for managing it [17].

2 RESEARCH METHODOLOGY

2.1 Sources of Information

The fact that this topic is very recent and has not been explored enough yet has been the reason why, apart from the information collected through an exhaustive literature review, it was necessary to capture information directly from industry. General information on the software obsolescence was collected through several COG meetings where obsolescence experts from all over UK gathered. Additionally, a total of eight interviews with experts on software and obsolescence from different organisations across the defence, aerospace and nuclear sectors in UK were carried out. The general perception from industry is that software obsolescence is becoming an important problem mainly because it is ignored in general. Both in US and in UK, the software obsolescence is neither been consistently managed nor mitigated proactively [16]. Contracting for availability has been studied by means of a literature review and the information collected across the major organisations in the UK defence sector [18].

2.2 Approach Adopted

The interviews were carried out using a semi-structured questionnaire in order to capture general understanding of the software obsolescence concept and then analyse in depth the key triggers of software obsolescence, the mitigation strategies that can be applied and the current practice to manage it. The information collected through the first set of interviews was systematically analysed and summarised identifying the key ideas. This summary was presented and validated at the final interview with a key expert from industry.

3 SOFTWARE OBSOLESCENCE

3.1 Software Obsolescence: An Overview

IEC 62402 [19] defines software as “programs, procedures, rules, data, and documentation associated with programmable aspects of systems hardware and infrastructure”. Some people argue that software can not become obsolete because it is not affected by degradation (and hence does not require replacement) and can be easily replicated. Their misconception is to try to apply the same reasoning to software obsolescence as to mechanical or electrical component obsolescence. It is necessary to acknowledge the different nature of the software obsolescence problem. The essence of obsolescence is that it prevents from maintaining and supporting the system. Taking this into account it is possible to identify the commonalities between hardware and software obsolescence. When an electronic or mechanical component becomes obsolete and there is no more stock available, the system cannot be maintained according to the original planning. Analogously, the software obsolescence prevents the software from being maintained accordingly.

In the area of computer science, the software development environment (SDE) is the “entire environment (applications, servers, network) that provides comprehensive facilities to computer programmers for software development” [20] and also for software testing. The software target environment (STE) represents the final system in which the software developed in the SDE will be ultimately run. Software obsolescence can happen in both, the development environment and the target environment, as shown in Figure 2, due to external factors (e.g. loss of support from COTS supplier) or internal factors (e.g. loss of skills). From the IPS2 business model point of view, it is important to make this distinction between environments. The reason is that an organisation may have several availability contracts, so it is in charge of supporting different systems. Therefore the organisation will have to manage obsolescence independently for each STE, at the project level, according to the terms agreed in each availability contracts. However, the obsolescence issues that happen in the SDE have to be managed at the organisation level, and they can have an impact on the supportability of the STE as shown in Figure 2, so this strategy to manage obsolescence needs to be aligned with the availability contracts.

3.2 Types of Software Obsolescence

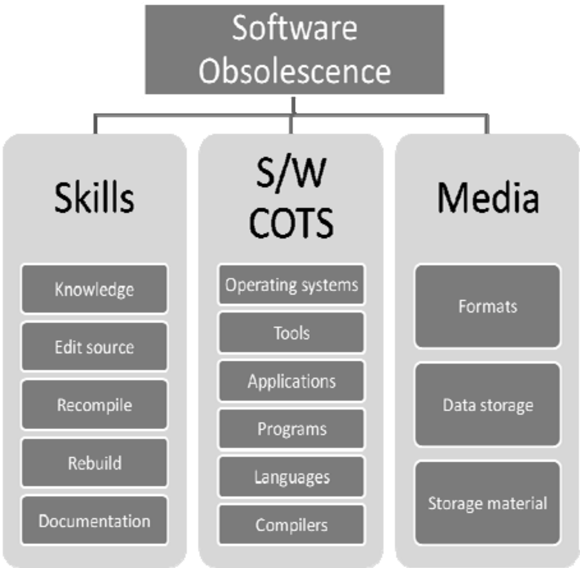

Figure 3: Types of Software Obsolescence

Software obsolescence can happen in three different areas as shown in Figure 3: skills, COTS software and media.

- Skills

It refers to the skills and information necessary to develop, support or modify software developed in-house or by a third party. The loss of required skills is regarded as skills obsolescence and inhibits the maintenance of the software. A common example of this is the difficulty to maintain legacy software (written using legacy programming languages) because the original programmers get retired and the new generations are only trained in new programming languages.

Skills obsolescence hinders the usage of the SDE to support in-house developed software hosted in the target environment.

- COTS Software

COTS Software is regarded as any commercial operating system, program, application, tool, compiler or programming language that is used in the development environment to produce in-house software or that is used directly in the target environment. COTS Software becomes obsolete when its supplier stops supporting it. This is the most common and risky software obsolescence problem because it is difficult to predict when it is going to happen and is usually beyond the control of the customer.

COTS Software can be found in the SDE in the form of tools for software development and in the STE in the form of software components or tools used for configuration at the end-user level.

- Media

It represents the data storage materials and formats used to keep the software information. If they are not properly managed and maintained, there is a risk of losing data and information because they can no longer be accessed from legacy media or legacy formats. Moreover, some forms of media have proved to be less stable and robust than expected.

4 KEY CHALLENGES TO MANAGE SOFTWARE OBSOLESCENCE FOR IPS2

The technology has been evolving rapidly over the last few decades. This has become a major issue for the support of long-life cycle IPS2 such as the availability/capability contracts in the defence and aerospace sector. Moreover, the fact that most of the electronics and software components suppliers have moved from the defence sector to a more profitable commercial market with higher volumes has exacerbated this problem [21]. In the present market, the use of COTS software is widely extended across the defence sector although they have little control over this supply chain [14]. This fact increases the risk of facing obsolescence problems because the defence interest of maintaining long-life systems over several decades clashes with the interest of COTS software providers, which is to reduce the life-cycle of their products, making the COTS software obsolete as a market strategy [14, 16].

The main problem related to software obsolescence is that it is generally ignored within the defence and aerospace sector and usually it is not included in the Obsolescence Management Plan (OMP) or just briefly mentioned without providing a detailed strategy to manage it. The current efforts in dealing with obsolescence are mainly focused on electronic components while software obsolescence is disregarded and not managed at all [16]. Apart from the lack of awareness, there is a lack of tools to assist in the software obsolescence management such as obsolescence monitoring tools (analogous to those used for electronic components such as those supplied by QinetiQ and IHS) which makes difficult the forecast of software obsolescence issues.

It is important to raise awareness of the software obsolescence problem as in most complex systems the cost of dealing with it during the life cycle is comparable to the cost of dealing with hardware obsolescence problems, or even higher [14, 16].

The IPS2 business model is triggering a shift in obsolescence risk, and now prime contractors are more responsible to manage the software obsolescence to guarantee the availability at an affordable price.

4.1 Cost Estimation of Software Obsolescence for IPS2

Nowadays in the defence sector the trend is moving towards contracting IPS2 for availability. The essence of availability contracts is that the suppliers are paid for achieving an availability target for the IPS2 (typically expressed as a percentage, e.g. “available 99.95% of the time”) and not just for the delivery of the product and spares/repairs. This helps to ensure value for money for the customer [18]. The risk of obsolescence in EEE components is progressively being included in this type of contracts. Eventually, the risk of software obsolescence will need to be included explicitly as well. The challenge is to be able to assess this risk at the bidding stage and to estimate the cost related to it for the duration of the contract. At the moment, no organisation is able to make robust cost estimations for software obsolescence.

It is acknowledged that the development of a validated cost model would facilitate the negotiation process for contracting; giving a common understanding to both parties about the risks and cost implications that software obsolescence will have on the system during its life-cycle. It would also increase the level of confidence on the software obsolescence planning through an analysis of Return on Investment (ROI) [16]. It is important that this cost model is developed at system level, so both the software and hardware obsolescence are concurrently considered, since they are so closely linked [16]. However, there are several reasons that make the development of the cost model very challenging at this stage:

- The data related to software obsolescence problems is frequently spread over different areas such as hardware obsolescence, software defect maintenance, or program schedule slips and additional resource requirements [16]. In most of the organisations there is not a common understanding about the concept of software obsolescence and what falls in and out its scope.
- In general, there is no map of interactions across the system between hardware and software, except for high reliability applications. Typically this is due to inadequate design documentation and configuration management. The lack of this information makes very difficult the prediction of the impact that an obsolescence issue in a component will have on the rest of the system, as this will depend upon the level of interactions and dependencies.
- The organisations are not keeping systematically record of the costs associated with obsolescence events. Historical data is essential to develop cost metric that can be applied to estimate the cost of software obsolescence and include this risk in the contract. It also allows measuring the overall consequences of using different software obsolescence management strategies [16].
- The strategies deployed to manage software obsolescence are usually not included in the OMP. Nevertheless, the software obsolescence management strategy will have a critical impact on the cost.
- Unlike the electronics obsolescence area, there are no monitoring tools available in the market that can assist with the monitoring and forecasting of software obsolescence. It makes it more difficult to develop a management planning and to estimate the number and nature of the obsolescence issues expected during the contracted period.

4.2 Mitigation Strategies

By means of interviews with experts in software and obsolescence across different sectors, where they have to deal with availability contracts for long-term support it has been identified a set of mitigation strategies to reduce the risk of software obsolescence in both the probability and the impact of having an obsolescence issue. The main mitigation strategies for software obsolescence are as follows.

- Loose coupling (Decoupling). The dependencies between hardware and software can be reduced by using standard interfaces and a middleware in the system architecture design. This will mean that an obsolescence issue in a component will be less like to impact the rest of the system, and hence can be easily replaced. This mitigation strategy is especially useful to reduce the interactions between obsolescence issues in electronic components and software.
- Make the development environment flexible enough to support changes in the target environment. This is particularly important for IPS2 as it contributes to its adaptability during the life cycle [22].
- Use of Technology Roadmaps that take into account:
  - Evolution of technology
    - Maturity of technology used
    - Technology stability assessment (identify potential changes in the future)
  - Evolution of suppliers (market)
  - Evolution of customer requirements
- Proactive analysis. To carry out a risk assessment for software obsolescence based on:
  - Impact of the obsolescence issue
  - Probability of becoming obsolete

There are other mitigation strategies that can be applied specifically for each of the software obsolescence areas.

Mitigation Strategies for COTS Software Obsolescence

- Escrow agreements. It is a legal arrangement in which the software source code and the software development environment is placed by the supplier with a third party to be held in trust pending some event, upon which the software will be delivered to the user [17]. This mitigates the obsolescence issue that may happen if the software supplier goes out of business.
- Develop contract clauses to ensure lifetime support (or at least until the next midlife upgrade).
- Keep good relationships with key vendors.

Mitigation Strategies for In-house Developed Software Obsolescence

- Maintain the supporting infrastructure [17].
- Collaboration across different departments to minimise problems of integration/interactions.
- Consider the use of COTS software instead.
- Ensure skills do not become obsolete (apply mitigation strategies for skills obsolescence listed as follows).

Mitigation Strategies for Skills Obsolescence

- Standardisation (Use of “Preferred Technology”) [17]. Minimise the number of programming languages/compilers/software components used across the organisation.
- Maintain people with skills and knowledge required (even after retiring) [17]. So they can continue supporting the system as consultants or they can transfer their skills and knowledge by training other people.
- Use a “Skill register” database to monitor experts and their skills.
- Develop training schemes to preserve skills and knowledge required, proactively identifying potential skills shortages.
- Implement knowledge management systems within the organisation.
- Make sure that the human resources department is aware of potential skills shortages, so new experts can be hired promptly.
- Consider outsourcing the maintenance or development of software. This may be a more cost effective solution than trying to keep the skills in-house for the maintenance or development of software. However, this decision may increase the uncertainty of having an obsolescence issue due to the loss of control over the supplier.

Mitigation Strategies for Media Obsolescence

- Keep structured documentation, formats and data storage systematically, and up to date.
- Plan the upgrades of media, formats and data storage.
- Outsource the media management.

5 CONCLUSIONS

Obsolescence has become one of the main problems that will impact IPS2 offering during its life-cycle so it needs to be considered and managed proactively. Obsolescence can have an impact on different areas of the physical artefact, such as electronic and mechanical components, materials, test equipment, processes and procedures, skills, software and media. The research carried out so far has been mainly focused on the obsolescence of electronic components and many tools and mitigation strategies have been developed to assist in the management of these issues and make it more proactive. However, there is little awareness about the obsolescence problems affecting software, skills and media; although the impact that it may have on the system is comparable to that from electrics obsolescence.

The IPS2 business model is causing a shift in obsolescence risk from the customer to the prime contractor. This is bringing prime contractors to a new scenario where they are more responsible to manage the software obsolescence to guarantee the availability at an affordable price. However, it has been identified a lack of understanding about the concept of software obsolescence and how it can be managed. Usually software obsolescence management is very briefly included, if at all, in the Obsolescence Management Plan (OMP), which is mainly focused on EEE components obsolescence. This lack of understanding about the software obsolescence concept and the lack of supporting tools (i.e. obsolescence monitoring tools) for the prediction of obsolescence issues are the main challenges to manage software obsolescence.

The software obsolescence issues can arise in both the software development environment (SDE) and the software target environment (STE). It is necessary to differentiate them in order to manage the software obsolescence properly. Moreover, software obsolescence can happen in three different areas: skills, COTS software and media. Each area has different characteristics and hence different management strategies should be applied to deal with each one.

A set of general software obsolescence mitigation strategies have been suggested, such as: decoupling, make the development environment more flexible, use of technology roadmaps that take into account the evolution of technology, the suppliers and the customer requirements, and risk assessment for software obsolescence. Additionally, a set of mitigation strategies have been suggested to deal with obsolescence in each of the following areas: COTS software, in-house developed software, skills, and media.

Finally, it has been identified that currently there are no models for the cost estimation of software obsolescence. The main reasons that make this development very challenging are mainly related to the lack of understanding of the problem, the lack of historical information about software obsolescence issues, the lack of software obsolescence management tool and the lack of information about the interactions between hardware and software. Future research on this area should be focused on the development of a model for the cost estimation of software obsolescence, tools for the monitoring, managing and predicting software obsolescence issues. Additionally, it is required to explore the correlation between hardware and software obsolescence due to the high level of interdependencies between them.

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7 REFERENCES

[1] Sandborn, P., Mauro, F. and Knox, R., 2007, A data mining based approach to electronic part obsolescence forecasting, IEEE Transactions on Components and Packaging Technologies, 30; 3; 397-401.

[2] Singh, P. and Sandborn, P., 2006, Obsolescence Driven Design Refresh Planning for Sustainment-Dominated Systems, The Engineering Economist, 51; 2; 115-139.

[3] Madisetti, V., Jung, Y., Khan, M., Kim, J. and Finnessy, T., 2000. On upgrading legacy electronics systems: methodology, enabling technologies and tools, VHDL International Users Forum Fall Workshop, 2000. Proceedings, Orlando, FL, USA, 18-20 Oct.: 7-14.

[4] Singh, P., Sandborn, P., Lorenson, D. and Geiser, T., 2002, Determining Optimum Redesign Plans for Avionics Based on Electronic Part Obsolescence Forecasts, Proceedings World Aviation Congress, November 2002, Phoenix, AZ, SAE International.

[5] Meyer, A., Pretorius, L., Pretorius, J. H. C., 2004. A model to manage electronic component obsolescence for complex or long life systems. Engineering Management Conference, 2004 Proceedings IEEE International, 3; 1303-1309.

[6] Pecht, M. G. and Das, D., 2000. Electronic part life cycle. IEEE Transactions on Components and Packaging Technologies, 23; 1; 190-192.

[7] Sandborn, P., 2007a. Designing for Technology Obsolescence Management. Proceedings of the 2007 Industrial Engineering Research Conference, 19-23 May 2007, Nashville, TN.

[8] Solomon, R., Sandborn, P. and Pecht, M., 2000. Electronic part life cycle concepts and obsolescence forecasting. Components and Packaging Technologies, IEEE Transactions on [see also Components, Packaging and Manufacturing Technology, Part A: Packaging Technologies, IEEE Transactions on], 23; 4; 707-717.

[9] Feldman, K. and Sandborn, P., 2007. Integrating Technology Obsolescence Considerations into Product Design Planning. Proceedings of the ASME 2007 International Design Engineering Conferences & Computers and Information in Engineering Conference, Sept. 2007, Las Vegas, NV.

[10] Howard, M. A., 2002. Component obsolescence – It's not just for electronics anymore. Proc.FAA/DoD/NASA Aging Aircraft Conference, San Francisco, CA, 16-19 Sept.

[11] Craig, R. W., Co, B. and St Louis, M. O., 2002. A methodology for addressing support equipment obsolescence. Aerospace and Electronic Systems Magazine, IEEE, 17; 5; 20-25.

[12] Frank, B. and Morgan, R. L., 2007. Obsolescence mitigation and management of electronics test equipment. Autotestcon, 2007 IEEE: 527-536.

[13] Mont, O., 2004. Product-service systems: Panacea or myth (Doctoral Dissertation thesis), The International Institute for Industrial Environmental Economics (IIIEE), Lund University: Lund, Sweden.

[14] Sandborn, P., 2007b. Software Obsolescence - Complicating the Part and Technology Obsolescence Management Problem. IEEE Transactions on Components and Packaging Technologies, 30; 4; 886-888.

[15] Sandborn, P. and Plunkett, G., 2006. The Other Half of the DMSMS Problem - Software Obsolescence. DMSMS Knowledge Sharing Portal Newsletter, 4; 4; 3-11.

[16] Merola, L., 2006, The COTS software obsolescence threat, Fifth International Conference on Commercial-off-the-Shelf (COTS)-Based Software Systems, 2006. San Diego, CA.

[17] Rumney, G. A., 2007, The Software Obsolescence Minefield: A Guide for Supporting Software and Electronic Information, 1st ed., COG International Ltd., UK.

[18] Romero, F. J., Roy, R., Shehab, E. and Wardle, P., 2009. Obsolescence Challenges for Product-Service Systems in Aerospace and defence Industry. The 1st CIRP Industrial Product-Service Systems (IPS2) Conference, 1st-2nd April 2009, Cranfield University, UK.

[19] IEC 62402:2007 - Obsolescence Management - Application Guide.

[20] Software Development Environment, available at: http://en.wikipedia.org/wiki/Software_development_environment (last accessed on 5/11/09).

[21] Shuman, L. L. (2002), Cost-Benefit Analysis Tools for Avionics Parts Obsolescence, Research Report AU/ACSC/02-103/2002-04, Air Command and Staff College, Air University, Maxwell Air Force Base, Alabama.

[22] Roy, R. and Cheruvu, K.S., 2009, A Competitive Framework for Industrial Product-Service Systems. Int. J. Internet Manufacturing and Services.

Characterization of Customer Requirements in IPS² creation

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Abstract

Industrial Product-Service Systems (IPS²) integrate product and service shares over the IPS² lifecycle to provide value and create solutions, which fulfil customer needs. To ensure potentials of IPS² the integration of the customer in the entire IPS² lifecycle is a key point to get a customized solution. With a support by an assistance system the interactive acquisition of customer needs can be done. A subsequent configuration of IPS² solutions, obtaining formalized and precise information, is shown. Together with the recommendation for an IPS² business model, the information's form the IPS² requirement specification and thus the basis for further development processes.

Keywords

Industrial Product-Service Systems, support, IPS² development, customer requirements, IPS² configuration

1 INTRODUCTION

Due to the globalization, companies have to deal with different market effects. By this competitive situation new business models, especially with customized solutions, can lead to a higher benefit and a long range customer provider relationship [1].

Machine tool manufacturers often sell with the physical product, the machine tool, add-on services. The influence of service aspects in the design and the use of the product are not considered, but especially the generated revenue of industrial services are increasing. This leads to potentials by the product and service integration over the entire lifecycle [1], [2].

Industrial Product-Service Systems (IPS²) are characterized by the combination of tangible product and intangible service shares. The combined shares provide added value to the customer over the complete lifecycle [3], [4]. IPS² is covering the industrial market, where typical supply chains [5] and industrial standards have to be taken into account.

To ensure an effective IPS², development support must be provided. In contrast to current industrial application, the customer needs ought to be fully gathered in the early IPS² creation phase. The acquired customer needs relate to the entire lifecycle of the Industrial Product-Service System to be developed. The presented methodology takes into account these aspects and ensures the acquisition of customer individual needs in a centralized, convergent way.

Therefore, the identification of influences for a support over the IPS² lifecycle has to be included. The paper presents a lifecycle oriented development process with the implementation of an adequate support.

2 IPS² BUSINESS MODELS

By analyzing the customer needs, an IPS² business model can be identified by the IPS² provider [6]. Three exemplary business models are described [7], [8]. The IPS² business model varies in function, availability or result oriented business models. The business models differ in the risks and responsibilities for the IPS² product and service shares and are distributed over the IPS² provider and the customer [6], [8]. The information about the ownership of product shares and resources needed for the service shares are an important input for the resultant IPS².

In a function oriented IPS² business model the function of e.g. a machine tool is guaranteed by the IPS² provider. The IPS² is operated by and in responsibility of the customer. In this business model the services, which are not combined with the guaranteed IPS² function, e.g. financing, training and process optimization, are planned in advance by the IPS² provider, so that the response time between the customer request and the IPS² provider's answer is short.

For an availability oriented IPS² business model the product share is in ownership of the customer and the responsibility for the availability relevant services is at the IPS² provider side. The IPS² provider guarantees the availability of the IPS² to the customer. Therefore, the IPS² provider must provide all services with all needed resources to obtain the availability. To ensure the IPS² provider to deal with this demand, a condition monitoring system can be used to inform the IPS² provider about the status of relevant product shares of the IPS². For time scheduling of service delivery, the customer and partners of the IPS² provider have to be integrated by the IPS² provider.

When the ownership of the IPS² product shares is at the provider side and the customer pays for a guaranteed result, e.g. parts per hour, a result oriented business model is focused. The responsibilities for the whole IPS² are provider driven.

Looking from the customer perspective on the IPS² service shares in a function oriented business model, the IPS² comprises of less service shares, which are more closely connected to the physical product. In a result oriented business model the service shares take over a dominant part.

Depending on the customer and IPS² provider needs the resulting business model influences the IPS² creation. In order to enable the IPS² provider to deal with this fact a support over an assistance system is constructed.

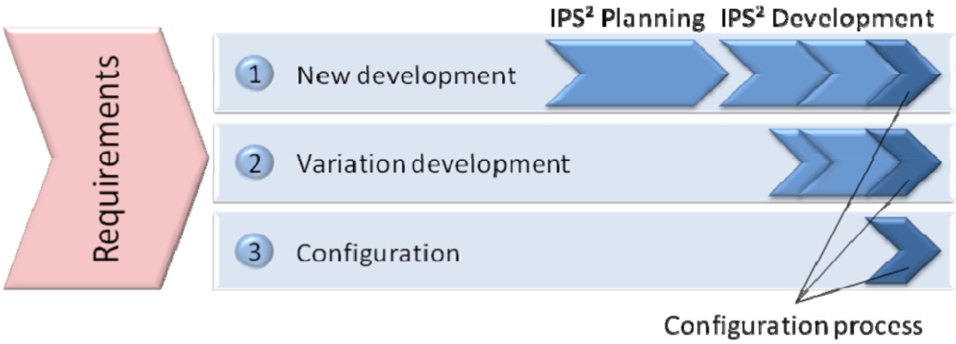

Figure 1: Context of the configuration within the IPS² creation phase

3 IPS² LIFECYCLE

The focussed IPS² lifecycle phases [9] can be divided into two main steps:

4.) Creation of IPS² and

5.) Operation of IPS².

Both steps are subdivided in several other steps. The main characteristic for the IPS² operation phase is the parallelism of the processes of the use of the IPS² product shares and the delivery of the IPS² service shares. In the IPS² creation phase a much more sequential progression is identified. The creation phase consists of the planning and development of IPS².

3.1 IPS² Planning Phase

In this paper the early stage of IPS² creation is focused on. The IPS² planning phase starts with the first customer contact, followed by the acquisition of customer needs by the IPS² provider and the comparison with his needs [2], [5]. The needs are used for the IPS² requirements specification. From these inputs an IPS² business model can be defined. At the end of this phase an IPS² offer is made to the customer that is based on a requirements list.

3.2 IPS² Development Phase

In the IPS² development phase, a functional and a conceptual model of the IPS² are generated from the IPS² requirement specification. The functional structure influences the product and service shares of the final IPS², because the named functions can either be fulfilled by one or more shares or special combination of both. This is the general concept of IPS², which assumes an interchangeability of product and service shares for the realization of a customized IPS². The solution must maintain the needed function; e.g. a product-service module with service processes can be replaced by a physical artefact (e.g. automated solution) and vice versa. This leads to the possibility to combine these solutions to special product-service modules. Thus, product-service modules consist of variable shares of physical artefacts (products) and intangible services. This combination fulfils one or more functions. In the subsequent drafting step, new product-service modules are developed, if they are not included yet in the configuration database.

In general the development phase is characterized by a “forward” process, where every stage only takes input from the preceding stage and generates a solution according to its abstraction level. Feedback loops are realized by iteration of one or more development steps until a suitable solution has been generated. Design methodologies like the V-Model [10] or VDI guideline 2221 [11] constitute the basis, which the development process follows loosely. Depending on the identified customer needs and the knowledge of the IPS² provider, three exemplary IPS² creation scenarios can be characterised (Figure 1):

1.) New development: the entire planning and development phase of IPS² must be passed through,

2.) Variation development: because of existing knowledge and product-service modules, which form the basis for the IPS² solution, the planning phase can be skipped, so that the task can begin with the IPS² development or

3.) Configuration: pre-developed product-service modules or full IPS² solutions can be used to fulfill the customer needs. The development of a draft has taken place beforehand during the development of the product-service modules.

Besides the early IPS² planning and development phase, the configuration step of the IPS² is the main focus for the assistance system being developed at Technische Universität Berlin [12]. The configuration of an IPS² accesses predeveloped product and service shares and combines them to a complete IPS² solution. Therefore, possible outcomes are already known in advance, since the solution set is limited to combinations of existing product-service modules. During the configuration of IPS² variants, possible solutions are generated and evaluated. The configuration module of the assistance system primarily works with data from existing product and service shares and databases with the interactions and compatibilities between both shares [12].

In case of a configuration of the IPS², the development of a draft is of minor importance (Figure 1). This is due to the differences between the two development paradigms new design and configuration (Figure 1). In the case of new design, all development phases are run through one after the other. There is no information beforehand about the solutions, since the development stages consist of creative processes with an open outcome.

For a supported configuration process, an instantiated requirement specification is needed which is realized in the IPS² planning phase. This specification should be as detailed and concrete as possible to ensure that an IT system, like the assistance system, can use this information. The creation phase of an IPS² ends with the realization and implementation of the IPS² shares and is followed by the IPS² operation phase.

3.3 IPS² Operation Phase

In the operation phase, where the IPS² is used and creates value, two parallel processes are identified. The use and the delivery phase describe two views on the same IPS² solution.

The use is product specific and the delivery is related to the IPS² service share. Beside these two processes a management process is needed. The management process realizes the dynamical configuration of e.g.

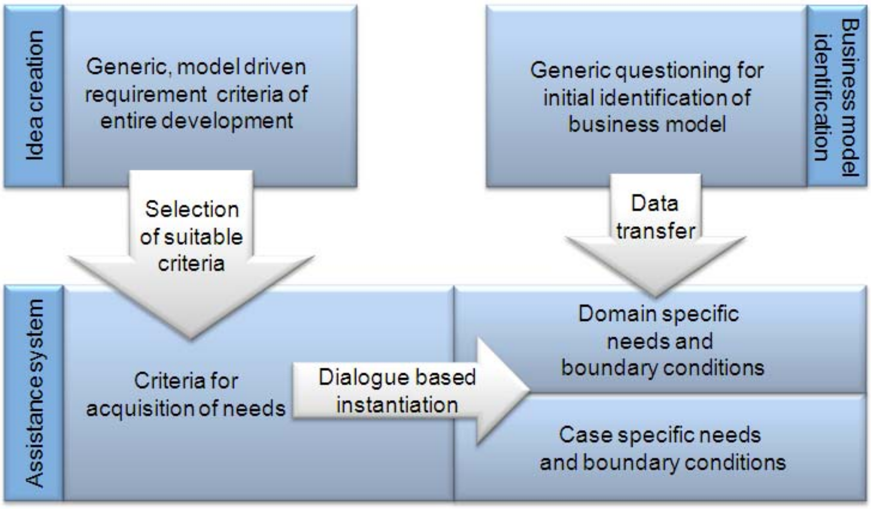

Figure 2: Influences of different information sources for the acquisition of needs

resources. It is important to react in an adequate way on changes in the IPS² operation phase and consists of different views on the IPS², depending on IPS² provider or customer processes [6].

4 FROM NEEDS TO REQUIREMENTS

4.1 Overview

Industrial Product-Service Systems are characterized by the offering of a customized solution. Within the Collaborative Research Project SFB/TR 29, the domain micro production has been chosen as the application example. Different customers have been examined and the results of their use cases have led to a general list of customer needs. The various needs form a comprehensive catalogue, which the IPS² provider uses for the first interaction with the customer in the IPS² planning phase. This procedure also enables the IPS² provider to document the changes of customer needs and requirements during the IPS² lifecycle phases.

The customer integration in the IPS² planning and development phase (see 3.1 and 3.2) is a key point to fulfil the customer needs. The main communication between the IPS² provider and the customer takes place during the interactive acquisition of customer needs by the IPS² provider. By giving the customer feedback on possible solutions, a knowledge transfer takes place which enables the customer to articulate his needs more precisely. Apart from customer specific factors also boundary conditions, like legislation, infrastructure, market and competitors have to be considered at this stage (Figure 2). These aspects are often not explicitly mentioned, or the customer may even not be aware of them, but nevertheless have to be considered for IPS² development.

The IPS² requirements are derived from the obtained needs in the next step. While the explicitly or implicitly expressed needs formulate a problem description that is preferably solution independent, a concrete solution is described by its requirements. The result is the IPS² requirement specification analogous to a product requirement specification in the conventional product development process.

4.2 Customer Needs

Starting with the first customer contact, the IPS² provider has to obtain the necessary information from the customer to clarify the development task (Figure 3). In contrast to conventional product design, this exceeds a technical specification list. The value that the customer obtains by the use of the physical product shares moves into focus. Therefore, the needs of the customer have to be gathered.

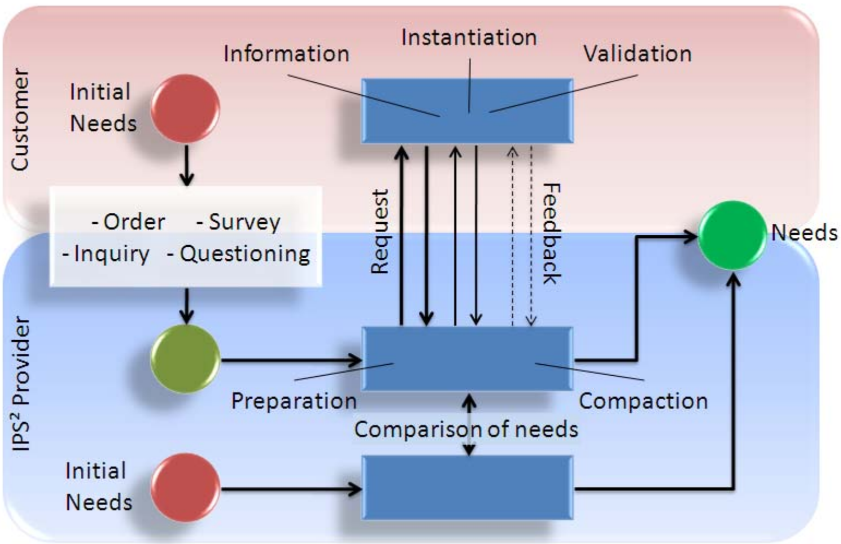

Figure 3: Acquisition of needs and boundary conditions

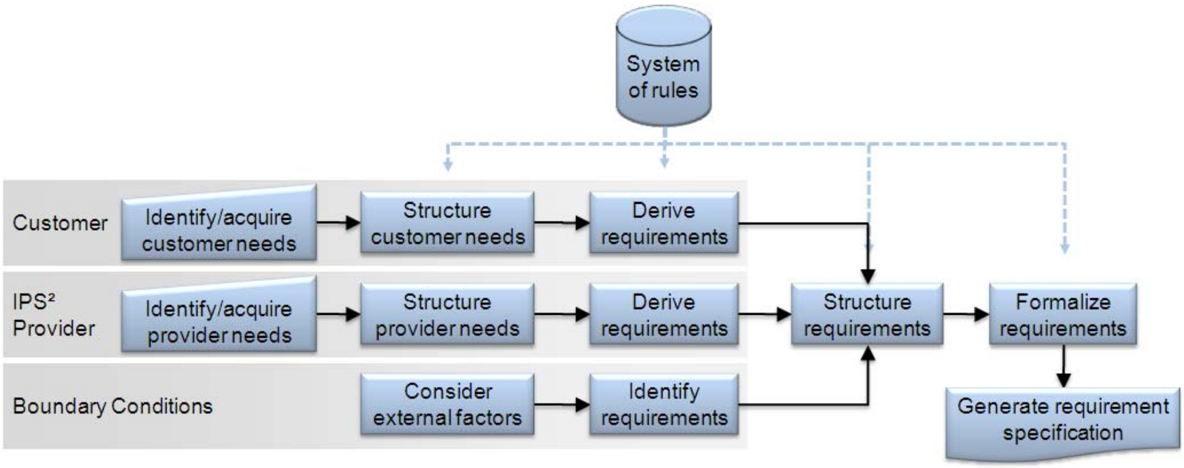

Figure 4: Process for the generation of the IPS² requirement specification

The areas of aspects to be considered for the IPS² development phase (see 3.2) are very broad and are specific for the application domain. The needs consist of a criterion and an associated value. They constitute the primary input for the assistance system and depend on the type of customer. The criteria for which information has to be acquired can originate from different tools and methods. In case of a direct configuration process without any variation development and where the field of application is known and narrowed down, the criteria can be predefined in a fixed set (Figure 1). In case of a flexible, multi domain use of the assistance system, the customer and IPS² provider may specify the criteria list manually or use e.g. the layer method, which is a method to analyze and synthesize ideas and concepts for IPS² [13].

The criteria are being detailed, and questions considering the application domain are assigned. An interactive, dialogue based instantiation takes place where specific values are attributed.

In principle customer and provider needs can be distinguished (Figure 3). The needs at the IPS² provider side should generally be known, e.g. because of the company strategy. This list of needs has to be compared to and put into context with the identified customer needs. Certain provider needs may be subordinated to the customer needs, but the IPS² provider must be able to fulfil his minimal needs.

The IPS² provider gathers areas of the initial customer needs and prepares information requests in order to obtain more detailed information from the customer (Figure 3). For further processing, the needs have to be sufficiently concrete which is reached by inquiries or questioning of the customer. At the customer side specific information about the need is provided and instantiated and in further steps validated. The obtained information has to be compacted on the IPS² provider side and finally merged with his own list of needs. As a result the IPS² provider is able to balance the respective needs and build a list of unified customer and provider needs (Figure 3).

Apart from obtaining the customer's needs, boundary conditions, which are not implied in the needs, but affect or determine the solution, have to be considered additionally (Figure 2). The customer may not be aware of these factors, may have no knowledge about them or omits them while formulating his needs. Examples are laws and regulations, infrastructure, information about suppliers and technical features that are state-of-the-art, but unknown to the customer. Last, but not least, the needs and boundary conditions of the IPS² provider also have to be considered in the development, see Figure 4.

Thus, three sources for the acquisition of needs can be identified, which are the customer, the IPS² provider and boundary conditions (Figure 4). This acquisition with the assistance system has to take place interactively. The main reason originates in the IPS² development as a customized solution. This implies a very close interaction with the customer throughout the entire planning and development phases and requires some degree of integration of the customer into these processes (Figure 3). Furthermore, in the above mentioned cases, where the customer is unable to specify exactly his needs, a knowledge transfer on decision areas will help him express his needs more precisely.

The needs and boundary conditions are queried interactively by the use of dialog based forms in the assistance system. Depending on the type of customer, two different ways to use the assistance system are possible. The user can either be the IPS² provider or the customer.

The customer is guided through the acquisition process by questions that are applicable to most use cases. Context sensitive help has been added to support the customer. Additional needs and boundary conditions that are not covered by the dialog system can be added in an expert form, which requires a user trained by the IPS² provider. While the dialog based forms provide a high level of user support, but lack in flexibility, the expert form allows for customer individual entries of needs and specifications with a very high degree of flexibility.

The acquired needs are being structured by assigning them to categories, which the developer can define dynamically according to the field of application (Figure 4). The obtained needs and boundary conditions form the base from which the requirements for the Industrial Product-Service System are determined.

4.3 Transformation to IPS² Requirements

Figure 4 depicts the process of transformation of IPS² needs to IPS² requirements in an IT specific view. The acquired needs, the boundary conditions and derived requirements have to be structured and finally formalized in order to generate the requirements list, which is sufficiently detailed and concrete so that a configuration process can be carried out.

The IPS² requirements are derived by a knowledge based process. Depending on the level of information, this process is executed fully automatically, interactively or manually by the assistance system. The knowledge about

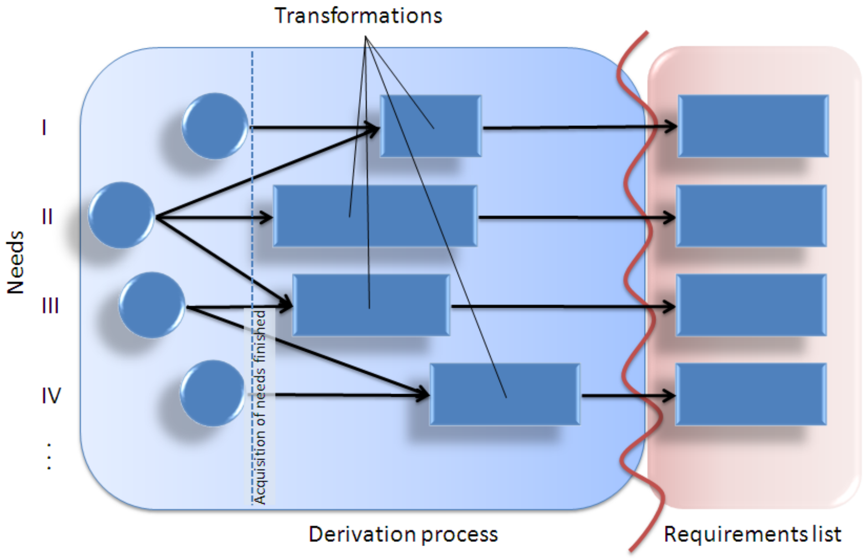

Figure 5: Derive requirements - Transformation of needs to requirements

interrelations between the acquired needs and the requirements can be classified into three categories: quantitative statements, qualitative statements and general statements. Quantitative relations are associated by mathematical formulas, database entries or tabular work. For example the geometrical dimensions of the product range determine the working space of the machine tool and can be expressed in a mathematical relation. Fuzzy logic and directional influences are means to describe qualitative relations, e.g. the competence level of the customer influences the degree of services that the IPS² provider has to cover. Finally, interrelations without attributable associations fall into the third category of general statements about the existence of an interrelation. Here it is known that a linkage is present and has to be taken into account. Information about the quality of the influence cannot be specified, however. Additional information of its importance towards the derived requirement may be attributed.

In the assistance system these interrelations are implemented as links between the needs and the requirements to be generated. The links can be associated with transformation processes, which take one or more needs as input and transform them automatically or with user interaction to requirements. This process for "Derive requirements" (Figure 4) is detailed in Figure 5.

The transformation process is implemented in the assistance system via user definable scripts, which assure a very high degree of flexibility and a customer individual processing of the specified needs. The technical basis for the transformation scripts is based on the .NET platform. The scripts are compiled and executed within the assistance system, which allows transformation processes from simple calculations to database access or user interaction.

4.4 Application Example

The development of the IPS² product shares are mainly influenced by the IPS² requirements (see 4.3). The requirements are built upon and lead in the IPS² development phase to customized IPS² solutions, which are represented in the IPS² product model. By the transformation of the IPS² provider, his partners and customer needs (see 4.3) concrete solutions of IPS² product-service modules (see 3.2) can be generated, e.g. a micro milling spindle. The IPS² business model influences the choice and realization of solutions (see 2).

The acquisition of needs and the transformation is supported via the assistance system. The dialogue based software module of the assistance system to obtain the needs from the customer is shown in Figure 6 on the left hand side. The user is presented with detailed questions

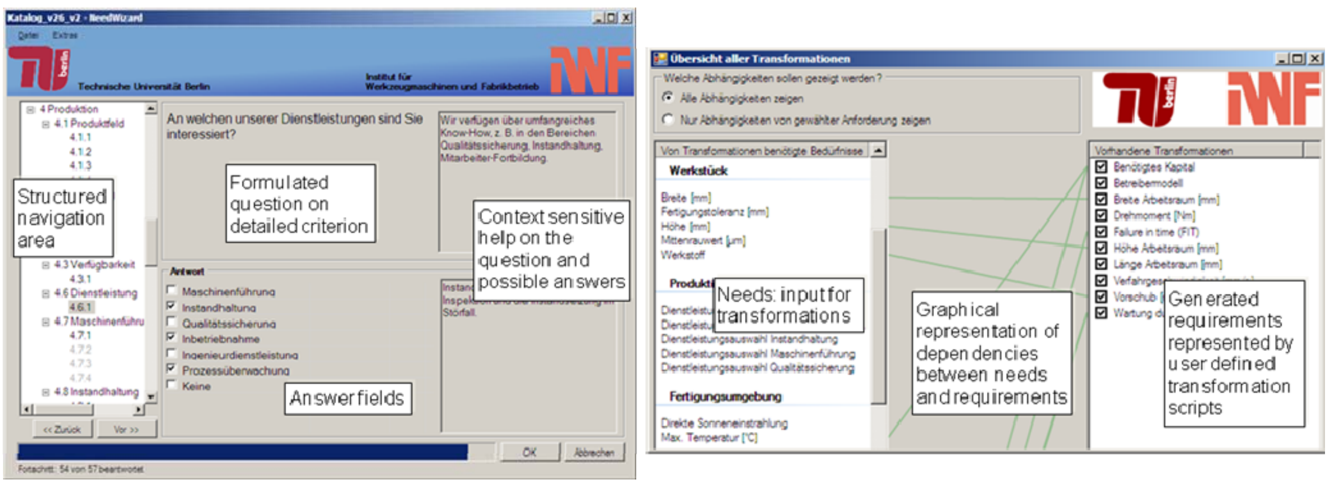

Figure 6: Implemented software modules of the assistance system for the acquisition of customer needs (left hand side) and transformation of needs to requirements (right hand side)

and one or several options to answer them. On the right hand side explanations and context sensitive help is displayed. The questions can be filled in in sequential order or be directly accessed via the navigation pane on the left hand side. The questionnaire is not static in order to take the customer individual aspects into account. A dynamic adjustment has been implemented to the list of questions depending on preceding answers of the customer. Partially completed lists of needs can be saved to allow for an iterative process of need acquisition.

The transformations of the acquired needs to IPS² requirements are depicted in Figure 6 on the right hand side. A graphical representation of the dependencies between the inputs and outputs of the transformations, the needs and requirements, respectively, allows to provide a domain specific set of rules and interdependencies for requirement generation.

Beginning with exemplary customer needs a milling spindle for a function oriented IPS² business model is described as

- lean design to realize the needed function with minimum costs and
- hampered intervention possibilities for the customer to reduce the customer influences on the functions of the spindle and to cause the relevancy for service shares of the IPS² provider.

For the use of the milling spindle in an availability oriented IPS² business model the spindle can be characterised as follows:

- integration of sensors for condition monitoring and
- easy to maintain to realize the guaranteed availability.

In the result oriented IPS² business model the realized function is mainly driven by strategically decisions of the IPS² provider, because the spindle remains in the ownership of the provider. The spindle can be designed with basic or with flexible elements for reuse in e.g. another IPS².

The spindle is generally designed concerning different main functions, which fulfil the customer needs (see 3.2 and 4.2). The exemplary functions of the spindle are:

- clamp milling tool,
- rotate milling tool,
- control rotary motion,
- true running accuracy and
- transmit cutting forces.

These functions can be attributed in the drafting step of the IPS² development by concrete technical requirements and implementation details (see 4.3) as follows:

- milling tool (2 mm shank diameter) fastener clamping: short taper,
- rotational speed of milling tool: 10000 RPM to 50000 RPM,
- control unit: Frequency converter,
- minimal true running accuracy: 0.01 mm and
- necessary torque: 60 Ncm.

The information shown above is example content for the different supported steps by the assistance system. Both general and concrete needs and requirements are shown.

5 SUMMARY

The early phase of IPS² development is in the focus of this paper. Industrial Product-Service Systems are characterized by the development of customized, integrated solutions. Therefore, the integration of the customer in the whole IPS² lifecycle is a key point. To ensure a support needs can be fulfilled according to different IPS² business models, of which three basic, exemplary business models are described. After an explanation of the IPS² lifecycle and its division into phases, the IPS² planning phase is examined in detail to characterize the potentials of IT support. A support for this phase is shown within a framework of an assistance system. In particular the acquisition of the needs and boundary conditions from the customer as well as the IPS² provider and their transformation into IPS² requirements are described under special consideration of a subsequent configuration process.

The support as shown is an important tool for an adequate and effective generation of IPS². This gives an IPS² provider the possibility to increase his revenue, strengthen his market position and to reach a strong customer provider relationship.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Nyhuis, P., Fronia, P., Pachow-Frauenhofer, J., Wulf, S., 2009, Wandlungsfähige Produktionssysteme, wt Werkstattstechnik online, Jahrgang 99, Heft 4, p. 205-210, Springer-VDI-Verlag GmbH & Co. KG, Düsseldorf, ISSN 1436-4980.

[2] Fleischer, J., Meier, H., Kaiser, U., Krings, R., Niggeschmidt, S., 2008, Verfügbarkeitsoptimale Dienstleistungskonfiguration, wt Werkstattstechnik online, Jahrgang 98, Heft 7/8, p. 601-606, Springer-VDI-Verlag GmbH & Co. KG, Düsseldorf, ISSN 1436-4980.

[3] Tan. A. R., McAloone, T. C., 2006, Characteristics of strategies in Product/Service-System Development, International Design Conference – Design 2006, Dubrovnik – Croatia, May 15-18.

[4] Matzen, D., Tan A. R., Andreasen, M., 2005, Product/Service-Systems: Proposal for Models and Terminology, 16. Symposium “Design For X”, Neukirchen, October 13-15.

[5] Schuh, G., Meyer, J. C., 2009, Kundenorientierte Gestaltung von Lieferketten, wt Werkstattstechnik online, Jahrgang 99, Heft 4, p. 244-249, Springer-VDI-Verlag GmbH & Co. KG, Düsseldorf, ISSN 1436-4980.

[6] Uhlmann, E.; Meier, H.; Stelzer, C.; Geisert, C. Völker, O.; Krug, C., 2009, Dynamic IPS² Networks and Operation Based on Software Agents, CIRP IPS² Conference (CIRP Industrial Product-Service Systems), 1-2 April 2009, p. 305-310, Cranfield, UK, ISBN 978-0-9557436-5-8.

[7] Tukker, A., Tischner, U., 2005, New Business for Old Europe – Product-Service Development, Competiveness and Sustainability, Greenleaf Publishing, Sheffield, UK.

[8] Müller, P., Stelzer, C., Geisert, C., Uhlmann, E., Knothe T., 2008, Kernprozesse hybrider Leistungsbündel, wt Werkstattstechnik online, Jahrgang 2008, Heft 7/8, p. 581-586, Springer-VDI-Verlag GmbH & Co. KG, Düsseldorf, ISSN 1436-4980.

[9] Uhlmann, E., Stelzer, C., 2009, Core Process of IPS² Working state of corporate process modeling in SFB/TR29 – Planning, development and operation, Second International Seminar on IPS², p. 37-41, Berlin, Shaker, ISBN 978-3-8322-8473-2.

[10] VDI 2206: Design methodology for mechatronic systems. Beuth Verlag, Berlin, 2004.

[11] VDI 2221: Systematic approach to the development and design of technical systems and products. Beuth Verlag, Berlin, 1993.

[12] Uhlmann, E., Bochnig, H., 2009, Computer Aided IPS² Development, Second International Seminar on IPS², p. 31-36, Berlin, Shaker, ISBN 978-3-8322-8473-2.

[13] Müller, P., Kebir, N., Stark, R., Blessing, L., 2009, PSS Layer Method – Application to microenergy systems, In: Sakao, T.; Lindahl, M. (Eds.), Introduction to Product/Service-System Design, p. 3-30, ISBN 978-1-84882-908-4.

Session 5B: Innovation

Exploring Modes of Innovation in Services

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Abstract

Manufacturing companies differentiating their offerings with new services need to combine both product and service innovation. We study how service development is influenced by (a) the choice of separation or integration of service development and (b) the modes of innovation. Our results show that service development often is more structured if services are developed separately. Furthermore, service innovations often follow a sequence of innovation modes different from those of product innovations. Since different innovation modes benefit from varying degree of structure in the development process, many companies find it hard to develop products and services within the same development project.

Keywords

Service development, Service Innovation, Innovation Modes, Multiple Case Study, Manufacturing Firms.

1 INTRODUCTION

Innovation plays a crucial role in competition at a firm level [1]. However, it has become inherently more difficult to compete and to differentiate a company's offerings in the market place using products and technology alone [2,3]. Traditional manufacturers must develop the service business [4] and they can generate new sources of revenues by going downstream the value chain [5].

New types of offerings and innovative services have become essential. The problem is that there are few systematic approaches to new service development and innovation in manufacturing firms and if there are, these are often based on a goods logic and engineering tradition. In the long run - can a manufacturing firm develop its service business without a state-of-the-art service development process?

When an advanced service for the installed base of products is to be developed, it can be developed in a separate development project or in an integrated development project. In theory, it is argued for a separation of services into a separate business unit [2], while others argue for an integration of products and services into one business unit [3]. The advantages developing both a new product and related services within the same development project would be increased collaboration.

The theory of innovation in manufacturing firms is based on the development of new technology. As a consequence, the development process of new products are often designed to improve the technical performance of a product [6]. However, for services it is often the customer experience, the business model or the service system that need to be developed. In addition, new services could differ in their mode of innovation [7] and theories of innovation developed on the basis of observations of products are inadequate to explain the forms of innovation which predominate in services [8]. The question is how to develop services in a manufacturing context where the experience of the service innovation process is limited?

Our paper reports on a two stage research study based on a multiple case study of 17 manufacturing companies and an in-depth study of three service development projects in SKF, Volvo Buses and Volvo Trucks. The purpose of our research is to show how the service development process in manufacturing companies is influenced by (a) the choice of separation or integration of service development and (b) the modes of innovation.

The paper begins with a theoretical framework regarding different modes of innovation and development processes. Then the research method is presented and the two stages of the research study are explained. This is followed by the results of the empirical studies and analyses of the two stages respectively. Finally, a discussion and conclusions part combines the results of the two studies.

2 TRACING SERVICE INNOVATION

2.1 Modes of Service Innovation

Manufacturing firms increase their amount and range of service offerings and the boundaries between goods and services become blurred. Hence, a general description for innovation, applicable both to goods and services, becomes relevant [7]. In a study exploring product and service innovation, the aim was to provide a synthesis of new service and product development research [9]. 217 service-based and 105 product-based companies in the Netherlands were studied. The results indicate a support for an integrated perspective; that is there are many similarities when it comes to success drivers. In their efforts to create a general description of innovation, Gallouj and Weinstein studied innovation processes in services and viewed innovation as any change that affects one or more terms of one or more service characteristics [7]. Based on this view, they identified six modes of innovation: radical innovation, improvement innovation, incremental innovation, ad hoc innovation, recombinative innovation, and formalization innovation.

The basis for the innovation modes is a characteristics-based representation encompassing four vectors: provider's direct competences (C), client's competences (C'), material and immaterial technical characteristics (T), and final user's value or service characteristics (Y) [7]. Based on this representation the innovation modes can be described as [10]:

- *Radical innovation*: creation of new sets of vectors of C, C',T and Y.
- *Improvement innovation*: the set of vectors of characteristics are unchanged but quality of some of their elements increase, the improvement can be in elements of C, C' or T.
- *Incremental innovation*: addition, elimination or substitution of a new characteristic but the whole set of vectors remain unchanged.
- *Ad hoc innovation*: typically a new solution to a client's problem implying significant change in C and T.
- *Recombination innovation*: various disassociations or associations of service or technical characteristics.
- *Formalization innovation*: one or more characteristics are formalized or standardized.

In a study of innovation modes related to integrated solutions [11], it was found that the recombinative innovation mode captures the innovation processes in their three case studies. In the case descriptions, also traces of the ad hoc and formalisation mode can be found. This shows that the concept of innovation modes can be used to describe the innovation of service in manufacturing firms. In addition it shows that there are several alternatives of innovation modes that can describe service development in manufacturing firms.

Innovation for services does not often follow a traditional product life-cycle [12]. Instead he suggested a "reverse product cycle" that corresponds to innovation processes in service sectors over the past twenty years. The reverse product cycle consists of three phases. First, new technology is introduced which leads to improved efficiency of the existing service delivery process. Second, the service quality is improved. In the third and last phase the process is no longer in focus but the product itself. Completely new services are created at this stage [12]. Gallouj and Weinstein argue that this innovation process is not universal for services, instead it should be seen as a diffusion process of technology derived from the manufacturing sector into services [7]. They argue that recombinative innovation is the dominant mode of innovation for services but that there are no specific trajectories for service innovations – each individual innovation can follow an individual trajectory.

2.2 The Product Development Process

The need for a systematic way of new product development (NPD) is pointed out in theory [13-15] and there are many propositions regarding the design of a product development process. One early model for product development, named the phase review process, was developed by NASA in the 1960s [16]. The process can be described as a measurement and control methodology, designed to ensure that the project proceeds according to plan [17].

Among the companies that have adopted a formal process, many make use of a stage-gate system [13], which breaks down the process into discrete and identifiable stages. During each stage, a number of parallel activities are carried out by different functions and cross-functional teams [13,18]. The stage gate system is a holistic cross-functional process, which covers every activity from idea to market launch, whereas the phase review process is a functional process restricted to engineering [17].

Concurrent engineering and integrated product development build on cross-functional cooperation in order to create products that are better, cheaper and more quickly brought to the market [19-20]. The fundamentals of concurrent engineering are an increased role of manufacturing process design in product design decisions, the formation of cross-functional teams, customer focus and lead-times as a competitive advantage [21].

2.3 The Service Development Process

It is well established that there is considerable diversity in NPD processes among firms, ranging from highly formal phase-gate processes to none at all [16,22,23]. Gustafsson and Johnson argue that the NPD process has many proven tools, methods and phase-gate processes, whereas the new service development (NSD) process tends to be a relatively arbitrary and unstructured process [24].

In general, when a process is used in service development, it consists of fewer steps than those used to develop manufactured goods [16]. However, service processes are nearly two steps less than the average goods-developing process. Which specific step is eliminated depends upon the firm, however, focus is on steps in the front end of the process rather than the later stages [16].

Edvardsson and Olsson argue that the main emphasis in service development needs to be placed on service concept development, service system development and service process development [25]. In this context, service concept development deals with examining customers' needs and wants and moreover with adequate ways how to satisfy these requirements. Service system development contains all the resources (human, technical, financial resources, etc.) needed to run the service that is to be developed. Finally, the service process development is about all the activities which have to take place to deliver the "new" service.

The existing frameworks and models that have been adopted by service companies originate mainly from product development. These product development models do not consider important aspects of the service logic such as its intangibility, customer heterogeneity, customers as co-producers of services, and that services are impossible to keep in stock. Services, however, have a tendency toward the previous four characteristics. When they are typified by intangibility and simultaneity, the process of evaluation, purchase, and consumption are critically important characteristics [26]. The quality of virtually any service depends on how well myriad elements function together in the same service process to meet customers´ expectations. These elements include people who perform various services that relate to the overall service, equipment that supports these performances, and the physical environment in which the services are performed." [27].

2.4 Service Development in Manufacturing Firms

Manufacturing companies that develop services have to combine both product and service innovation [28]. Hence, simply applying development processes developed for either products or services might not be a successful strategy. Furthermore, services might be developed at the same time as a related product, i.e. integrated service development, or independently after the product is already developed, i.e. separated service development [28].

A study of companies in the German and Swiss machinery and equipment manufacturing industry shows that the development of product-related services were often integrated in the development of a product, whereas customer services were often developed separately [28]. The customer services were often a solution to a customer request and the development process unsystematic. Hence, none of the service types were developed in systematic processes.

This is in line with research that identified new service development as a strategic hurdle for manufacturing companies looking to increase their service orientation [29]. They found that service innovation 'just happens'. Many manufacturing companies are striving towards increased focus on services and their service offerings are becoming even more advanced [2,30]. Despite the increased number of service offerings in many manufacturing companies the service development processes seem to remain unsystematic [31].

However, research has shown that a structured development process is preferable. Gebauer et al. found that manufacturing companies that successfully achieved high service revenues conducted market-oriented service development and had a clearly defined new service development process [32]. Three phases were identified; (a) identification of market needs, (b) development of new services, and (c) market introduction. Furthermore, the study of German and Swiss machinery and the equipment manufacturing industry investigated antecedents for the development of customer support services. It revealed the importance of organizing development activities, providing service manager decision-making authority at development gates, and creating an innovation culture in the service organization [31]. The two antecedents related to the development process affect overall profitability to a greater extent than the creation of an innovation culture does. In a further study, Gebauer and his co-authors argue that to succeed with service innovation a manufacturing company needs to align their way to develop service innovations with the existing product-service systems and the service strategy. Dependent on the service strategy, a company needs to develop their services accordingly [33].

3 RESEARCH METHOD

3.1 A two-stage multiple case study

To study how the service development process in manufacturing companies is influenced by the separation or integration of service development and the modes of innovation, a two stage multiple case study approach was used [34,35]. The research subject is well suited for case study research since it is a contemporary phenomenon for which scant academic research has been published [3]. Case study research is also a research strategy that is suitable for understanding the dynamics present within a single company [34]. The first stage of the study covered 17 organizations from the machine industry. In the second stage an in-depth study of three specific service innovation projects was conducted.

3.2 Stage 1: The Machine Industry

The sample for the first stage of our study was companies that belongs to the machine industry and that are employing 500-1000 people. Altogether 17 organizations participated in our empirical investigation. The main data collection method has been interviews with managers. The interviews followed a semi-structured interview protocol, where the protocol had been designed to better understand service development in manufacturing firms. In total, 17 interviews that lasted between 45 and 150 minutes were tape-recorded and transcribed by the authors, resulting in approximately 500 pages of text.

The data from the interviews were analyzed in two steps. First, a naïve reading of the interviews was conducted in order to get a sense of the text as a whole. Through this analysis we extracted important concepts from each interview that were not explicitly guided by theory. Second, an analysis of each case was performed regarding how service development was conducted. The classifications of companies into categories were performed independently by two of the authors. The inter-coder reliability was calculated resulting in a mean value between the two independent judges of 82%.

3.3 Stage 2: An In-depth study of Service Development

In the second stage an in-depth multiple case study was conducted in order to study specific service innovations. The case studies are based on studies of archival records and interviews with originators of innovations, service development personnel, sales managers, service managers, and customers. A total of 16 interviews were conducted, each of which lasted approximately one to two hours.

Seven interviews were conducted at SKF, six at Volvo Buses, and three at Volvo Trucks. The interviews were conducted with the assistance of an interview guide, and were tape-recorded and transcribed. Information was sought in the following areas: service innovation, service development, the service's relationship to the product, sale and delivery of the service, and reasons for the service innovation's success or failure.

Data collection and data analysis was carried out in a research team in order to achieve complementary insights and enhanced confidence in the findings [34]. The data analysis was based on detailed case study write-ups for each company followed by a thematic analysis.

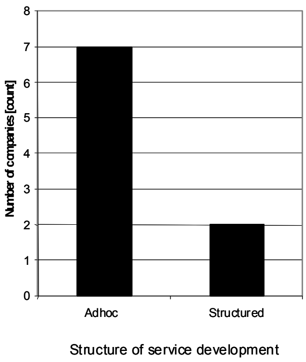
4 EMPIRICAL INVESTIGATION

4.1 Stage 1: Separation or Integration of Service Development

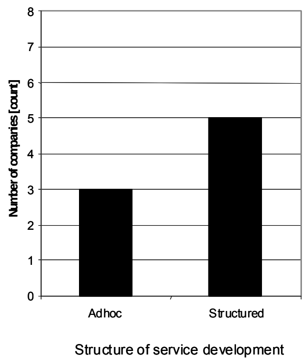
The first stage of the empirical investigation focused specifically on the separation or integration of service development. Many of the organizations studied view services as a part of the augmented product and use them as a strategy to sell more goods. For instance, maintenance of the goods is often viewed as free add-on services and can be manifested by technical support or call centers. More advanced contract management programs, such as proactive maintenance programs or rental services, are chargeable services where customers decide on what service level they want to buy. In a full contract program, the supplier offers complete service accessibility. An example may be that a company sells "a number of fastened screws" instead of assembly tools, or a "transport solution" instead of transport vehicles.

One specific example of service development concerns the development of services related to fork-lifts. They argue that when service development was introduced, much of the development work was centralized and often conducted to support the sales organization or service personnel. In addition, many services come from discussions with customers where the organization has had a long-term business relationship. One deliberate strategy used by many organizations is to transform intra-organizational services to end-user services. Support systems are often developed to help the service personnel to provide better services to end-users. After they have been tested, implemented and used by the service personnel, they can be improved to aid the end-user directly. In one example concerning updates of software, non-sophisticated interfaces for service personnel are improved by developing a user-friendly interface making the service available to customers.

An overview of the organization of service development in the 17 companies is presented in Figure 1. About half of the companies claim that they have integrated service development with the development of goods. When it comes to the description of service development, though, the practices and methods used are mostly performed ad hoc. One possible explanation is that when services are introduced into the setting of the product development process, the traditional engineering work does not allow services to get enough attention. The reason for the problems can be related to the different modes of innovation for goods and services.



a) Integration of product and service development.



b) Separation of product and service development.

Figure 1: Integration and separation of service development.

Within the companies that develop services separately from the development of goods, the services are to a greater extent developed in a development process tailored to services only. One of our case companies describes service development as "more *business oriented and graphical… it includes more models to build up the service … instead of just text"*. The service development model is also described as less linear, it is iterative so the development model should reflect this.

This development can be organized in different ways, however; either it occurs in a central development unit, or it is placed in the various local service units. Organizations with a centralized service-development unit strive to make service offerings available globally, while local service-development units provide services to their specific marketplace only. In our empirical investigation, it seems that the most successful strategy for initiating a structured way of developing services is to incorporate a separate unit for service development and to use multiple organizational competencies. As a step towards better integration of service and product development, a number of companies arrange yearly conventions for product developers and service personnel. One purpose of these conventions is to generate new features and services for the installed base of goods.

Analysis

The first stage in our empirical investigation shows that the service development process is often more structured if the service is developed separately, compared to if it is integrated in the product development process. The activity, interactional and relational nature of services is focused on. The reverse product cycle [12] might help us explain why it is harder for manufacturing companies to structure the development of services within the product development process. The development process is designed to support a specific mode of innovation for the products while the services might follow a different trajectory of innovation modes and integrate customers more directly in the development process. As a consequence, the activities in the product development process will not support the development of the service – and the development process will be perceived as unstructured. The empirical observation that the development process is more often structured when service development is conducted separately support this argument. When service development is conducted separately, the development process can be designed to support the mode of innovation for services. The better fit between the mode of innovation and development process should result in a higher success rate for services developed separately from the product.

4.2 Stage 2: Modes of Innovation and Service Development

Building on our results from stage 1 of our research, we focused specifically on the service development process and the modes of innovation in the second stage. Three service innovations were studied; Asset Efficiency Optimization (AEO) at SKF, Parts-on-Line at Volvo Buses, and Fuelwatch at Volvo Trucks.

Development of Asset Efficiency Optimization

In the late 80's SKF's interest in conditioning monitoring started to grow and was connected to a maintenance system. The interest in condition monitoring and a decision to have deep knowledge of this within SKF lead to the acquisition of a number of companies specialized in this area.

Towards the end of the 90's Sune Karlsson was appointed CEO of SKF, he earlier started ABB services and with that background the interviewees feel that he strongly contributed to the development of the service area in SKF. For a service person in a product dominated company such a service oriented CEO was of help: "you didn't have to explain to the CEO 'you're stupid and don't understand this', rather he pushed this forward 'why don't you do this?' This was very helpful in the organization as it made it difficult for middle management to say that this wasn't good." During this period a separate division for the service business of the firm was created.

With Sune Karlsson as CEO a number of service companies were bought and the entering of those new employees affected the way SKF worked as well: "they were a bit wild and we learned from that, they were more of entrepreneurs". Together with those service specialists the AEO-concept was created. One driver was that "we understood that those black boxes with condition monitoring and our excellent bearings and all that, it had no effect out there if you didn't educate the customer in understanding this, and that is one part of the AEO-concept." As concisely stated by another interviewee: "we didn't get our fantastic systems to the market."

With the integration of a number of newly bought companies with competencies in the consultancy area the AEO concept was further broadened with focus on maintenance strategy. Another contributor to the creation of a more visible service offer was when charges for products and services were separated. From the customer side it seems as the personal relation to an account salesman at the separate service division and is experienced as a key for long term cooperation.

The key to the accomplishments through AEO also falls back to the culture of SKF: "I think the key is that our base is not bearings but to solve problems, and how you do it – that is not so [important]"; the main thing is to solve the customer's problem in some way, not necessarily with a bearing.

Development of Parts-on-Line

The development process at Volvo Buses was originally introduced to develop new vehicles. Due to the rigidities of this model, later a development process for software was introduced. This is the model that has been used to develop new soft products or services. The process used for service development consists of prestudy, concept study, development, final development, industrialization and deployment. About 2 percent of the development budget is used for development of service. Altogether about 10 persons are involved in development of service.

The idea with Parts-on-Line is that customers have direct access, through an Internet portal, to Volvo's parts supply system. This means that customers can order parts at any time without having to consider workshop opening hours. Volvo Buses initially targeted large customers for this service, since this was for whom the system had primarily been developed. The idea was as follows:Volvo Buses maintains a certain degree of scepticism about intangible services. Parts-on-Line, however, is a service based on hard issues like spare parts, and the likelihood that the system will increase the sale of spare parts has led to greater acceptance of the service.

The technical solution within Parts-on-Line has its origin in a large-scale project at Volvo that aimed to create an e-business system. Following the completion of this project, certain personnel at Volvo Buses felt that this knowledge could be leveraged and used as the basis for developing a new service. "In the e-business project, Volvo wanted to learn and a consulting firm wanted to educate about the web so it was a giant project. I believe we were 90 persons and half of them from the consulting firm so we spent a lot of money… it was a fun time."

The necessary resources were not available at Volvo Buses at the time, so funding was obtained from other Volvo companies. Once the system was in place, the solution was tested with a key customer, whose solution has been used as a reference.

Although a formal development project was formed during the development of Parts-on-Line, it did not follow the suggested development process. Despite a business case being documented, the process was mainly continued on an ad hoc basis. In practice, most projects are conducted with the involvement of a limited number of people. The development team in the Parts-on-Line project consisted of six members.

After the first cases, this service has been developed further. Especially, the customer interface and databases have been upgraded. "Afterwards, Volvo Parts is now the owner of the application – and they have done two upgrades…it now is the third generation of the system." This service has now entered a new phase of development, where a bundling strategy is used to develop the service further. "In the project, we have to create a dialogue and make something good out of it using intelligent bundling of a business concept – so we get better payed for the [free] system… then we can assure loyalty so it does not become an ad hoc thing."

Development of Fuelwatch

The idea of Fuelwatch is to reduce the customers' fuel consumption and consequently cut fuel costs. This is done through the combination of six individual services that are packaged and sold under the designation of Fuelwatch. All services included already existed although they were offered by different units within Volvo Trucks. Furthermore, they were delivered differently at different locations, e.g. different countries. As Fuelwatch was developed the quality of the services was secured by educating the staff to offer the same service. It also facilitated the marketing of the services. "Fuelwatch is an umbrella term […] used to market the services with only one denomination and to have a clear structure in what is offered to the customer."

As the project started there were a few enthusiastic people getting a small amount of money to develop the idea of Fuelwatch. After some months though, the work was accepted and it developed into a project with a budget and a steering committee consisting of managers from different organisations. The development of Fuelwatch was performed within the business unit "Business solutions", working with sales and support. The development process was performed in this business unit because that was where the people getting the idea were working at the moment, and they were the ones enthusiastic to develop it. One of them explains the development process like this; "Some of our engineers got ideas that they thought were fun, then there were people like me who thought it could be useful and salable, and later on it was the customer needs that set the direction for the development."

Although the development of Fuelwatch was performed as a project it did not follow any structured development process. Since new ideas for services are more ad hoc and has a shorter development time than products, the existing development process, originally developed for products, was not considered suitable. "It cannot be done the normal way [i.e. follow the product development process] because it will take years from that you get the idea until you have the service on the market, it simply doesn't work."

Analysis

The three services and development projects investigated in our case studies share a number of characteristics. First, the services were developed separately from the goods. Second, the three services are driven by technology and based on this a service has been developed for the customer. Third, all three case companies have structured development processes for services, but neither of the three development projects have used it. Furthermore, the empirical investigation showed that different modes of innovation [10] have been observed throughout the development of the three services (Table 1).

The development of AEO has taken place during a long period of time. In a first phase condition monitoring was developed within SKF, having high priority. In parallel, services within maintainability were developed. The connection between the two was made in a second stage, maintainability services and condition monitoring was combined, or bundled, as a means of getting "the fantastic systems to the market". However, the AEO concept has been refined and repackaged in what can be defined as a formalization innovation mode.

Mode of Innovation	SKF	Volvo Buses	Volvo Trucks
Radical Innovation	1. Condition Monitoring	1. An e-business system	1. Online program for surveillance of truck efficiency
Improvement innovation		3. Parts-on-Line	2. Improving existing services
Incremental Innovation			
Ad Hoc Innovation	1.Maintaina-bility services	2. Parts-on-Line	
Re-combinative Innovation	2. AEO	4. Parts-on-Line	2. Fuelwatch
Formalization Innovation	3. AEO		3. Fuelwatch

Table 1: Modes of innovation (numbers indicating an approximate time sequence of when the services were developed within the companies)

Considering the case of Volvo Buses and their service Parts-on-Line, the service has gone through a number of innovation modes. The first development of an e-business system can be seen as a radical innovation in this context, since it made a new technology available. Then a phase building on ad hoc innovation took place including the first implementation at a customer. Then the service followed an improvement innovation mode covering a large number of installations of the service. Recently, the service has entered a recombinative innovation mode where the service provider looks for possibilities to combine different service modules.

The development of Fuelwatch within Volvo Trucks started with technology driven services that were new to both the company and most of their customers. The online program for surveillance of truck efficiency; Dynafleet, is an example of a radical innovation that forms the basis of Fuelwatch. At a second stage a number of services that were already offered by the company were improved and bundled and sold under the name of Fuelwatch. Finally, the service is continuously improved through standardization and modification, which could be seen as a formalization mode of innovation.

The development of ad hoc innovations seems to be dependent mainly on factors other than structured development processes; foremost a service orientation in the company seems to be a prerequisite for the development of services. Ad hoc innovations take departure from a specific client problem, and in a separate service division close relations to clients are probably established through which client problems are easily identified and addressed. As in the case of SKF the attitude of the personnel at the service division is focused on solving a client's problem - either through goods or services.

5 DISCUSSION AND CONCLUSIONS

The product development processes has their origin in the development processes from NASA and the innovation modes of technical products. In addition, the service development processes build on translations of product development processes into the service sector. This means that phases, methods and gate criteria in models for service development initially have been constructed for developing goods. Service developers often perceive the development process as an obstacle instead of a supporting factor. This is one of the explanations for the lower use of development processes for services.

When manufacturing companies start developing services, they seem to adopt one of two strategies (a) they use the product development process for service development; or (b) they develop services without any support of a development process. In either case, the company experience service development as difficult. By using innovation modes to investigate service innovation in manufacturing companies, we can better understand failures of either of these two strategies.

Service innovation often follows a sequence of innovation modes that is different from the sequence of innovation modes of products [12]. This makes it hard to develop products and services within the same development project. As an example, the product could be a case of a radical innovation while the service might be in a formalization mode. These two innovation modes need different kinds of support and it might be difficult to design one development process and co-ordinate the work related to both the product and service. Different innovation modes benefit from varying degrees of structure and support in the development process. As a consequence, integration of product and service development within one project is difficult.

We argue that to develop and manage processes that support service innovations we need to understand the innovation mode of specific services. This means that rather than having common support for service innovations in general, there is a need to have several development processes for services. For ad hoc innovation that often originates from an ongoing customer relationship, a basic support structure is needed. Such a support structure might include a service culture, formulas for developing a business case and slack time for development personnel.

For other innovation modes such as improvement and incremental innovation a more traditional development process can be used. Here, development methods and tools such as service blueprinting, QFD, customer surveys and building a more detailed business case can be used. For re-combinative innovation and formalization innovation, issues like business model, service modules, standardization and bundling strategies becomes central in the development process.

Our research shows that Gebauer's identification of the structured development processes as a prerequisite for successful service development is not valid for all innovation modes [31]. As an example our in-depth cases illustrate that ad hoc innovation modes are better supported by factors such as a service-oriented culture than a structured service development process. With a better alignment of the characteristics of the development processes and innovation modes the success rate of development projects will increase. As a consequence, we argue that the success factor for service innovation in manufacturing companies is the fit between the innovation mode and the development process and not the development process as such. An ability to innovate provides a strong basis for organisations to obtain and sustain superior performance and competitive advantage [36]. We have in this article argued that service innovation success in manufacturing companies is linked to selecting and managing the proper mode of service innovation fitting the company's development process.

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7 REFERENCES

[1] Cefis, E., Marsili, O., 2006, Survivor: The role of innovation in firms' survival, Research Policy, 35:626-641.

[2] Oliva, R., Kallenberg, R., 2003, Managing the transition from products to services, International journal of service industry management, 14:160-172.

[3] Neu, W.A., Brown, S.W., 2005, Forming Successful Business-to-Business Services in Goods-Dominant Firms, Journal of Service Research, 8:3-17.

[4] Allmendinger, G., Lombreglia, R., 2005, Four strategies for the age of smart services, Harvard Business Review, 83:131-145.

[5] Wise, R., Baumgartner, P., 1999, Go Downstream: The New Profit Imperative in Manufacturing, Harv.Bus.Rev., 77:133-141.

[6] Gremyr, I., Löfberg, N., Witell, L., 2010, Service innovations in manufacturing firms, Managing Service Quality, 20:Forthcoming.

[7] Gallouj, F., Weinstein, O., 1997, Innovation in services, Research Policy, 26:537.

[8] Gadrey, J., Gallouj, F., Weinstein, O., 1995, New modes of innovation: How services benefit industry, International Journal of Service Industry Management, 6:4-16.

[9] Nijssen, E.J., Hillebrand, B., Vermeulen, P.A.M., Kemp, R.G.M., 2006, Exploring product and service innovation similarities and differences, International Journal of Research in Marketing, 23:241-251.

[10] Gallouj, F., Savona, M., 2009, Innovation in services: a review of the debate and a research agenda, Journal of Evolutionary Economics, 19:149-172.

[11] Windahl, C., Andersson, P., Berggren, C., Nehler, C., 2004, Manufacturing firms and integrated solutions: characteristics and implications, European Journal of Innovation Management, 7:218-228.

[12] Barras, R., 1986, Towards a theory of innovation in services, Research Policy, 15:161-173.

[13] Cooper, R.G., 1993, Winning at new Products, .

[14] Ulrich, K.T., Eppinger, S.D., 1996, Product Design and Development, .

[15] Urban, G.L., Hauser, J.R., 1993, Design and Marketing of New Products, .

[16] Griffin, A., 1997, PDMA Research on New Product Development Practices: Updating Trends and Benchmarking Best Practices, J.Prod.Innovation Manage., 14:429-458.

[17] Cooper, R.G., 1994, PERSPECTIVE: Third-Generation New Product Processes, Journal of Product Innovation Management, 11:3-14.

[18] Hughes, G.D., Chafin, D.C., 1996, Turning New Product Development into a Continous Learning Process, Journal of Product Innovation Management, 13:89-104.

[19] Andreasen, M.M., Hein, L., 1987, Integrated Product Development, .

[20] Clausing, D., 1994, Total Quality Development, .

[21] Smith, R.P., 1997, The Historical Roots of Concurrent Engineering, IEEE Transactions on Engineering Management, 44:67-78.

[22] Alam, I., Perry, C., 2002, A Customer-Oriented New Service Development Process, Journal of Services Marketing, 16:515-534.

[23] Booz, E., Allen, J., Hamilton, C., 1982, New Product Management for the 1980s, .

[24] Gustafsson, A., Johnson, M.D., 2003, Competing in a Service Economy, .

[25] Edvardsson, B., Olsson, J., 1996, Key Concepts for New Service Development, Service Industries Journal, 16:140-164.

[26] Johne, A., Storey, C., 1998, New service development: a review of the literature and annotated bibliography, European Journal of Marketing, 32:184-251.

[27] Zeithaml, V.A., Parasuraman, A., Berry, L.L., 1990, Delivering quality service: balancing customer perceptions and expectations, .

[28] Gebauer, H., Krempl, R., Fleisch, E., Friedli, T., 2008, Innovation of product-related services, Managing Service Quality, 18:387-404.

[29] Martin, C.R.,Jr, Horne, D.A., 1992, Restructuring towards a Service Orientation: The Strategic Challenges, International Journal of Service Industry Management, 3:.

[30] Mathieu, V., 2001, Product services: from a service supporting the product to a service supporting the client, Journal of Business & Industrial Marketing, 16:39-58.

[31] Gebauer, H., 2007, An Investigation of Antecedents for the Development of Customer Support Services in Manufacturing Companies, Journal of Business-to-Business Marketing, 14:59-96.

[32] Gebauer, H., Friedli, T., Fleisch, E., 2006, Success factors for achieving high service revenues in manufacturing companies, Benchmarking, 13:374-386.

[33] Fischer T, Gebauer H, Gustafsson A, Witell L. Managerial recommendations for service innovations in different product-service systems. In: Sakao T, Lindahl M, editors. Introduction to Product-Service Systems: Springer; 2009.

[34] Eisenhardt, K.M., 1989, Building Theories from Case Study Research, Academy of Management Review, 14:532-550.

[35] Meredith, J., 1998, Building operations management theory through case and field research, J.Oper.Manage., 16:441-454.

[36] Barney, J., 1991, Firm Resources and Sustained Competitive Advantage, Journal of Management, 17:99.

User-Inspired Design. Co-creation processes vs. business-to-Customer industry

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Abstract

User-Inspired Design can be defined as the discipline relating to a new idea of what innovation means today in the design field. This idea derives from the consciousness that innovation does not just relate to high-tech fields. Innovation affects also products and services, public and private bodies, factories, research centres and universities, which all aim to renew and be competitive in their own fields. Three different kinds of innovation have been determined: price-driven, research-driven, user-driven. Companies, sometimes, use a combination of these three types of innovation.

It seems clear that research in high-tech does not take you straight to high innovation in the performances of products and services that relate to them. There is a new idea that focuses on “users’ needs”. Bodies, companies, industries must meet users’ needs in order to be competitive. User-driven innovation is a strategy that points out - co-creation processes - a complete knowledge of users’ needs based on B-to-C industry.

Keywords

Grassroot, Open Innovation, Co-creation processes

1 INTRODUCTION

The aim of this paper is to show that User-Inspired Design is the area of User-driven Innovation which describes a bottom-up process starting from the joint action of end users, who interpret the meanings and opportunities provided by emerging technologies in creative, original ways. The idea is to show that user-driven innovation is a process producing a diffuse creativity which innovates at all levels, i.e. the design, production, distribution and social acceptance of the goods and the technologies themselves. A number of methods have been proposed over time, including the Lead User Method (Von Hippel, 1986), which are used to learn user innovation in a systematic way and then transfer it to the design of new products and services.

The user innovations which are known as of today concern the use of products and services, urged by the analysis of new behaviours; the design of technologies to make objects easier to understand (e.g. interfaces design); innovation of new technologies, such as Open Source Software (OSS), producing innovation for the social sharing of design choices and their impact on life contexts. The old idea whereby user innovation was focused on the use and design of existing projects having in mind the end user or was closely linked to mixed working groups where consumers were involved in design choices (co-creation processes) gives way to new types of involvement. These are consumer-inspired rather than consumer-oriented choices - which claims the crucial role played by the user as designer.

2 OPEN INNOVATION AND NETWORKS

2.1 Development of human skills and self-organisation

Today’s society is based on the development of human skills, and is carrier of new contents viewing the wellbeing/productivism pair as some possible alternative; the uniqueness and abilities of the individual are the response to change: the individual is no longer at the service of production, but production is oriented towards a human development enhancing the production of the self. In André Gorz's view, a society aiming at each individual's development is mainly defined as a “society of culture”, one of its priorities being identifying the people and groups carriers of values and knowledge who will lead this transition within enterprises and institutions alike. This process entails an emancipation of the human capital from the economic capital: according to Gorz, one instance of this is the "craftspeople of free software and networks” who hold a highly technical know-how and therefore oppose the privatisation of the means to access a shared knowledge - a common good of humanity as a whole.

These instruments are essential for the development of the self in transforming humanity from an instrumental “labour force” to an “independent force": thanks to software it is possible to produce contents that are accessible to everyone and whose only value is their “use”, going beyond the outdated value of “exchange”.

It is a revolution from inside the system, where “practice is the programme” and starts from a learning self-organisation. According to Gorz it develops within spontaneous communities acting from the strategic perspectives of production, orientation, distribution and property of knowledge.

The impulse of communication technology (ICT) has enhanced the birth and spreading of self-organised Networks – interconnected entities (e.g. companies, universities, public bodies and consumers) that create, acquire and bring together various types of knowledge and skills necessary to innovate products and services. As a matter of fact, Innovation Networks revolve around the constant acquisition of knowledge and self-organisation of contents.

The term “grassroot” identifies this type of structures whose organisation is not hierarchical, but is based on peer relationships, and whose nodes, made up of groups of critical users, draw on the idea of interdependency.

The emerging of a movement of aware consumers has played a major role in strengthening the issues of personal development within market mechanisms, affecting the choices of industry in producing shared goods. The evolution from consumers to users with negotiating skills on the quality of goods leads to another important consequence: the user re-acquires his/her decision-making ability on the products and services related to the place where s/he lives.

The ability to see a result ahead and to achieve it in an original way gave birth to creative communities that had their say on various sensitive social issues which had not been resolved through the conventional instrument of delegating institutions.

Re-gaining one’s role in co-designing and co-production in the change of or response to everyday needs side by side with experts entails a direct responsibility and thus the care for the good or service put in place by the local communities.

Creative communities are groups of people who get together to achieve a result and share it. This space for action has a virtual homologue where aggregation occurs by raising a topic, acceptance of which will help promote initiatives affecting social and economic policies by forcing their implementation criteria.

While most of user innovation focuses on the use and design of existing products and technologies, new tools (web-based forums) foster innovation that is produced by the consumers themselves in virtual environments and is later transferred to the partner companies in various stages of the development of a product and, most importantly, in other activities having a creative content.

2.2 Open Innovation: Price-driven, knowledge-driven, technology-driven, user-driven, social-driven…

For almost twenty years the driving sectors of economy have gone through a major transformation, shifting from a price-based competition to a knowledge-based one.

Ideas and innovation have become the focus of social and economic actors, supporting new or renovating existing products and services, processes, production organisations, educational bodies, etc. i.e. all the categories of goods and services requiring constant updating to remain competitive.

Knowledge-based economy has increased competition between economic actors by focusing mainly on innovation.

Technology-driven innovation has recently shifted its focus towards a greater understanding of consumers and the definition of their needs. This type of competition gives priority to understanding emerging needs and to the ability to use this knowledge when designing new products and services. The consumer thus becomes the crucial element of the design process and his/her needs are identified through a systematic, scientific approach.

The mapping of the consumer's experiences and of his/her latent (non explicit) needs is based on an investigation methodology drawing inspiration from social sciences and ethnography. In addition, new forms of work have enhanced the development of professionals-consumers mixed groups.

This approach has brought about a substantial process innovation, which has been named “user-driven innovation”: even when a new technology becomes part of the design process, innovation will always be called "user-driven" if the inspiration originates from consumers' needs. The consumer is thus the focus of user-driven innovation, and it is the will to give voice and respond to the consumer's needs by improving their manifestations that leads innovation.

Similarly, research remains at the core of technology-driven innovation. In the industrial age technology-driven innovation was the content needed to be competitive on the market: research and education centres were set up to develop and support technology and innovation was thus automatically associated to technological change.

Experience, however, shows that technology-driven innovation alone cannot ensure major returns in a long-term perspective. Analysis on the field also shows that companies create innovation in various ways, including user-driven innovation, which may potentially have a significant impact. It is a kind of innovation driven by consumers and end users and borrowed by manufacturers; many products and services are developed or re-defined by users in the very place where they use them.

Any possible re-definitions, that is new ideas, go back along the supply chain to be implemented in new products and services. Actually it is a process whereby the needs contained in the products and services are shared, which only happens when the product or service has been defined in its final shape and when the user is only in charge of checking its implementation.

The new approach reverses this procedure, and the implementation of the user’s needs can be shared with the manufacturers since the very conception of the product or service. This process is made possible by Internet technologies, Open Source Software (OSS) and by the fact that consumers are social promoters of their own needs.

The need arises to set up social-driven innovation, which explores collaborative approaches for the resolution of conflicts, regardless of their size and nature – from the micro-scale of life contexts to the global scale that becomes the sharing of a given problem, using open source communication and operational tools.

Through social networks user innovation contributes to fostering the social and socio-technical spreading and distribution of new products and services right within knowledge-structuring processes entailing the acquisition, dissemination and use of information.

Experiences, learning and the production of collaborative contents are considered fundamental in the innovation generation process at large: social innovation is the expression of self-organisation and do-it-yourself strategies, as competences resting on a set of users’ expertises and enabling them to intervene directly at the heart of a problem and provide solutions to it.

As for user-driven innovation, because it does not have its own area of study within educational bodies as yet, manufacturers devise their own instruments to cope with users’ needs, which is evidence of the proliferation of best practices in user-driven innovation within the companies themselves.

However, user-driven innovation remains a top-down process at best: led by the companies, formulated on the basis of consumer needs’ analysis, it develops methods which include the user in the design process to reach solutions that only ensure competitiveness on the markets.

3 USER TOOLKITS FOR INNOVATION VS WEB-BASED USER TOOLKITS

Following this logic, Eric von Hippel e Ralph Katz (2002) identify a new approach as the key to solve the problem of manufacturers, which consists in being always able to come up with products and services responding, constantly and properly, to the needs of users.

In their view, manufacturers shifted from interpreting and understanding users' needs to outsourcing this task to the users themselves after equipping them with "toolkits for user innovation" (E. von Hippel, R. Katz).

These tools consist of sets of "user-friendly design tools" enabling users to develop new products or innovation, usually on their own.

According to the procedure, users are equipped with specific design tools, such as design software, etc., and find their way along the process: first, a preliminary design is produced, followed by simulations or prototypes and, finally, users themselves test the product in their own environment and keep improving it until they are fully satisfied with the result.

Recently, the concept of mass customization (MC) has seen increased attention in marketing.

The core idea of mass customization is to provide a web-based user toolkit that allows the individual customer to design a product which suits her individual preferences and is then produced exclusively for his.

Many companies have set up MC systems that have been identified as a promising strategy in markets. These MC systems represent where customers have sound preference insights, where preferences are heterogeneous, and where production technology facilitates small lot sizes at mass production costs.

4 USER-INSPIRED DESIGN APPROACH

As was mentioned above, the grassroot experiences identifying cooperative organization forms are supported by the spreading of Open Source Software (OSS) IT tools. In Open Source Software the source code, that is the program files needed for its functioning, is given to the user on purchasing the software.

The user (just like the network of users) is therefore enabled to analyse the functioning of the programme and to modify it to adjust it to his/her needs. Free Software communities have developed methodologies whose organisation is open to sharing and joint action and which is useful to define horizontal design and communication tools to the benefit of communities of non software developers.

This dynamics has encouraged a shared view of technologies, bringing about organisational models of virtual communities based on autonomous tools. The spreading of highly-performing IT tools has produced a kind of "participative technology", building the net as an infrastructure or a technological support for the joint design and production action.

A real evolution of user-driven innovation, it originates from a new approach which grows little by little going beyond the monological view of manufacturer-driven innovation.

4.1 Co-creation processes vs business-to-customer industry

New organizational models skilfully re-shape the areas of research, design and creation at large, bringing innovative practices into production, distribution and, the end stages, of waste recovery and re-use.

Complex creative processes combine codified knowledge with new value systems that develop in environments benefiting from the exchange that takes place between very different educational and research areas. These are knowledge-based processes, whose prerogative is that of re-organising knowledge into non-predetermined paths and which consolidate contents and re-shape them with a view to an end result.

The sense-making paths that are established each time are generated in open systems - environments where, starting from different initial needs, the same results can be achieved following different ways. The term to identify this type of process is equifinality [3], which points to an equivalent competitive advantage based on fundamentally different competences in a complex production framework.

In particular, in knowledge-based systems the competitive advantage concerns intangible goods like human knowledge and the ways to turn implicit value into other negotiable types of values. The future of many entities will mainly depend on their ability to transform a given value into another - for example an intangible good like professional advice will be turned into a more negotiable kind of value, like consulting services. Intangible goods, which have increased thanks to the commitment in intentional actions, are generally accepted today - almost as much as other types of goods.

As a matter of fact, it is widely accepted that a company's reputation is closely related to its brand value, which includes goods such as social and environmental responsibility, as is shown by the companies acting on the basis of sustainable values and practices. To have a hands-on approach to everyday reality one must be able to choose contents and, above all, to arrange connections, that is create a "chain of knowledge and practices". Knowledge and work practices - including the most exclusive ones - can merge with others coming from different disciplines in a bottom-up approach.

This must also be combined with the substantial contribution of creation viewed as an innovative practice, which through the dynamics of re-contextualisation and re-conceptualisation, benefits from the real possibility of using existing materials to design evolutive scenarios for products and services. The system of products and services thus rests on a texture of external inter-relations, which come in at different levels and determine its driving force. These processes are characterized by evolutive dynamics interacting at the various levels of value creation and are constantly on the move.

The main characteristic of this type of interrelations lies in establishing transparent ways to benefit from the knowledge available, through dynamics, that are not only science and capital intensive, but originate from immaterial qualities in uncodified (and thus fluctuating) creative paths. This kind of innovation is called "poiesis intensive", meaning to do in the immaterial field, create, creativity: it is a kind of innovation that attaches growing importance to knowledge and is able to give rise to new, different creative pathways.

Within these paths, apparently diverging knowledge and practices may interact, which at a closer look appear as integrated strategies and symbiotic cooperative processes. These chances have established themselves around the idea of orienting re-organization processes from a design perspective, meant as a strategic vision, the engine of innovation, which is open to inter-discipline collaborations involving the design of new products for new markets or new entrepreneurial models based on unusual chains in close contact with the existing productive environement.

In this sense design confirms once again its role of driving force for new micro-entrepreneurship actions that, on the one hand, recover the handicraft tradition to re-propose it in new forms and, on the other, are able to merge these forms with the most up-to-date engineering processes, giving life to chains that bring together micro-businesses and globalized companies, renovated handicraft production methods and well-established industrial production ones.

It is a flexible, constantly evolving structure which is far ahead of the traditional model of supply, and can meet a variety of market and consumer needs, which are becoming more and more sophisticated – an eco-system which creates links between the productive, educational and institutional systems, acting in symbiosis and without hierarchies.

It is defined as the co-existence of various organisms where each one benefits from the other. In the given context the term applies to cooperation between the university, institutions, manufacturers and industry, where a number of entities including universities, research centres, public bodies, NGOs, industries or manufacturers of any size, together, mutually benefit from their own or others' educational, research and production abilities, making up a network based on performative cooperation and on the concept of equifinality.

Design becomes the driving force of online entrepreneurship and, by recovering a historical aptitude, brings together educational and research chains with producers anywhere on the national and international scene. The search for specific qualities and knowledge, re-organised around complex design visions, includes systems of products and services experimenting with new distribution and communication forms to intercept global market niches.

In addition, the symbiosis among organizations appears alongside the methodological hypotheses and on-field investigations of Design for Environment or Life Cycle Design, where the actions identified, aiming at minimising the use of resources and impacts on the environment, are implemented by the actors in the product-service life cycle and where economic and institutional actors take the place of production stages. A further step beyond the exclusive availability of goods is constituted by the socalled "integrated cycles", which concern the service accompanying the good, i.e. intangible goods.

The reference literature for Design for Environment or Life Cycle Design sets up the links and relationships existing between those who produce (and design) products and services, those who supply or produce the materials, those who distribute, those who consume or use, those who dispose of and the new actors - new actors who make up the panel full of activities and interventions, which confirms the configuration of fluid organisational structures aimed at setting up a place-based symbiotic network of actors.

4.2 Case study

A new, parallel approach develops within the company organization at the same time, based on the simultaneous integration of user-designer, technology, IT and industrial production, which is to be ascribed to generative design. The Breeding Tables project (2005) by Reed Kram and Clemens Weisshaar takes on the challenge, considering the production process as an integral part of the design, thanks to the contribution of the computer as a tool generating innovative cognitive processes and industrial operational ones.

The new frontier is represented by the transformation of a set of data into matter: this is entirely achieved within the design process, which is identified through the creation of a software (BT) which begins to work in the first creative and design stage and then manages the production stage: the process diagram of the software first provides the machines used with the data (size, type, etc.), then with the algorithm which generates a series of two-dimensional geometries (each inherits a set of properties from the mother object) giving rise to a "species" of objects with same genetic traits.

In the case of the Breeding Tables, the constructive surfaces are generated by a triangulation of the basic geometry created by the algorithm in the previous stage; later the structure of the table is taken out by means of oblique cutting planes resulting in a three-dimensional model of the table.

The stage following a series of feasibility tests consists in cutting the components: the cutting pattern is sent to the numerical control machine which performs the laser cut; then the components are taken to the folding and prepared for assembly. Designers define software as "a super-extension of the designer's hands", which expands into a wider dimension than that of production; "a sort of digital factory, a sweatshop which constantly comes up with proposals among which we pick up the most promising ones".

It is a hypothesis belonging to user-inspired design which gains a new dimension from this instance, i.e. the extension of the factory distributed over relational territories following an advanced way of working - a practice defined by the paradigm of Open Source Software identifying in a strategy that rests on a network of specialised partners in design and production: actors in a boundless geography which only works if there is a connecting capacity to control the whole.

5 CONCLUSIONS

The case presented is paradigmatic of the evolution of the design and organizational skills taking place on the Web, which opens up to society at large and proposes innovation in (not only digital) supply chains.

The expansion of the community organization with its fundamental feature of cross-fertilisation with technology, and of the socio-technical distribution of innovation, moves from the individual to collaborative platforms. These are the logistical bases from which to experiment with alternative possibilities to create new design opportunities.

The hypothesis takes shape around the definition of peer-production (Benkler, 2006), that is the production of goods which are durable because they are relational, founded by a shared design process based on the trust in the individual-community relationship.

User-Inspired Design rests on experience-based knowledge and insight, which is useful to design as it proceeds from unsaid knowledge of design expertise.

It originates from the assumption that the design process is shared by several subjects and is comprised of several different phases aiming at both exploring and operating.

It is closely linked to the context of activities, developing a collaborative and cooperative nature, and uses heterogeneous resources: flexible, ever-changing structures, eco-systems creating links between production and creation with no hierarchy.

User-inspired design is based on the co-existence of various organisms, each benefiting from the other. In the given context, the term applies to the cooperation of users in manufacturing and designing, where a certain number of users and small, medium-sized and big manufacturers make up a digital platform using their own or others' production and design abilities, setting up a network based on performing cooperation and on the concept of equifinality (von Bertalanffy, 1968). In this sense, equifinality brings about an equivalent competitive advantage in a complex productive context, based on fundamentally different competences.

In particular, the competitive advantage of knowledge-based systems relates to intangible goods like human knowledge and to modes to convert the implicit value into other negotiable values. The spaces of creativity laying in such platforms need to be equipped with practical tools as well as cognitive instruments.

Designers define relational software as “a super-extension of the designer’s hands” which reaches production, and thus manufacturers.

The idea of customer co-creation is most commonly applied to concepts of approaches to new product/service innovation, it represents customer and brand-company working together in any type of partnership to develop a joint outcome. Co-creation has lived for years in the B2B world. (For example, in a public-relations agency, many of the agency’s outcomes and marketing of itself, are very much collaborative and result from a partnership between agency and client.)

Co-creation remains very new to the B2C world, yet it is quickly becoming a critical concept - one that is being used to respond to the fundamental shift in power; moreover, co-creation is being applied to a broader range of customer-brand interactions.

It is a hypothesis belonging to user-inspired design, which gains a new dimension from this instance, i.e. the extension of the factory distributed over relational territories following an advanced way of working - a practice defined by the paradigm of Open Source Software identifying in a strategy that rests on a network of specialised partners in design and production: actors in a boundless geography which only works if there is a connecting capacity to control the whole.

6 REFERENCES

[1] Bauwens, M., Peer to peer and Human Evolution on the Relational Dynamic as the Premise of the Next CivilizationStage,http//www.networkcultures.org/weblog/archives/P2P_essay.pdf

[2] Benkler, Y., The wealth of networks:how social production transforms markets and freedom, Yale University Press, New Haven Connecticut, 2006.

[3] von Bertalanffy, L., General systems theory. New York: Braziller, 1968.

[4] Dawson, R., Living Networks: Leading Your Company, Customers, and Partners in the Hyper-Connected Economy, Prentice Hall, New York, 2003.

[5] Drucker P. F., Management Challenges for the 21st Century, New York: HarperCollins, 1999.

[6] Gorz, A., L’immatériel. Connaissance, valeur et capital, Galilèe, Paris, 2003.

[7] Gorz, A., Métamorphoses du travali. Critique de la raison économique, Folio essias, Paris, 2004.

[8] von Hippel, E., “Perspective: User Toolkits for Innovation”, The Journal of Product Innovation Management, Vol. 18, 2001.

[9] von Hippel, E., and Katz, R., “Shifting Innovation to Users via Toolkits”, Management Science, Vol. 48, No. 7, 2002.

[10] von Hippel, E. (2005), Democratizing Innovation, Cambridge, MIT Press, 2005.

[11] Pine, J. B., Mass Customization: The New Frontier in Business Competition, Harvard Business School Press, Cambridge, MA, 1993.

[12] Prahalad, C.K., and Ramaswamy, V., The Future of Competition, Harvard Business School Press, 2004.

[13] Raymond, E. S., The cathedral and the bazar, First Monday, 3, 1998.

[14] Tuomi, I., Networks of Innovation (http://www.oup.com/uk/catalogue/?ci=9780199256983), Oxford, MA, University Press, 2002.

PSS Innovation: Discussing Knowledge Based Tools

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Abstract

Product-Service systems (PSS) introduce the alternative for manufacturing firms to address sustainability in early development. In aeronautic industry, sustainability is an issue that challenges the innovation capabilities. The question if engineering tools and software are apt to manage innovation aspects guides the study in this paper. The study embarks from tools which can be categorised as knowledge based tools, and concludes that there are constraints that delimit the use in innovation projects. However, some of the constraints are more related to the approach rather than to the tools as such.

Keywords

Product-Service Systems, Innovation, Life-cycle, KBE, KBS, knowledge based engineering, knowledge based systems

1 INTRODUCTION

A Product-Service Systems (PSS) solution is commonly seen as a life cycle commitment, since the manufacturers take extended responsibilities to deliver the agreed performance. This is a complete different business model compare to selling goods as standalone products. In recent time, environmental and sustainability concerns have become a vital part in product development. Thus, adding to the complexity of managing the 'well known' aspects of shortening lead time, reducing costs and improving quality. PSS is a change towards a result-oriented perspective [1] and is an opportunity for manufacturing firms to integrate several perspectives in early development. PSS is foreseen to open up for sustainability aspects, where for example, a change in usage patterns is triggered by a PSS vision, and in turn this reduces waste [2]. In the aerospace industry, the sustainability opportunities and also a possibility to include maintenance into the business can be a reason for adapting towards PSS [3]. Airline companies spend on average USD 870 per flight hour in direct maintenance costs [4], where the engines represent over 40 %.

Though, to reach a PSS vision, the voice of the customer has to be understood in depth, i.e., to address the use of the product the customer's goals and intentions have to be understood by the development team [5]. Typically, a life cycle commitment is contracted on the characteristic to provide "functions per unit", e.g., power by the hour or thrust on wings. The PSS providers also agree to meet such need on the basis of a long term contract. Obviously, the identified basic need can be met by different solutions over time; hence companies have to deal with innovation in a different way compared to a traditional business model.

For the roll-out of a PSS innovation strategy, lessons can be learned from an open innovation approach [6]. Even though open innovation is promising, such an approach still has some complicated issues to tackle, e.g., to change mindset [7]. Still, it is suggested that companies need to be more open to position themselves in future collaborative provision of products [4]. Thinking, seeing and doing first are three ways to decide about the future [8]. Where seeing and doing are important when you have vague information to act upon, as in the case of PSS where the customer information is becoming more abstract. For instance, computer aided design (CAD) tools are a vital part of the engineering activities, such tools allows the engineer to visualise the product. Service/product engineering is identified to have a great advantage if implemented into typical engineering tools [9]. The focus for such tools seems to be to support the engineering area to deal with the service parts in PSS. Thereby, supporting service innovation, so, still, the possibilities for typical engineering tools to support technology innovation are interesting. Hence, the purpose in this paper is to contend with the question how engineering tools are apt to manage technological innovation aspects in a PSS situation.

2 DELIMITATION

In this paper, the engineering tools and software are refereed to those commonly used by engineers in manufacturing companies. In particular knowledge based tools are in focus. A distinction of typical information system tools and knowledge based systems is done in this study. Information systems are seen as used for monitoring, coordination and control, while knowledge systems (or tools) support the development team to take design decisions. Thereby, also knowledge and some of its dimensions have to be managed in this paper.

A presentation of the tools, for what purposes they are used and in what stages of early development they are used will be done. But, first, the method for gathering data for this study is shortly outlined. Second, a theoretical framework that includes different perspectives on the innovation concept is presented. The theoretical framework is based on the constraints of the research project, namely innovation, knowledge sharing and support for engineers. In this paper the theory serves as a point of view for the discussion.

3 METHOD FOR DATA GENERATION

The study builds on empirical data from a manufacturing company. The data has been generated by studying internal document, knowledge systems inclusive its use. Data has also been generated by applying a participative action research approach [10]. This means that the researchers have been part of the studied phenomena making reflections in practice, one as an industrial PhD student, thus having close access to the day-to-day work.

The empirical data set has been analysed in the light of a literature study on knowledge and innovation strategies.

4 THEORETICAL FRAMEWORK

The theoretical framework builds on three parts, namely some dimensions of knowledge, innovation and implications, knowledge based engineering.

4.1 Some dimensions of knowledge

Knowledge is archetypically defined as 'justified true belief'. This definition has been a subject of controversial discussions, but in recent time the emphasis is put on '*justified'* rather than '*true'*. This shift has inspired firms to consider a wider range of knowledge dimensions than mere facts. Nowadays, a firm's intellectual assets commonly are said to encompass dynamic and humanistic dimensions of knowledge as well. Usually, knowledge is divided into two main categories, namely tacit knowledge and explicit knowledge. Tacit knowledge is not easily expressed, it is highly inherent in the human's experiences and actions, while explicit knowledge can be articulated and (relatively) easily formalized. A difference between theoretical and practical knowledge is also related to these categories. That is, people can posses the theoretical view, but not be able to apply the knowledge practically, and vice versa. In this perspective, a human can convey knowledge by intellect and/or by skills. Also, a distinction between information and knowledge is done. Information can be separated from context and humans, while knowledge is context dependent and part of a human's mind and body [11]. Though, knowledge has no direct value for the company if it cannot be transformed into performance. Thus, knowledge is from this perspective described as actionable information [12].

A company's knowledge base can be described as facts, rules and procedures gathered and organised into schemas [12]. Yet, it is understood that a firm's knowledge base is built up of more that what is produced in activities [13]. For instance, what is interpreted by individuals, given a new context, anchored in the beliefs and commitments of individuals are also part of it [11].

Four categories of knowledge assets, i.e., resources that create value for a firm, are [11]:

- Experiential – tacit knowledge shared through common experiences, e.g., skills, know-how, emotions, conceptions. These are difficult for others to imitate.
- Conceptual – explicit knowledge articulated through images, symbols and language, e.g., product concepts, design. Manifested in products etc., thus easier to grasp, yet still difficult to come to terms with what is perceived.
- Routine – tacit knowledge embedded in actions and practices, e.g., culture, every day practice. These are reinforced and shared through certain patterns of thinking in everyday business.
- Systemic – systematized and package explicit knowledge, e.g., manuals, databases. Can relatively easily be transferred, also the main focus for contemporary knowledge management.

These assets are interrelated, dynamic and constantly evolving and cannot be seen as a snapshot of all assets.

4.2 Innovation

Innovation is often seen as a key for companies to be viable in a competitive business environment. There exists several definitions of innovation; there are at least 15 constructs on the term 'innovation' and at least 51 different variants that can be related to these [14]. This points out that the point of view play an important role. Yet, since long ago, the characteristics for defining the term innovation lean on the idea that it is something *new* that has reached *a market*. Commonly, the definitions also highlight that the innovation should lead to some changes in that market. For example, one definition of innovation is:

"Innovation consists of the generation of a new idea and its implementation into a new product, process or service, leading to the dynamic growth of the national economy and the increase of employment as well as to a creation of pure profit for the innovative business enterprise." [15].

In recent time, the emphasis is on added value for those who should benefit from the innovation, thereby the perspective of customers or users are usually highlighted [16]. For product innovations (in the literature, a product refers to both physical goods and services or a combination) the point of view commonly includes market *and* technology to asses the newness of the innovation [17], [14]. The company's knowledge about market and technology is challenged by innovations, i.e., an innovation either sustains or disrupts established knowledge [18].

Also, the types or categories of innovation differ. In general, there are similarities in the descriptions, tough the name differs. Two of categories of innovation are [17]:

- Architectural innovation: existing knowledge of market and technology becomes obsolete due to the innovation. This kind of innovation disrupts established know-how. It can be described as discontinuous since it does not emerge in an iterative state; rather it seems to come from nowhere. High risks are part of the strategy.
- Regular innovations: improves existing technology and market relationships. Here, the firm's aim is to enhance an existing product, e.g., making the production more cost efficient or extend the shares of a mainstream market. These innovations build on the firm's established knowledge base and do not make market or technology obsolete. This strategy assures low risks.

There are similarities with architectural innovation and the concept of disruptive innovation [20]. Disruptive innovation, as is also architectural, supersedes the established technology or existing product. From a product development perspective, companies often strive to go beyond the 'normal' customer's need and exceed the expectations on the product. Usually, the outcome of disruptive innovation performs worse than the established technology when introduced to the market. Companies that introduce a disruptive innovation can become a strong competitor on a market that has overlooked the innovation opportunity. In a best case, the innovation is addressing undiscovered customer needs [20], thereby the needs can be met by different solutions over time.

Also, there are similarities with regular innovations and the concept product innovations [17]. Since, both types aim to improve established markets and technologies, e.g., in terms of improving performance, lower costs, increase usability.

Different types of innovation can also be described on the basis of a market development life cycle [17]. In Figure 1, starting from the left, a new technology is introduced in the disruptive innovation phase. This technology is initially underperforming, but early adopters find it useful hence the technology has reached a niche market. Product innovation takes it into another level, i.e., the technology is being improved to perform better. As time unfolds, the technology reaches wider recognition and market, thereby insisting on process innovation to, e.g., make production processes cost efficient. At the “top of the hill” in Figure 1, experiential innovation is applied to, e.g., improve customers’ perception of the technology. The subsequent state is marketing innovation, where the interface to customers is improved. And, “downhill” at the right side in Figure 1, business model innovation, e.g., reframes the value proposition or the established roles in the value chain. Here, in this declining state, next generation technologies are spotted, though they do not yet affect the existing technology. Before the end, at right, a gap between what is sold and what the market now wants appears. Last, in Figure 1, Structural innovation describes the end of the life cycle, thus the beginning of a new cycle starting from disruptive innovation. This phase capitalizes on the disruption and creates new industry relationships in relation to the new technology, e.g., the opportunity to offer a broader variety of products and services [17].

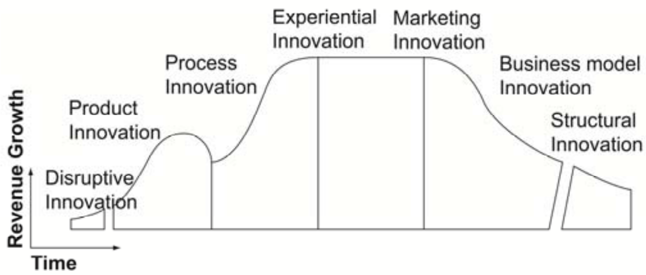

Figure 1: A market development life cycle, adapted from [17].

Companies tend to stay too long in the states for product innovation and process innovation, focusing on, e.g., minimizing cost and shorten lead times [19], [21]. The capabilities to continuously explore new technologies and new markets are vital for firms to be competitive, the same goes for the abilities to exploit the findings [21]. The explore and exploit capabilities relate to an innovation process. Such process is described as <u>*never*</u> being:

“…a one-time phenomenon, but a long and cumulative process of a great number of organizational decision-making processes, ranging from the phase of generation of a new idea to its implementation phase.” [15] (p. 3).

Further, new idea generation and exploration includes ambiguity and uncertainty about the future. Companies can take three strategic postures vis-à-vis uncertainty [8]. These postures should not be regarded as applied at all the company performances; rather they are part of a portfolio for strategic actions to be applied where they are best suited. First, the company can choose to “shape the future”, that is they can take a leadership in fundamentally change e.g., customer demands or how the industry operates. Second, the company can choose to “adapt to the future”, e.g., by recognizing opportunities in existing markets, respond quickly and be first. Adapters are typically relying on pricing and effective execution, rather than on product innovation [8]. Third, the company can choose “reserve the right to play”. The company makes investments that in the present put them into a privileged postion, e.g., by having superior customer – supplier relationships or possessing expertise. The company can then wait for the uncertainty to decrease and then design a strategy. This posture is a special kind of adapting and can only be used when the future is perceived to encompass at least a number of possible outcomes [8].

4.3 Innovation and knowledge creation

Within innovation processes, new knowledge is also created. A company’s capability to knowledge creation is a vital part of making use of the exploration phases where something previously “not known” is searched for. In this sence, both tacit and explicit knowledge have to be understood. Based on the knowledge creation activities socialization, externalization, combination and internalization derived from the SECI model [11], the explore and exploit apporach are used to map innovation concepts [18]. In Table 1, the left column, show that technological breakthrough and major product/service innovation relates to the tacit knowledge domain, and market breakthrough and regular innovation relates to the explicit knowledge domain. This indicates that the interaction between innovation and knowledge creation is depending on balancing tacit and explicit knowledge to turn capabilities into products and services that add value for the customers [18].

Tacit knowledge *Socialization and externalization (Exploration)*	***Explicit knowledge*** *Combination and internalization (Exploitation)*
▪ Arhitecural innovation ▪ Radical innovation ▪ Major product/service innovation	▪ Niche innovation ▪ Modular innovation ▪ Market breakthorough
▪ Revolutionary innov. ▪ Major process innov. ▪ Technological breakthrough	▪ Regular innovation ▪ Incremental innovation ▪ Incremental product, service, process innovation

Figure 2: Tacit and explicit knowledge in relation to innovation, modified from [18].

In the early 2000’s it was argued that the field of aeronautical engineering could find the opportunities for innovation in incremental technology and process innovation, due to the high expenditure nature of the products [22]. For example, by focusing on lowering cost in the manufacturing processes such innovation pays off. The innovation often comes from suppliers or emerging smaller firms, since they can allow the risk of innovating [22]. In the collaborative setting of aircraft engine industry, companies share risk and revenue among the partners [23]. Also, the knowledge creation for innovation is performed inbetween partners. This means that some parts of the processes are based on a virtual company structure, where other parts are not easily managed in the same virtual structure [23].

4.4 Knowledge based engineering

Knowledge based systems (KBS), Knowledge based engineering (KBE) and the combination Knowledge based engineering systems (KBES) are some of the terms that can be found within the literature.

KBS *“…refers to a special class of computer programs that purport to perform, or to assist humans in performing, specified intellectual tasks.”* [24] (p.11). Knowledge based system focus on specialized knowledge related to a specific task [24]. Such knowledge has to be attained from people having expertise in the targeted area and the knowledge has to be transformed into “if-then” rules [25], while the process of capturing knowledge resides outside a knowledge based system. Thereby, KBS opens up for the critique that these systems have to be maintained and upgraded ‘manually’ and constantly.

On the contrary, the capture and re-use of domain specific knowledge is part of KBE, making the systems more interactive. Knowledge based engineering is explained as: *“The use of advanced software techniques to capture and re-use product and process knowledge in an integrated way.”* [26] (p.11). KBE specifically focus to support the engineers' design assignment by making expert knowledge organisationally available. Thereby, KBE in some aspects also have the intention to nurture the user's learning.

While, the combination KBES *"…aims to capture product and process information in such a way as to allow businesses to model engineering design processes, and then use the model to automate all part or part of the process."* [25] (p. 905). Hence, KBES focus on efficient engineering, e.g., shortening lead times, rather than knowledge sharing and a learning process.

KBE is recommended to not be used when, for example, the design process is unclear, knowledge is not available and technology is constantly changing. Also, the company must have the will and the resources to introduce KBE [26].

KBS, KBE and KBES all have benefits and are seemingly intertwined in some aspects. A proposal to integrate the traditional KBE and similar knowledge rich strategies can be found in the concept of Knowledge Enabled Engineering (KEE) [27]. KEE adds an additional view of a simulation approach that allows standard solutions to be generated, evaluated and reported iteratively. In this way, the development team can elaborate on several design alternatives at a low cost [27]. This approach emphasize frontloading, i.e., to define product solutions and their combinations upfront and capture that knowledge into a computer application. A methodological challenge is to provide users with necessary control and not make the KEE a "black box" [27], since one objective with KEE is support a learning process. Thus, the rationale and the rules have to be understandable to the users if they should learn from using KEE, as opposed to applying a KBS for routine/non reflective tasks.

A key for the development of knowledge based tools is to identify, capture and formalize knowledge [26]. Tacit knowledge is recognised as problematic, though qualitative methods are recommended to at least capture some dimensions of it [26].

Examples of knowledge based tools that can be categorised into KEE is a flange wizard tool that support analysing design alternatives [28] and a rear turbine structure analysis tool that support optimisation of structural performance in relation to design alternatives [29]. These KEE tools are developed within research projects, improved and implemented in the studied company.

5 EMPIRICAL DATA

The manufacturing company in this study acts in a business-to-business context within the aerospace industry. They are a business partner in a globally extended enterprise, thus have to possess the ability to act independently and with partners in the development of products. This business-to-business setting makes the company operate both as a supplier and as a client.

The company acts on contract, i.e., the provision of a product is initiated by a directive. Also, meaning that the product is sold before it is developed. The development process is divided into two main types. The first type is called technology development, and includes the early phases where knowledge and concepts are built in parallel. The activities or projects here range from improving existing products to breakthrough innovations. The second type is the subsequent processes to implement the result from the technology phase into a production process. In the latter phases, no breakthrough innovation regarding the product is searched for, but here an innovation perspective might serve to make the production more effective. The empirical data in this study focus on the technology development, though to align with literature, we call these early phases "product development" and the project is called "product project".

Briefly, the product development processes embark from an internal order including a technical specification. In some cases, also the technologies, e.g., expertise, tools, know-how and methods, needs to be developed in relation to the product development. This is particularly true when the product project focuses to find new solutions. The development teams usually consist of a spectrum of disciplines, which disciplines to include depends on the type of the project. Typically, competences from manufacturing, design, quality and purchasing are needed in a product project. Also, resources from external sources are involved in product projects, for instance suppliers, subcontractors, consultants or other firms possessing additional competences. Further, the flux of team members is common in product projects. This flux, people going in and out of the project, depends on, for example in a best case, the progress in the project, where next level of expertise enters the project, or in a worst case a specific expertise is prioritized to other projects.

The company develops components for jet engines; this is a branch where security is of utmost concern. In turn, this makes it necessary to certify the technologies, the processes, the production and the use. Computer supported tools play a significant role in this context, since they inherently have the ability to enable people to store, retrieve and disseminate information. But, also they provide traceability of the performed activities.

The company has a long tradition in the aerospace industry, the roots goes back to 1930. Starting in the 1970's, the company has gone from providing engines only for military purposes to also encompass civilian engines. Hence, the experiences of aerospace industry have been established over the years, but also the company has been challenged by entering a new market. Moreover, in the business partnerships the company have initialized to incorporate a PSS business model based on extended business contracts. Still, the goods are not developed in respect of a PSS development process. The lack of computer support is recognised as contributing to that situation. Especially the ability to simulate business and product features simultaneously to make decisions in early development for how to offer the solution, i.e., as a product with supporting services or a life cycle commitment, seems important. A jet engine is of high total capital expenditure, it is expensive to develop, as well as buying. Typically, the life cycle for a jet engine is around 30-40 years. In order to reduce the descent in performance it is necessary to upgrade it over the life cycle, also the time loops for the periodic maintenance are highly related to its working environments and operating parameters. For instance, differences in the pilots' behaviours, as well as the conditions at different airstrips, have an effect on the jet engine's life cycle.

In recent time, the traditional development stands in front of a change of trends, where fuel economy and emissions are found challenging the innovation capabilities. As part of the aerospace industry, the company has agreed upon a strategic agenda, commonly referred to as ACARE [30]. In this agenda, the goals for CO_2 and NO_X emissions are deliberately set lower than rules and legislation demands, i.e., the goals are set to a reduction by 50 % CO_2 per passenger kilometre and a reduction of NO_X emissions by 80 %. Obviously, the ACARE agreement is challenging and to reach the environmental goals it is not doable to improve the concepts of existing jet engines. Instead, completely new concepts for a jet engine have to be designed.

5.1 The knowledge based tools at the company

Innovation includes risks and radical innovation is a high risk task. Knowledge based tools are use to decrease risk by planning, simulating and visualising potential solutions before creating physical prototypes. Also, the use of full scale physical prototypes can be minimized.

Commonly, engineers involved in product development have expertise in specific engineering domains. Broadly, the support systems can be categorized in a similar way, i.e., they fulfill different purposes in relation to expertise areas. For example, Computer Aided Design (CAD) is used for model based development. CAD is tightly coupled with Computer Aided Manufacturing (CAM) thereby allowing integrated generation of 3-D and 2-D product and process models, drawings and machine tool sequences controlled by Computer Numerical Controlled (CNC) machines. Numerical methods such as the Finite Element Method (FEM) and the Computational Fluid Dynamics (CFD) method are frequently used for analyzing the behavior of engine components. Support tools used at the company combine these characteristics to provide for dialogue and learning, thus can be categorized as KEE.

Overall, the knowledge based tools are used to support analysis of two modes, namely during production and in-use, i.e. in flight. These kinds of tools are often developed internally and are a combination of different tools. Engineers are able to use the tools for design space exploration and to validate and verify design solutions. Benefits are identified in terms of, for example, faster, more efficient and robust design iterations that releases engineering resources or the ability to transfer product and process information upfront in the development process.

The company have used knowledge based tools within a PSS business model for about three to four years, and the knowledge for how to use the tools to elaborate on design alternatives has increased. So, still the common engineering knowledge based tools are used, yet the parameters for evaluating the design solutions in a PSS context are different than before. For PSS, an upcoming work is to create the models that are needed to visualise these parameters in relation to others. Also, the visualisation is foresighted to include more ways than previously.

For the case of radical innovation caused by the strategic agenda that the company has agreed on, reoccurring analyses done on previous jet engine families probably will be needed also for the new products. As a whole the new jet engine might turn out to be a breakthrough product, but the development processes might not change radically. Thus, the company considers the degree of radical innovation for the internal processes. The challenging situation is thereby put in relation to how radical it will be to the company's contemporary approaches. Here, they have to judge how flexible the knowledge based tools need to be to adapt to the future. In this context, the knowledge based tools need to be improved to suit the new application area. Discussions of constraints and possibilities in relation to the knowledge based tools are inherent in organisational culture at the technology development department. The development of internally used knowledge based tools is part of the core competences at the company.

The company perceives that the ability to define and create knowledge based tools still relies on the availability of experts, so called Knowledge Engineers. A bottleneck for large scale implementation is the maturity of formal processes that the knowledge engineer can work with.

The knowledge based tools used at the company intends to assist engineers in design space exploration by capturing, formalizing and automating tedious processes within different engineering domains to a feasible extent. This allows for consequent optimization of products and processes and aims to relive engineers from mundane time consuming tasks, making them available for innovative studies not performed otherwise.

6 DISCUSSION

It can be argued that a successful product development process can be applied whatever the intended outcome. So, hypothetically, a development process can deal with innovation and does not need a specific process. Innovation processes are commonly described in innovation management literature as being an entity separated from product development. On one hand, the fact that radical innovation and incremental innovation leads to technology changes, indicates that an innovation process has to be intertwined into the product development processes. On the other hand, the fact that radical innovation is built upon a different knowledge base than incremental, the practice of an intertwined process becomes a challenge. Here, there are similarities with PSS development where products and services are based on distinct logics, yet they have to be integrated.

In a radical innovation approach the development team starts from a vague idea, or as is the case for the company in our study, they start from the insights that they have to do *something* completely different to reach the emission goals in the strategic agenda. So, we can argue that this is a really challenging case were they have to start from somewhere to make it. But, from where can the innovation process start? What are the competences needed? And, what can be carried over from earlier development cases? In the view of a market life cycle one can see that a different explore/exploit-focus is needed of the engineering team through each phase, but how does this model correspond to a company producing PSS solutions in a business-to-business market?

From literature, the arguments that companies tend to stay too long in incremental and process innovation phases [19][21], and that they should never regard innovation as a one-time phenomenon [15] are stressed. These are good advices, in particular for consumer goods. There are many examples of firms that have fallen into that trap, but when the product has a life cycle of 30-40 years this argument seems to be out of context. Also, an established incremental innovation approach can be a platform for a steeper learning curve, provided that the development team is supported to achieve that.

Learning from other disciplines is beneficial especially for PSS, though, as argued; the context for aerospace industry seems far away from the commonly business-to-consumer (b2c) perspective in literature. Typically, such a b2c perspective emphasizes *one* relationship, namely that one between the company and a potential consumer market. The business environment for aerospace industry is within a business-to-business setting (b2b), where several partners work jointly to develop the product. The company in this study contributes with components, but is a partner in the overall product development process for the jet engine. This has two implications. *First*, the business relationships seem more complex. For example, the relationships can be describes as working jointly with

- suppliers to develop the components
- collaborative partners - the jet engine developer and affiliated suppliers
- the customer - the airline company

to meet the flight staff and passengers needs of safety and robustness. Working in a b2b setting means that some degrees of insights into each others knowledge bases are necessary for knowledge creation. Also, in general, collaborative efforts are based on the recognition that the own firms' expertise is not enough and additional competences is needed. For PSS, it can be argued that the experiences of working in complex business relationship are an advantage, since collaboration is identified as a prerequisite to service provision. For the use of knowledge based tools, such tools have to be apt to communicate cross-company despite choice of application systems. Accordingly, it will not be viable to invest in expensive and extensive knowledge based tools for the collaborative efforts. Further, the transparency between the tools has to be balanced to transfer just enough knowledge for the operation, but not too much.

Second, being one partner in an extended enterprise, like the one described above, means that, e.g., processes, methods and tools have to be compatible. This is particularly true for jet engines, for example because development activities and maintenance have to be traceable through out its lifecycle. For PSS, this might serve as a valid point of departure, since understanding of the whole lifecycle, including use and recycling, is vital. Though, one challenge for the realization of PSS is to capture and transfer this kind of knowledge into the early development phases. For knowledge based tools the challenge is to transform tacit knowledge into explicit. Here, the knowledge sharing can be supported of a focus on assessments in lack of real facts and figures, and as a complement the reasoning behind the assessed measurements. Knowledge based tools can be used to visualize and to jointly elaborate on rough design ideas, maybe complemented with a brainstorming tool. Here, the use should support idea generation and dialogue, rather than validation. This stage of explorations might be crucial to apply knowledge based tools in PSS; where a core question is how to create a product model of a service or of "functions per unit". Here, we argue, that the constraints are more a matter of *what* to model than *how* to model. A first step towards making tacit knowledge to become explicit is through a socialization process [11], e.g., to jointly reflect and formulate questions.

The company's and the entire extended enterprises' innovation capabilities are put to the test by the strategic agenda for lowering emissions. It is recognized that the next jet engine family cannot be built on an incremental improvement approach of existing concepts. Here, understanding of which design concepts and features that can be transferred are a real challenge. For PSS this situation can prove to be vital, since the innovation opportunity opens up the possibilities to take in the PSS vision into the development from start. For knowledge based tools the radical innovation approach puts pressure on the formal applications and systems, in particular how to update, change and adapt the tools. Also, some of the formal knowledge based tools might become obsolete in the same vein that technology becomes outdated in disruptive/radical innovation situations.

To be able to use contemporary knowledge based tools the engineers need to have information about the product, e.g., geometrical and physical properties. From this the design activities can aim to improve the existing product from the perspectives of robustness and utility, i.e. in flight mode. For PSS, the support for, first, a general understanding is needed and, second, the knowledge based tools have to support a team to generate a decision base to act upon in view of that holistic level. A key for going into a PSS business contract seem to be the capability to assess the development process related to such a business model beforehand. For example, besides insight into cost, properties and behavior, the engineers have to have support for the choice of ecologically sustainable material. They have to have knowledge for how the material is extracted, processed and how to recycle it, also the environmental effects from both the extraction processes and the machining processes has to be known. Further, if used in a PSS solution they have to have upgrading and replacement of the material in mind, thus taking a continuous innovation perspective into account for the development of the physical goods.

Traditionally, knowledge based tools are used for incremental innovation. Commonly, validation and verification are emphasized, meaning that a product model or a prototype has to be the base. For a PSS business, the life cycle perspective has at least two levels. First, a perspective on the existing PSS solution, and, second a perspective on the whole PSS business including several alternative PSS solutions and their life cycles. At a certain point in the PSS business life cycle, several solutions can correspond to the customers' needs. Here, the development team has to explore which solution to go or not to go for. In such a situation, the traditional use of knowledge based tools for validation and verification delimit the exploration phases. The use of the tools has to open up the design space and create several alternatives in two dimensions, namely the business model (traditional, extended or PSS) and the product (stand alone, added services or PSS) to provide. To support an innovative PSS solution a change in the use and the integration of different knowledge based tools seems to be needed, rather than totally new tools as such.

PSS in itself can be regarded as a radical innovation affecting the whole business. Thus, the first movement in that direction can be taken as small steps, rather than one huge leap. The company presented in this study has chosen a small scale approach for developing and implementing knowledge based tools within the organization where modular and generative properties are some of the tools' characteristics. This aims to increase the level of adaptability of each tool when it is being faced with new sets of requirements. One ambition for the company is that the investment in developing and implementing the tool should give the engineer an advantage at the first time of its usage as compared to not having the tool at hand at all. It is important that engineers can call upon and use the tools with minimum effort at any point in time, without depending on access to a Knowledge Engineer. For PSS, and for the use of knowledge based tools to support innovation, lessons can be learned from this approach. First, systems used are put together based on flexibility and exchangeable applications. An object oriented bottom up approach combining standalone tools in an aggregated way also provide a platform for the development of a large scale system. Second, the approach to apply knowledge based tools is supported by a mindset of learning, reasoning and elaborating on alternatives.

7 CONCLUDING REMARK

This study embarked from the purpose to discuss the question how engineering knowledge based tools are apt to manage technological innovation aspects in a PSS situation. On the basis of the limited data we cannot draw conclusions; rather we, have by twisting and turning on the issue, elaborated on a wider picture of the challenges of knowledge based tools for PSS innovation in b2b situations to find a platform for further research. Though, to sum up the discussion we here present an implication for turning into PSS businesses.

The realization of PSS should address the need for "functions per unit" over a long term period; this has to be built on a thorough understanding of the customers' goals and intentions. This is an extension in focus from incremental innovation of the existing physical goods to a radical innovation approach to explore upcoming technological solutions. We have discussed the interaction between incremental and radical innovation which seems necessary to both improve the running solution and to keep new ones into the loop. Further, within the frame of PSS we have discussed knowledge based tools and found that in some senses the tools as such can delimit the engineers to spot radical innovation opportunities, provided that radical innovation mostly rely on tacit knowledge and that the engineer does not have the possibilities to reasoning about the ideas with colleagues. Tacit knowledge is, due to the difficulties to express it, not formalized into "if-then" rules. Thereby, knowledge based tools are built upon formalization of explicit knowledge into rules. Accordingly, merely working the tools is not enough for technical PSS development.

The company in this study have implemented small scale systems of knowledge based tools that draws on technology which is traditionally used within engineering tasks. They have added a design exploration approach that allows alternative solutions to be discussed. We find this promising, since it can be a relevant first step towards the realization of PSS development. PSS entails that the development team have to manage to constantly switch from a validation and verification mood (of running product) to an innovation exploration mood (of future solutions) and back again. From our study presented in this paper, we can see that the existing knowledge based tools can prove to be useful for technical PSS development and needed changes relate more to the engineering practice and use than the tools as such.

8 FUTURE RESEARCH INTERESTS

In general, our effort has not been to distinguish between knowledge based tools to categorize them into KBS, KBE or KEE. Yet, the discussion has indicated some differences in the interpretation of the distinct concepts. For example, KBE seem to be a commonly used term though it does not fit into the definitions found in literature. In literature, KBE is outlined to not have the objective to deal with exploration of innovation opportunities, rather the focus seem to be on dissemination of knowledge to ensure that the chosen product concept will fulfil the specifications. This finding can be useful to investigate to develop a terminology or typology for the knowledge based tools, though for our future studies we find it more interesting to focus on the engineering practise. In particular, the themes presented in this paper will guide our future efforts. Namely, (1) how engineers manage incremental and radical innovation on a day to day basis, (2) how engineers will deal with the "fuzzy" customer information within PSS development, and (3) how engineering processes and their subsequent methods and tools will be affected by a PSS business model. Framed by this, the empirical study presented here has resulted in ideas for further research. Three main guiding statements and questions have been formulated:

1. In general, manufacturing companies are firmly acquainted with incremental innovation, and literature highlights that companies tend to stay in that state too long. Thereby, radical innovation is not part of the existing product development approach. For a b2b setting and a long product life cycle it is not clear *how* to integrate the radical approach, or *where* to integrate it. *What is radical innovation in b2b, and how does it affect the collaboration specifically?*
2. A change in how customers express their needs of "functions per unit" is at the heart of PSS development, in turn insisting on a different strategy to collect customer information. As a consequence of a changed approach a wider palette of customer information will be the result. Within such an encompassing information base, there are innovation opportunities to seek and there are high risks to avoid. *How will this affect the engineering processes, tools and practice?*
3. The balancing between tacit knowledge and explicit knowledge has similarities to the radical and incremental innovation approaches needed for PSS development, as well as the intangibility of services and tangibility of products. A product model is a requirement to apply contemporary knowledge based tools in technical PSS development. A complete PSS model has to be viewed from more than the technical dimension. *How does such a PSS model look like?*

We have in the study presented here excluded service innovation, but the work of how to integrate service simulation into knowledge based tools is of interest. Also, we find our engineering perspective delimiting our efforts to in depth investigate the service aspects. We have two suggestions. First, a joint research effort from both a service and an engineering perspective would enhance the results. Second, an effort to investigate the concept of radical innovation and incremental innovation within such a joint research project would be of great interest.

9 ACKNOWLEDGMENTS

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10 REFERENCES

[1] Williams, A., 2007, Product Service Systems in the Automobile industry: contributing to system innovation? Journal of cleaner Production, vol. 15: 1093-1103.

[2] Mont, O., Dalhammar, C., Jacobsson, N., 2006, A new business model for baby prams based on leasing and product remanufacturing. Journal of Cleaner Production, 14: 1509-1518.

[3] Alonso-Rasgado, T., Thompson, G., Elfström, B-O., 2004. The design of a functional (total care) product. Journal of Engineering Design, 15 (6): 515-540.

[4] Carpenter, R., Henderson, A., 2008, Keep them flying - find your winning position in the MRO game. IBM Global Business Services, Aerospace and defence. http://www-935.ibm.com/services/us/gbs/bus/pdf/gbw03020-usen-00_keep_flying.pdf. Accessed 2009-10-20.

[5] Ericson, Å., 2007, A need-based approach to product development. Doctoral Thesis 2007:68. Luleå University of Technology, Department of Applied Physics and Mechanical Engineering, Division of Functional Product Development, Luleå, Sweden.

[6] Chesbrough, H., 2003, Open innovation: The new imperative for creating and profiting from technology, Harvard Business School Press.

[7] Parida, V., 2008, Challenges in Open Innovation Practices for Industries. Nordic Innovation Research – NIR 2008, nr 3. December 8-9, Oulu, Finland.

[8] Courtney, H., Kirkland, J., Viguerie, P., 1997, Strategy under uncertainty, Harvard Business Review, November-December: 67-79.

[9] Hara, T., Arai, T., Shimomura, Y., 2009, A Method to Analyse PSS from the Viewpoints of Function, Service, Activity & Product Behaviour. In proceedings of the 1st CIRP IPS2 Conference, Roy,

R. Shehab, E. 2009. Editors. Cranfield University Press, UK : 180-185.

[10] Stringer, E.T., 1999, Acton Research, 2nd ed. Thousands Oaks, Sage Publications Inc, CA.

[11] Nonaka, I., Toyama, R. and Konno, N., 2000, SECI, Ba and Leadership: a Unified Model of Dynamic Knowledge Creation. Long Range Planning, 33: 5-34.

[12] Turban, E., Aronson, J. E., 2001, Decision Support Systems and Intelligent Systems. New Jersey: Prentice-Hall, Inc.

[13] Brusoni, S., Prencipe, A., Pavitt, K., 2001, Knowledge Specialization, Organizational Coupling, and the Boundaries of the Firm: Why Do Firms Know More Than They Make? Administrative Science Quarterly, 46: 597-621.

[14] Garcia, R., Calantone, R., 2002, A Critical Look at Technological Innovation Typology and Innovativeness Terminology: a literature review. The Journal of Product Innovation Management, 19: 110-132.

[15] Urabe, K., 1988, In Popadiuk, S., Choo, C.W., 2006, Innovation and Knowledge Creation: How are these concepts related? International Journal of Information Management. 26:302-312.

[16] Regnell, B., Ritzén, S., 2008, Mätning av innovationsförmåga i team (In Swedish). In Olsson, A. (eds.), 2008, Innovationsförmåga: PIEp – product Innovation Engineering Program. Sweden: 78-105.

[17] Moore, G.A., 2004, Darwin and the Demon: Innovating Within Established Enterprises. Harvard Business Review, Top-Line Growth, July-August 2004: 86-92

[18] Popadiuk, S., Choo, C.W., 2006, Innovation and Knowledge Creation: How are these concepts related? International Journal of Information Management. 26:302-312.

[19] Abernathy, W.J., Clark, K.B., 1985, Innovation: Mapping the Winds of Creative Destruction. Research Policy, 14: 3-22.

[20] Christensen, C.M., 2000. The Innovator’s Dilemma. Harper Business Essentials, USA.

[21] Benner, M.J., Tushman, M.L., 2003, Exploitation, Exporation, and Process Management: The Productivity Dilemma Revisited. Academy of Management. 28 (2): 238-256.

[22] Murman, E.M., Walton, M., Rebentisch, E., 2000, Challenges in the Better, Faster, Cheaper Era of Aeronautical Design, Engineering and Manufacturing. The Lean Aerospace Initiative Report Series RP00-02.

[23] Prencipe, A., 2004, The changing boundaries of the firm: Empirical evidence from the aircraft industry. In The economics and management of technological diversification. In: Cantwell, J., Gambardella, A., Granstrand, O., The economics and management of technological diversification. New York, Routledge: 234-261.

[24] Dixon, J.R., 1995, Knowledge-Based Systems for Design. Special 50th Anniversary Design Issue, Transactions of the ASME, 117: 11-16.

[25] Chapman, C.B., Pinfold, M., 2001, The application of a knowledge based engineering approach to the rapid design and analysis of an automotive structures. Advances in Engineering Software, 32 (12): 903-912.

[26] Stokes, M., 2002, Managing Engineering Knowledge – MOKA: Methodology for knowledge Based Engineering, ASME Press.

[27] Bylund, N., Isaksson, O., Kalhori. V., Larsson, T., 2004, Enhanced engineering design practice using knowledge enabled engineering with simulation methods. In proceedings of Design 2004, 8th International Design Conference University of Zagreb.

[28] Boart, P., Nergård, H., Sandberg, M., Larsson, T., 2005, A multidisciplinary design tool with downstream processes embedded for conceptual design and evaluation. In proceedings of ICED 2005 International Conference on Engineering Design, August 15-18, 2005, Melbourne, Australia.

[29] Boart, P., Isaksson, O., 2006, Enabling variation of manufacturing process parameters in early stages of product development. In proceedings of IMECE2006, 2006 ASME International Mechanical Engineering Congress and Exposition.

[30] www.acare4europe.com., Accessed 2009-10-25

Development of an innovative IPS2 model

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Abstract

High-tech companies invest R&D efforts into pacing technologies. R&D projects enable companies to respond to critical drivers for innovation and to R&D needs in technology domains to develop new IPS2.

This paper presents the Sustainable-Knowledge (S-K) model for innovation management in companies. This model focuses a new relation among R&D activities and the strategic driver of change towards new IPS2. This relation adds value to the technology-driven objectives within company's strategic innovation perspective, following the ManuFuture approach to speed up IPS2 time-to-market.

An industry case in the space sector is reported for the critical driver "Safety and Security".

Keywords

Knowledge economy, Innovation management, Production paradigm, CBA, Product-service system, Commercial feasibility

1 INTRODUCTION

In high-tech sectors, such as the aerospace industry, big companies invest R&D efforts into pacing technologies at different stage of development. The project-intensive approach targets the launch of new IPS2 that respond to emerging strategic needs and grand challenges. R&D projects, therefore, enable companies to respond to critical drivers for innovation - such as Energy and waste, Safety and security, etc - and to R&D needs in specific domains with the mid-long term objective to develop new product and service systems [1].

In this context, a new approach is needed to frame and integrate different findings emerging from multiple projects to identify a wide set of improvements that meet market expectations and technology development requirements. Now industry R&D projects mainly refer to technology management and report about different level of maturity of technological advancements. At present, each project follows or goes in parallel one another, according to a linear development from *pacing* technologies to *key* technologies. The projects target both new sustainable IPS2 and innovation of existing products/services in today's markets.

This paper[3] focuses this technology transition towards sustainable IPS2 in response to specific industry drivers.

A new model – life-cycle oriented – for managing multiple R&D projects can support to frame and integrate the knowledge development into a R&D value chain.

R&D results will be related to expectations arising from the critical drivers for change and to market expected impact.

A unique framework for this purpose is not yet in use in companies, but it is becoming urgency for competition, efficiency, cost savings, time to market, R&D return of investments and in the future scenarios for the sustainability evaluation of new high added value products/services.

This paper presents the Sustainable-Knowledge (S-K) model that relates the strategic objectives and R&D operational activities. This model follows the ManuFuture approach with the scope to speed up IPS2 high value added development.

The S-K model provides an innovative framework for innovation management in companies. It frames multiple R&D projects, carried on at company level or in collaborative partnership, into an industrial products-service response to socio-economic drivers of change and barriers. This framework represents a new relation among R&D activities – made of multiple projects – adding value to the technology-driven objectives within company's strategic innovation perspective. For each single driver of change, this relation enables to develop a streamline of knowledge generation considering also the multilevel perspective (MLP) of innovation.

In this paper, an industry case is also reported. It refers to R&D projects targeting the industry driver for innovation "Safety and Security" carried on by an important Italian company that operates in the space sector.

2 STATE OF THE ART

In the literature, the management of the innovation process of companies represents an important research area in enterprise studies.

The importance of management innovation raised in 80's-90's. Ray Stata in "Organisational Learning – The key to management innovation" affirmed that in many USA companies the bottleneck of the progress was recognized in and related to the management of innovation and not primary in the product and process innovation [2]. The first country that builds its growth on management innovation was Japan. Western economies, such as USA, Germany and Great Britain, based their progress on technological innovation [3].

In the last decade, management of innovation received serious academic consideration. A lot of approaches, models and methodologies emerged for managing

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projects, such as the Critical Chain Project Management (CCPM) [4].

In the context of project-based industries, Keegan and Turner pointed out the importance to manage the innovation rather than a project, revealing that innovation is considered more a cost than a value [5].

As Utterback and W.J.Abernathy teach, management innovation alone is not enough to guarantee the success and the growth of companies or countries. It depends on the circumstances in a particular industry [6]. In particular, technology transition not only involves changes in technology, but also changes in user practices, regulation, industrial networks, culture [7]. The co-evolution of technology and society should be focused in the analysis of innovation [8].

Three types of change have been defined for MLP: reproduction (incremental change along existing trajectories), transformation (change in the direction of trajectories), transition (discontinuous shift to a new trajectory and system) [9]. The importance to focus the long-term dynamics on management of innovation has been affirmed in the context of MLP for technology transition. This concept is adopted and developed by Genus and Cole [10] who argued that MLP may be rethought, enhancing understanding of processes of innovation affecting the transformation of technology and society. New approaches are developing taking into account the multi-level perspective of innovation and the interaction between the different levels of general management [11, 12].

In the engineering fields, such as technology management for innovation, the reports and contributions of CIRP proceedings – the Society for production research – and of European Technology Platforms – particularly the ManuFuture ETP – have opened a new interesting area for investigation on new approaches to IPS2 and – in mid term – to the next generation of high value added products/services [13, 14, 15, 16]. The innovation management and the technology development processes have been seen as business processes (together with the product/service system development process) for the Integrated Technology and Product-System Lifecycle Management [17].

The complexity of products-services development requires a new approach to the design phase of such systems. As R. Roy argues *"The design of PSS is a complex problem, and must meet the challenges of the changing financial and resource models that align with PSS strategy"* [18].

New methods and tools to evaluate new IPS2 since the design phase are required to assess the different elements and factors (social, economical, environmental and technological) that are included into IPS2 [19].

Paci and Chiacchio pointed out the importance to carry on an early impact assessment of new IPS2 evaluating the technology of future IPS2 compared with performances currently available. Through a new methodology, S-CBA, the technology at pacing level is analysed to investigate its potential impacts in terms of competitiveness and sustainability aspects [20].

On this area of sustainability evaluation of High Added Value Products [21] – in the area of Energy driver for sustainability - provided LCA methods for evaluation with insights to specific solutions for new High Added Value Products. They showed that technology replacement is not by definition a win according to eco-sustainability requirements, and different evaluations should be played.

The investigation of a new commercial environment for competitive IPS2 – which is particularly relevant for companies – has been recently proposed by Roy and Cheruvu [22]. It considers drivers the complex commercial environment area and the sustainable customer value and integrates all these elements into an IPS2 framework for industrial competitiveness.

3 INDUSTRY TRANSITION MANAGEMENT

The model presented in this paper aims to support transition management and evaluate impact on innovation achieved by a set of company's projects in the area of technological innovation. High-tech companies are now involved in many projects to innovate their industrial products and services systems. These projects differ for many reasons: the R&D needs, the field level of application, the technologies on which the products and services are built, the addressed market, the time horizon of innovation development, human resources whit related competences and capabilities etc. Fund rising and partnership are defined taking into account the R&D programmes at national, regional and European level.

However, they share a common specific industry driver of change that companies tries to respond to with R&D investment.

Therefore, due to the complexity in the current innovation path, a company requires a new approach to R&D projects management.

The new approach focuses the coexistence of reproduction, transformation and transition types of change.

The research approach describes three important aspects for IPS2 development:

- to integrate the efforts in implementation through R&D projects; this aspect strengths the value of innovation for business.
- to provide a streamline of knowledge generation to meet the needs of specific socio-economic factors and barriers adding value to the technology-driven project approach; this aspect strengths the R&D outputs towards the company strategic innovation objectives.
- to manage with a trajectory multiple projects as "steps forward" towards new IPS2, monitoring the transition through early impact assessment of innovation development; this aspect strengths the time-to-market of innovation.

This approach supports high-tech companies to be leader by investing in R&D in mid term horizon for the development of new industrial product-service system and to play the role of "innovator" in the market.

Therefore, this approach to transition management considers the sense of urgency of innovation to speed up IPS2 development with value innovation.

3.1 The model

The model proposed in this paper, called Sustainable-Knowledge model (S-K model), frames the combination between strategic objectives and R&D projects management.

The proposed model is not yet in use within companies that traditionally carry on several R&D projects targeting distinct features of specific potential technologies.

Therefore, the model proposes a framework for sustainability that unifies technological innovation and complex industrial / innovation strategic perspectives meeting R&D needs in specific domains, innovation drivers and market's and company's expectations (Figure 1).

Socio-economic factors for innovation, featuring each specific industry driver, could be estimated to target the preferred new IPS2 with investigations of consumers', companies' and stakeholders' needs. The socio-economic factors analysis will contribute to define and enable the competitiveness and sustainability of projects' outcomes and potential commercial feasibility of new IPS2.

Inside the S-K model, the operational environment, through R&D projects for transition innovation towards IPS2, plays a fundamental role to respond to the critical driver of change selected by the company for market development. To this end, the dynamic overall evaluation and the life-cycle technologies assessment – maturation from pacing to key technologies – resulting from multiple R&D projects is needed.

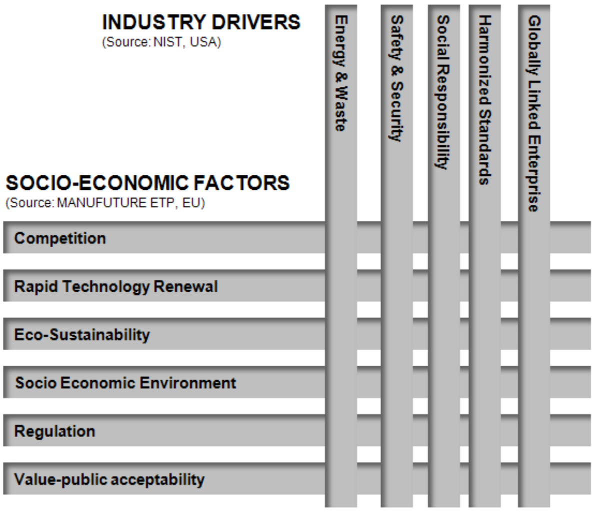

Figure 1: Sustainability framework for R&D projects for IPS2.

This maturation process is reported in a vertical representation to support the management and monitoring of R&D projects with related technological advancements. The figure below outlines the trajectory needed to achieve the company's preferred new IPS2 (Figure 2).

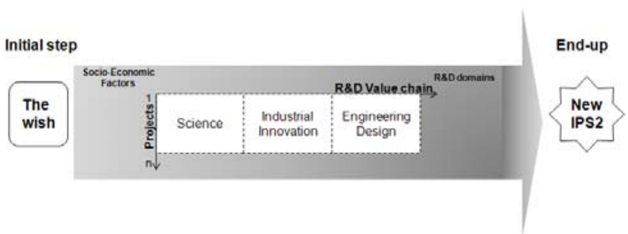

Figure 2: The R&D trajectory for new IPS2.

The base of the arrow represents the initial step and marks the company "main wish". This wish contains – in addition to market success – other values, such as improving the company image, a value expectation from society, citizens and environment.

The shaft of the arrow reports the distribution of R&D projects along the R&D value chain. The phases of the R&D value chain for new IPS2 are the following:

- Science phase refers to generic and applied technology research. The related projects, in general carried on with research institutes or universities, focus the potential of the technology in generic areas of services (mid-long time horizon).
- Industrial innovation phase refers to projects that focus on key technologies with a demonstration approach. These projects target new needs in specific area of services to get competitive advantages (short-mid time horizon).
- Engineering design phase refers to projects dedicated to the integration of key technologies in IPS2 (short time horizon).

In the shaft are also reported the socio-economic factors (for competitiveness and sustainability), interdependences and different R&D domains of R&D projects. In particular, the socio-economic factors play the role of constant at project and R&D value chain level.

At the arrowhead, the end up represents the market development of particular new preferred IPS system.

This environment (deeper represented in Figure 3) enables to manage efficiency in the R&D value chain and to relate all these achievements to the selected driver of change for time to market reduction. The interdependencies among R&D projects assume the role of indicator of efficiency in knowledge development.

Through this view it is possible:

- to assess the knowledge intensity in strong or weak areas of the R&D value chain that maybe influenced by socio-economic factors;
- to identify gaps in the innovation strategy of companies.

In fact, this environment supports high-tech companies to bond science and market, avoiding the following scenarios:

- many projects in the science phase and few projects in the engineering design phase: the risk is to loose today's markets;
- many projects in the engineering phase and few project in the science phase: the risk is to loose the leading position as "market innovator".

The S-K model proposed in this paper supports:

- flexibility due to evidence based technology;
- modularity to look at the broad spectrum of market and organizational issues;
- time to market of innovation;
- sustainability of new IPS2.

For these features, the Sustainable Cost Benefits Analysis (S-CBA) – presented in the last CIRP IPS2 Conference 2009 by the authors – contributes to this model. It allows the early impact assessment evaluating the short and mid term expectations of relevant stakeholders. The results of the S-CBA estimate the value of the R&D projects and, therefore, support the industry decision-makers for new IPS2 development responding to the main company's wish since the design phase of the IPS2 life cycle.

4 EXPERIENCES

The industry case reported in this paper refers to the activities carried on by the Technological Innovation team of Telespazio S.p.A., a Finmeccanica / Thales Company (www.telespazio.it).

This Italian company, leveraging on technological competences, facilities, participation in the main European Programmes (COSMO-SkyMed, Galileo and GMES) and on the "Space Alliance", is a world-wide player in:

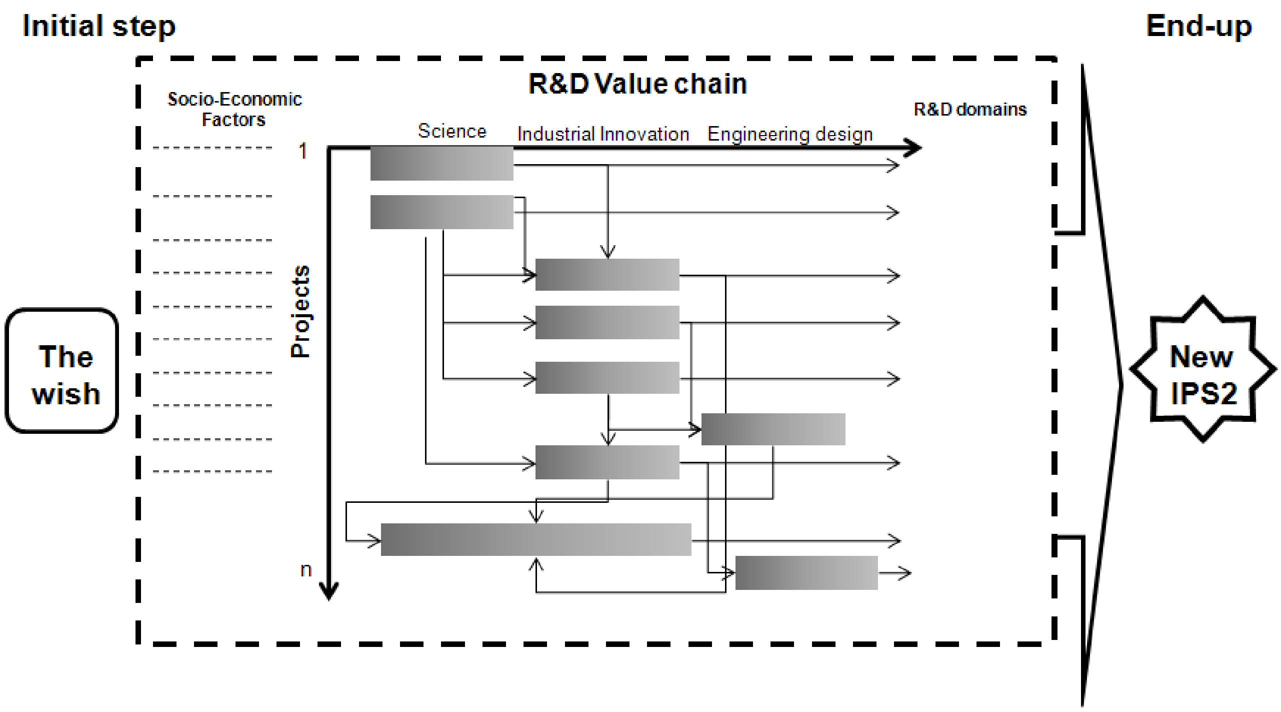

Figure 3: Operational environment for IPS2 within R&D value chain.

- Satellite Operations;
- Services for Earth Observation;
- Navigation and Infomobility;
- Integrated and Value Added Connectivity.

Company's mission is "*from space to services*" to provide Value Added Service & applications (VAS) design targeting business and institutional market segments. In particular among VAS Telespazio S.p.A. offers:

- Networks & Applications for Civil Defence;
- Solution & Services for Internet & TV on high speed Trains;
- Telemedicine;
- e-Learning.

The R&D needs of the company refer to the following domains of technological development which represent the core content in R&D projects: Navigation, ICT, Earth observation.

Recently, a big part of this core content has been focused towards the critical industry driver "Safety and Security" to provide technological solutions for new services targeting security and safety issues of operators, infrastructures, means, vehicles, etc.

The S-K model proposed in this paper is now in use in the company Technological Innovation team to manage technological innovation for dual use to respond to competition and sustainability needs.

The "Safety and Security" constitutes the selected driver of change of this company for industrial innovation becoming the objective of multiple R&D projects in the reported experience that constitute a unique big project.

This big project is the environment where multiple R&D projects concur with their interdependencies to provide answers that make feasible the design and development of new IPS2.

With reference to the company's technological plan, the big project contains several R&D projects, clustered in two main headings: Safety and Urban security clusters. Security cluster is articulated in five projects:

- Secure Space (2S) (EU) – Analysis of satellite technologies in overall economy structure and in emergency operations for different scenarios (Start December 2007 – End March 2010).
- SIT-MEW (EU) – Integrated System of Broadband telecommunications for the territory and emergency management in case of natural disasters comprehensive of early warning (Start 2008 – End 2011).
- GINS (ESA) – Study of the feasibility for a Global Integrated Network for Security (dual use for civil and military defence) (Start November 2007 – End July 2008).
- EDRS (ESA) - Study for the Definition of an Enhanced Data Relay Satellite (EDRS) (Start November 2007 – End September 2008).
- Small GEO (ESA) - To define telecommunication (TLC) missions based on small geostationary (GEO) satellites as part of a European secure TLC network (Start November 2007 – End October 2008).

Urban security cluster is articulated in four projects:

- 2SI (EU) – Earth Observation for crime prevention (Start December 20 07 – End January 2010).
- IMSK (EU) – Urban Security in case of big events (Sport's events, political summit or musical events) (Start 2009 – End 2012).
- CADMO (IT) – Daily urban security in the public transport framework (autobus) (Start April 2008 – End 2010).
- SAFER (EU) – Daily urban and extra-urban security in the railway public transport (train) (Start 2007 – End 2010).

All these projects respond to specific objectives related to the "Safety and Security" driver that consider different socio-economic factors. The technological solutions, carried out within these projects, play a great aid to solve security and safety problems.

At operational level these projects cover different phases of R&D value chain and have interdependencies that represent achievements in horizontal knowledge development.

The team needed a model and an operational environment to manage and evaluate the potential impact at short, mid and long term in order to prepare the ground for new IPS2. This supports the in-house assessment - based on the company's Technological Plan – of R&D advancements in order to enhance the efficiency of the company's R&D efforts.

The application of S-K model and its operational environment is reported in the Figure 4 that combines the critical driver of "Safety and Security" with the value chain phases of R&D projects and related socio-economic drivers and R&D domains. The R&D projects are listed according to their start date.

For the industrial innovation, the S-K model supports:

- Comprehensive view of single R&D project's positioning that forms the company's R&D value chain (in the centre of the figure).
- In-house assessment of each R&D project within the R&D value chain, establishing interdependencies for the knowledge advancements (in the centre of the figure).
- Needs-driven relation between R&D value chain and company's strategy focusing "Safety and Security" as the main industry driver for innovation (in the outer part of the figure's left side).
- Early market data capture according to the socio-economic factors, where the issues for sustainability complement the competition (in the left side of the figure).
- Leadership in the technological selected domains (in the right side of the figure).
- Next generation of IPS2 for new needs responding to socio-economic factors within "Safety and Security" driver (in the outer part of the figure's right side).

This operational environment becomes a dynamic tool to focus, through the interdependencies, the knowledge development for value creation. Interdependencies are shown among GINS, EDRS and Small Geo projects that refer all to the study and development of a Global Integrated Network for Security (dual use for civil and military defence) with the relevant satellites.

This knowledge creation concerns either the technology life cycle advancements or barriers and opportunities related to the socio-economic factors that are very relevant for IPS2 market feasibility.

For example, considering CADMO and SAFER projects, the in-house assessment shows that:

- These projects are positioned in the Engineering Design phase that means that efforts are dedicated to the integration of key technologies (intelligent sensors) for the design of new services and products for the transport market (road and rail). This positioning marks a milestone within the R&D value chain relevant for the in-house assessment.
- These projects are interlinked and have interdependencies with past and on-going projects that have dedicated many efforts on the development of strategic enabling technologies within different R&D domains.
- These projects provide deep understanding of the potential market, providing information on socio-economic factors including the competition.

This experience is on going with hopefully further results.

5 CONCLUSION

In the knowledge economy, the endless transition from science to market is exploited through R&D projects.

Companies are now project-intensive and are in turbulent markets.

The proposed S-K model supports companies to frame single R&D project into an overall view of R&D value chain from science to engineering design trajectory.

R&D projects enable companies to respond to critical drivers for innovation - such as Energy and waste, Safety and security, etc - and to R&D needs in specific domains with the mid-long term objective to develop new IPS2.

The experience reported shows how to speed up IPS2 with high added value development in real company setting. This model enables to manage the follow-on with reflections on the results back on the provided case study.

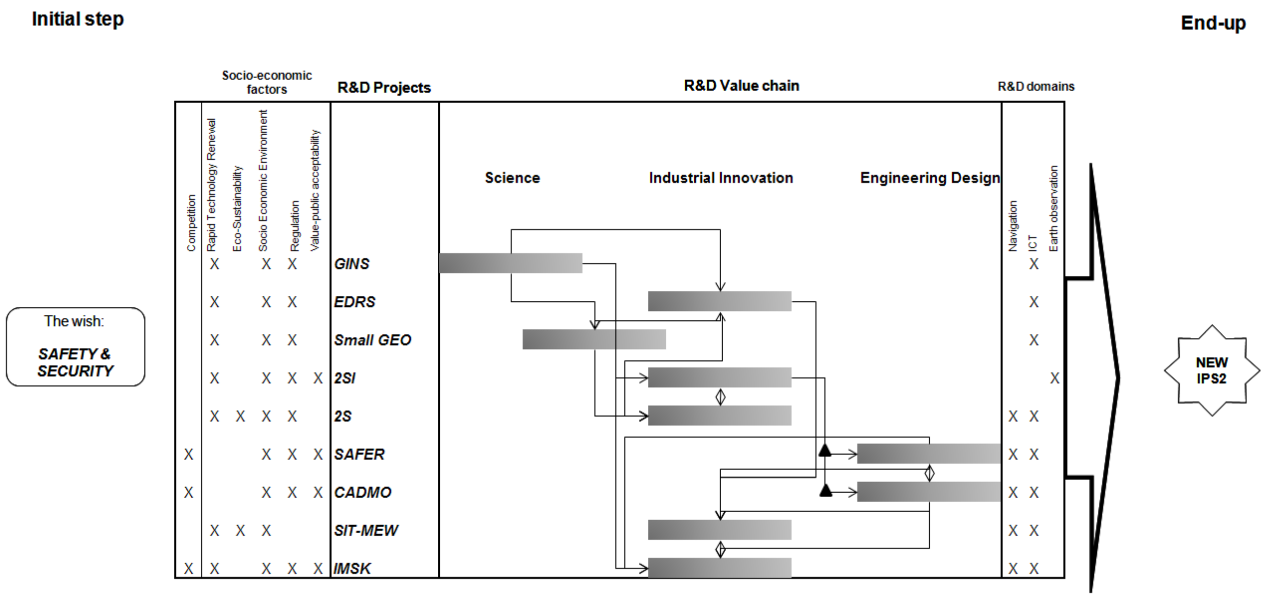

Figure 4: Operational environment for IPS2 within Telespazio S.p.A. R&D value chain.

6 REFERENCES

[1] Discenzo, F.M., Pai, R., Carnahan, D., 2009, Distributed Power-aware Machinery as a Foundation for Next Generation, National workshop on Challenges to Innovation in Advanced Manufacturing: Industry Drivers and R&D Needs, Gaithersburg, Maryland, USA, 3-4 November: 1-2.

[2] Stata, R., 1994, Organisational Learning – The key to management innovation, The training and development sourcebook, second edition, Editor Schneier, C.E., Russel, C.J., Beatty, R.W, Baird, L.S., HRD press, ISBN 0-87425-247-4: 31-42.

[3] Drucker, P.F., 1988, Management and the world's work, Harvard Business Review, Volume: 66, Issue: 5: 65 – 76, ISSN: 0017-8012.

[4] Raz, T., Barnes, R., Dvir, D., 2003, A Critical Look at Critical Chain Project Management, Project Management Journal, Volume 34, Number 4: 24-32.

[5] Keegan, A., Turner, J.R., 2002, The Management of Innovation in Project-Based Firms, Long Range Planning, Volume 35, Issue 4: 367-388.

[6] Utterback, J.M., Abernathy, W.J, 1975, A dynamic model of process and product innovation, Omega, Volume 3, Issue 6: 639-656.

[7] Geels, F.W., 2002, Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study, Volume 31, Issues 8-9: 1257-1274.

[8] Geels, F.W., 2004, From sectoral systems of innovation to socio-technical systems: Insights about dynamics and change from sociology and institutional theory, Research Policy, Volume 33, Issues 6-7: 897-920

[9] Geels, F.W., Kemp, R., 2007, Dynamics in socio-technical systems: Typology of change processes and contrasting case studies, Technology in Society, Volume 29, Issue 4: 441-455.

[10] Genus, A., Cole, A.M., 2008, Rethinking the multi-level perspective of technological transitions, Research Policy, Volume 37, Issue 9: 1436-1445.

[11] Burgelman, R.A., Christensen, C.M., Wheelwright, S.C, 2008, Strategic Management of Technology and Innovation, 5 edition, McGraw-Hill/Irwin, Pages: 1088, ISBN:0073381543.

[12] Markard,J., Stadelmann, M., Truffer, B., 2009, Prospective analysis of technological innovation systems: Identifying technological and organizational development options for biogas in Switzerland, Research Policy, Volume 38, Issue 4: 655-667.

[13] ManuFuture High Level Group, 2004, ManuFuture: a Vision for 2020. Assuring the future of manufacturing in Europe, Report of the High Level Group, EU DG Industrial research. ISBN 92-894-8322-9.

[14] Manufuture HLG, 2006, Manufuture High Level Group and Support Group, Manufuture Platform, Strategic Research Agenda, assuring the future of manufacturing in Europe, European Commission.

[15] Jovane, F., Westkamper, E., William, D., 2009, The Manufuture Road: Towards Competitive and Sustainable high-adding-value Manufacturing, Springer-Verlag Berlin.

[16] Roy, R., Shehab, E., 2009, CIRP Industrial Product-Service Systems (IPS2), Proceedings of the 1st CIRP IPS2 Conference: 341.

[17] Guelere Filho, A., Pigosso, D.C.A, Ometto, A.R., Rozenfeld, H., 2009, Remanufacturing on a Framework for Integrated technology and Product-System Lifecycle Managemente (ITPSLM), CIRP Industrial Product-Service Systems (IPS2), Proceedings of the 1st CIRP IPS2 Conference, Cranfield, UK, 1-2 April: 273-279.

[18] Roy, R., 2009, Foreword, CIRP Industrial Product-Service Systems (IPS2), Proceedings of the 1st CIRP IPS2 Conference, Cranfield, UK, 1-2 April.

[19] Maussang, N., Zwolinski, P., Brissaud, D.,2008, Evaluation of Product-Service Systems During Early Design Phase, Manufacturing Systems and Technologies for the New Frontier, Publisher Springer London, ISBN 978-1-84800-266-1 (Print) 978-1-84800-267-8 (Online): 547-552.

[20] Paci, A.M., Chiacchio, M.S., 2009, Sensitivity Cost-Benefit Analysis to Support Knowledge Capture of Industrial Interests, Proceedings of the 1st CIRP IPS2 Conference, Cranfield, UK, 1-2 April: 261-267.

[21] Bos, H., Meesters, K., 2008, Sustainability evaluation of high value-added products, ISBN 978-90-8585-346-6.

[22] Roy, R., Cheruvu, K.S., 2009, A competitive framework for industrial product-service systems, International Journal of Internet Manufacturing and Services, Issue: volume 2, Number 1: 4 – 29.

Business Model innovation paths and success in the machine tool industry

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Abstract

Service-oriented business models are regarded as one of the main competitive priority for European machine builders willing to keep their global leadership, menaced by the growth of Asiatic competitors and by the financial crisis. Despite the efforts of the research community and of industrial companies in the direction of servitization, there is empirical evidence that only few companies successfully innovated their business model. In this paper, the results of an European case study research are reported, aimed at the understanding of business model innovation mechanisms and success in the machine tool sector. Companies resulted distributed in different clusters, each of them characterized by different business model innovation levels, strategic consciousness and achieved performance. The clusters suggest the existence of three alternative paths of business model innovation, which are described in the paper, showing specific innovation mechanisms that can be followed.

Keywords

Business model, machine tools, services, service strategy

1 INTRODUCTION

Advanced service business models are an innovative concept in the European machine tool industry, which represents the 44% of the worldwide value of machine tools' production and counts 155,000 employees [1]. In this sector, equipment suppliers are traditionally oriented to the offering of production systems with a limited number of additional product related services (e.g. installation, training, etc.). The relationship between customers and suppliers are mainly limited to the sales operative phase (transaction based relationship) and machine tool builder core competencies are related to the engineering and production of machines [2]. In the past, such an approach allowed European machine tool companies to get and preserve a strong position in their sectors [3]. In recent years, the European industry competitiveness has been strained by the increased turbulence of the business arena, determined by new aggressive competitors from emerging Countries [4].

To cope with this situation, companies should innovate their business models establishing more collaborative long-term relationships with their customers and offering value added services beyond the traditional technical ones [5]. In fact, the technological innovation does not represent anymore a sustainable differentiating strength point which companies can base their offer on. Instead, the integration of value added services with the physical products (i.e. production systems) could guarantee a stable source of revenues, an increasing market demand and a not easily imitable competitive weapon [6]. Furthermore, service offerings incentive the creation of sustainable long-term relationships with customers [7].

Despite the unanimous agreement on the described innovation need, European machine tool companies are still far from reaching this goal [4] [8]. The main reasons have been identified in the lack of specific managerial culture and of operative tools supporting this complex change, which requires market, organizational, financial, and supply chain innovation [2, 9].

Few empirical studies are available on the real diffusion of service oriented business models in the machine tool sector and the innovation mechanisms are not clear [10].

To contribute to the in-depth understanding of the different business model innovation mechanisms that machine tool companies follow to implement advanced service strategies, a case study research was conducted at European level and presented in this paper.

In paragraph 2 available literature is presented and its limits outlined. In paragraph 3 the case study research is explained in terms of methodology and results. Finally, paragraph 4 summarizes the conclusions of the paper and suggests directions for future investigations.

2 STATE OF THE ART

2.1 Literature analysis

Before the new century, the literature related to the industrial equipments industry was traditionally dedicated to the technological innovation needed to cope with the changes of the business context and the relevant manufacturing paradigms. To evolve from the mass production to the mass customization, up to the agile production paradigms, the theories and technologies of dedicated production systems, flexible production systems and reconfigurable production systems have been developed and widely discussed [11-16].

The evolution of the market on one side and the maturity of the sector on the other, made clear in the end of the nineties that technological innovation was not enough to guarantee the competitiveness of leading equipment producers, and that new strategies characterised by advanced cooperation models between customers and suppliers had to be investigated and implemented [15, 17, 18].

This concept was strengthened by the servitization trend of the mature industry sectors with slow market growth, where the potential of technological innovation had been already exploited. Authors started to see unanimously services as the differentiating key competitive asset for industrial manufacturing companies. Suddenly, taxonomies for industrial services started to be proposed, derived from previous marketing research [19-24]. Concerning industrial services, two broad categories of services have been distinguished: maintenance and repair services on the one hand, and business advisory services on the other [21]. In the field of product related services, one type of classification is based on whether the service is offered before, during, or after the sale [25-29].

Another type of services classification considers them in relation to the product which is contextually offered and to their scope [30]. The distinction is between a service which supports the supplier's product (a typical illustration of such a service is an after-sale service), and a service which supports the client's action in relation to the supplier's product (for example a training service) or in relation to competitor's product. Concerning supplier's goals, the service might facilitate products sales, contribute to supplier's turnover by considering sold products as a vehicle to offer services, or contribute to turnover by leveraging on the customer process, independently from the use of supplier's or competitor's products. This type of classification was adopted by several authors, which refined it and added further elements describing the type of business cooperation between customers and suppliers [31-34]. They distinguish between:

- product oriented services, which add value to products previously sold by a technological upgrade or the increase of its value over time through the provision of maintenance or additional guarantees;
- use-oriented services, when the product is owned by the supplier, who sells functions instead of products by means of modified distribution and payment methods, such as sharing, pooling or leasing;
- result-oriented services, when supplier's revenues are linked to the effective output and performance he provides through the services. Thus, the customer does not pay for the product or the functionality of the product, but for the result of using the product (for example, for machined parts).

By extending the sphere of operation of service providers, other authors distinguish between products focused services, service focused activities and value chain focused activities, affirming that the future trend will consist in the shift form the first to the latter type [35].

In order to give relief to a category of high value added services whose implementation necessitates of deeper cultural and organizational changes in companies, authors proposed other classifications implying a wider business dimension. Mathieu [30] proposes a classification based on two axis: one is the service specificity, which classifies services based on their scopes (customer services, product services, services as a product). The other is organizational intensity, meaning with this the organizational level at which each type of service should be managed (tactical, strategic and cultural). For example, services as a product require a cultural change in manufacturing organizations and can not be considered tactically.

Oliva and Kallenberg [8] classify services along two dimensions: the nature of services (transactional and relationship based) and their orientation (product and customer's process orientation). They argue that in order to advance in service strategies, suppliers have to evolve in order to be able to offer relationship based and customer's process oriented services. Windahl et al. [5] name this type of advanced services "integrated solutions" and describe them as enablers of situations where "customers use the outcome without owning, maintaining or even operating the equipment". They argue that providing integrated solutions means keeping a close continuous relationship with customers, where the provider becomes part of the customer's on-going operations. Davies [36] refers to these services as "operational services".

In the frame of the above mentioned services taxonomies, the "Product Service System" (PSS) stream took a specific place. Baines et al. [9] argue that the concept of a Product Service System is a special case of servitization. A PSS can be thought of as a market proposition that extends the traditional functionality of a product by incorporating additional services. Here the emphasis is on the sale of use rather than the sale of product. The customer pays for using an asset, rather than its purchase, and so benefits from a restructuring of the risks, responsibilities, and costs traditionally associated with ownership". A differentiating aspect from other service literature is that the concept of a Product Service Systems often embraces the dimension of environmental sustainability.

Besides taxonomies, the emphasis on literature has been on the benefits that service strategies can bring to manufacturing companies. Authors agree with the classification of benefits offered by services along three dimensions: financial, marketing and strategic [4, 8, 30].

From the financial point of view, services offer substantial potential revenue (due to the wide installed base of machines and industrial products) and higher profit margins. Furthermore, services are a more stable source of revenue compared to products, since they can sustain companies turnover in negative economic cycles, when manufacturing customers do not have financial possibilities to invest in machinery. Marketing opportunities consist in one hand in the fact that services allow suppliers to maintain closer relationship with customers over time and put in the privilege condition of identifying and fulfilling changing needs; on the other, they constitute an useful channel supporting the sales of products. Thus, services are a way to increase customer loyalty and brand image [37]. Finally, strategic arguments consist in the acquisition of a sustainable competitive advantage due to the difficulty of imitation, since they are intangible, labour and knowledge dependent [38]. From a strategic point of view, especially in mature markets, services offer a new opportunity to undertake a differentiation strategy, once products do not allow it anymore [37]. Lay and Erceg [39] empirically verified that, compared to other strategic options such as innovation and product technology, service strategies allow product manufacturers to earn the highest potential margins. The enthusiasm around services lead to the famous statement : "The service market is bigger than we ever dreamt" [40].

Despite the growing attention of industrial services of the last years, authors claim that the services strategies are far from having reached their maturity. In one hand, the transformation process is slow, especially for the offering of the most advanced type of services. Mathieu [41] claims that, if product oriented services are spread and quite common, customer services are still very rare. Windahl et al. [5] believe that, in order to offer integrated solutions, companies have to undergo a deep cultural and change management process. Oliva and Kallenberg [8] argue that, due to the challenges that advanced services present to equipment suppliers and the current cultural situation of companies operating in traditional technological industries, advanced service strategies will not appear soon in industrial practice.

On the other hand, companies struggle to take out of services the promised benefits. While from a theoretical point of view the benefits of service strategies should be proportional to the intensity and specificity of the service manoeuvre [30], Gebauer et al. [4] define the “service paradox”: returns from services are clearly not aligned with the expectations and with the investments companies are doing to develop service strategies. A German-Swiss survey reported that only one third of manufacturing companies earn more than 20 percent of their revenues from service sales [4]. Roughly another third of manufacturers receive between 10 and 20 percent of their revenues from service sales, whilst the rest of the manufacturers generate service sales below 10 percent. Another quantitative study analysed the content of more than 10,000 firm descriptions in the OSIRIS database and concludes that only 30 percent of manufacturers had servitized [42].

Literature proposes a series of explanations to motivate the difficulties of companies in the implementation of service strategies. The most cited are reported below:

- culture: traditional technological and manufacturing culture is in contrast with the needs of services, which require a higher knowledge and relationship orientation [4, 8, 30]. Authors argue that a paradigm shift is necessary, to evolve from the goods-dominant-logic to the service-dominant-logic [43];
- strategy: companies often lack of strategic commitment in the implementation of advanced service strategies. Case study research verified that success in services is always linked to a deliberate decision followed by the definition of a clear strategy to reach service goals [37];
- organization: due to their specificities, services need dedicated departments in companies, where the new service culture can be cultivated, the service business processes can be activated and the service employees concentrated. Furthermore, in order to solve the “service quality erosion” problem, by which the quality of provided services is mined by the limited time of service employees (4), services need the infusion of new multidisciplinary labour force in companies [5, 30];
- marketing management: service strategies and service process development should move from customers needs and should involve customers since the early phase of definition, thus establishing relationship marketing practices [4]. Authors claim that manufacturing companies do marketing and sales of services as they do marketing and sales of products [7, 10]. New methods are needed to understand customers’ service needs, to design new services, to segment and properly target the market for services [5]. Researchers outline also that the problem involves the credibility and brand image of service suppliers, which are not often able to establish a communication suitable for services;
- networking and supply chain: the complexity, multidisciplinary nature and variety of services makes it impossible to supply them through integrated supply chain [5, 8]. Advanced servitizers are called to play a new role of network system integrators and new specific competences are needed for that [36];
- capacity to measure costs, benefits and to manage risks: companies are generally not aware of the costs of services [37]. Furthermore, they tend to underestimate the needed investments and to overestimate the returns [44]. Also specific metrics are missing for advanced service management [45];
- customers: they might be not committed in the process of value co-creation with suppliers [7], neither enthusiastic about ownerless consumption [9]. Nevertheless, some authors argue that customers are often the initiators of service strategies because they ask suppliers to offer new services they were not proposing [4, 8, 36, 41];
- products: it might happen that product technology is not able to support the efficient supply of services, because it does not guarantee stable performances or it does not provide on line status information during utilization [7]. Some authors claim that in order to deliver the best possible solution, an integrated solutions provider could hence be expected to build both on customer relationship and advanced technology [5];
- social system: cultural and cognitive proximity are important aspects determining the success of service strategies [41]. It has been noted for example that Product Service Systems, which started to diffuse in north Europe last decade, have been more readily accepted in the communal societies of Scandinavia, the Netherlands and Switzerland [9]. All economic and social actors should be resource integrators for service creation, thus the concept of value-in-use is potentially extended to a more descriptive ‘‘value-in- context’’ [46]. Summarizing, it can be argued that manufacturers operating in a region where the demand for their products-services is strong and where customers’ culture is ready to accept new service offering have an advantage in respect to competitors [7].

After having outlined the barriers limiting the diffusion of advanced service, literature is prescriptive in the indication of what companies should do to overcome them, such as create separate business divisions, adopt a marketing approach, define a deliberate strategy, use networked supply chains, invest in human resources and new competences, etc. [4].

Some attention has been dedicated also to the type of innovation process of companies. The most accredited theory is the incremental one. Oliva and Kallenberg [8] observe that the transition form products to services companies proceeds gradually following always similar phases in which suppliers add services to their offerings, consolidate skills and experiences and adjust the organizational structure to properly manage services operations. Similarly, other authors [36] [47], [48] and [37] describe incremental multi-step transformations. On the other hand, some researchers contradicts the incremental theory by affirming that advanced service strategies need radical innovation to create new structures suitable to services in traditional companies [5, 7].

2.2 Limits of current literature and research questions

Current literature is fragmented and mainly prescriptive, in the sense that general suggestions are addressed to companies independently from their characteristics and the innovation process phase they are running. Few quantitative analysis are available [4, 42] and, apart rare exceptions [49], no distinction between service innovators strategies and innovation paths are available. Researchers claim that service oriented business model innovation mechanisms have not been studied in-depth until now [10]. Furthermore, literature was focused on traditional product related services and neglected the most advance type of business model innovation, the one implying the offer of operational services in which machine suppliers co-participate actively to customers’ business, having thus a crucial role in customers’ performances increase [5, 36]. Example of advanced service oriented business models in the machine tool sectors are the offer of total cost of ownership or availability guarantee contracts, of short term full service renting, of lean machines with pre-fixed reconfigurable options, etc. [50].

In order to contribute to research progress in this field, the present paper aimed to answer to the following research questions:

- What is the current situation about advanced service business model innovation in Europe?
- What are the observable innovation paths companies are following?
- What are the advantages that innovators experience from advanced service strategies?

3 CASE STUDY RESEARCH

3.1 Methodology

The sample of interviewed companies was composed with the intent of involving organizations that have the adequate characteristics to understand business model innovation practices, according to the relevant variables outlined in previous literature. In particular, companies have been selected considering:

- size in terms of employees and turnover;
- location;
- type of offered machines in terms of technology, complexity and customization;
- adoption of innovative or traditional business models.

Previous researches failed to involve significant examples of business model innovators, due to their limited number and to the difficulty to identify them [8]. In order to overcome this problem and to involve in the study representative organizations, companies have been identified using the network of experts created in an European Research project in the machine tool sector ("Next - Next Generation Production Systems" FP6 EU Project) and requiring the support of Cecimo, the European Association of the Machine Tool Industries. This privileged bridge between research and machine tool industry was a significant added value for the research. The final sample consisted in the companies reported in Table 1.

Case studies have been elaborated combining multiple sources: face to face interviews, phone interviews, public financial information and reports, products catalogues, fairs information (EMO 2007 – Hannover, EMO 2009 – Milano) and the observation of products and processes where it was possible. Face to face interviews have been conducted with marketing/commercial managers and the entrepreneurs, depending on the dimension of companies. In some cases, also the research and development manager has been interviewed, together with the service business unit responsible. Besides the formal position occupied in the organization, the interviewees were the persons aware of the strategy and business model of their company and were participating to its definition.

Interviews were semi-standardized and had an average duration of one hour each. The interviewer was supported by a questionnaire with predetermined questions, which has not been shown to the interviewees and which guaranteed to discuss all the relevant aspects. The questionnaire has been preliminary tested with research specialists and industrialists of the network of experts above mentioned. To be able to get additional spontaneous information, interviewees were also free to discuss any other important topic in relation to the argument, as well as their personal positions. In some cases, interviewees were re-contacted by phone after the face to face interview in order to clarify some aspects or provide some more details. When the interviewees agreed, interviews were recorder and transcribed for elaboration.

3.2 Results

The analysis of case studies outlined two important dimensions along which companies can be clustered:

- the innovation level of the business models they currently adopt. It depends on three factors: the innovation level of offered services, as classified in previous literature [8, 36, 41]; the adoption of innovative revenue models linked to services offerings [51]; the adaptation of the supply chain to the offer of advanced services through a wide recourse to networking partnerships [36];
- the strategic commitment of the companies towards the implementation of advanced service business models. It is expressed through the awareness of advanced service strategies options, a deliberate and convinced statement about the service strategy to implement and the top management commitment to its realization, promoting cultural change at all company levels.

Based on these dimensions, companies were grouped as follows (Figure 1):

- **Traditional product companies:** companies adopting a traditional business model with a strict technological focus and a conservative culture. They are often not aware of new service business models options and they do not consider them a potential source of competitive advantage. Some of them have

Company	Machines	Country	Size
A	High precision grinding and milling machines	England	Medium
B	Manual and CNC lathes	England	Large
C	High precision sawing, turning and grinding machines	Spain	Medium
D	Electroerosion machines	Spain	Medium
E	Flexible manufacturing systems	Finland	Medium
F	Machines controls and drives	Germany	Large
G	Machining centres	Germany	Large
H	Machining centres and robots	Italy	Large
I	Flexible machining centres	Italy	Medium
J	High speed milling centres	Italy	Medium
K	Slitting lines, roll feeders, levelling machines	Italy	Small
L	Bending and cutting machines	Italy	Small
M	Band saw and custting machines	Italy	Small
N	Drawing presses and lines	Italy	Small

Table 1 – Case study companies

experienced unsuccessful attempts of service offerings after customers' request. New service business models are seen as a different business which is out of their mission, quite far from the design and production of machines on which their competencies are traditionally focused. These companies are mainly small-medium sized, but also a big company belongs to this cluster.

- **Strategically prepared companies:** companies still adopting a traditional product model where machines are directly sold to customers and a small range of technical services are offered, but that show a clear advanced service strategic intent to be realized in the future, derived from a proactive way to cope with market changes and the economic crisis. They are aware of the potential value that innovative business models can bring to their customers and they have a positive attitude towards new kinds of doing business in order to continue improving competitiveness. They have autonomously identified possible solutions to be implemented, have started to deeply study their customers to understand how to create value for them and to design the organizational changes needed to make advanced service models real. In some cases, they recognize they are not able to proceed in the implementation of advanced service strategies with the current endowment of competences and resources. These companies have a medium-large size.
- **Passive innovators:** companies adopting service strategies of intermediate innovation level, pushed by customers having high contractual power. By managing these types of new offerings, their strategic awareness is intermediate, since they are in a certain sense forced to develop a service culture to provide the required services. In parallel to these services experiences, that are often seen as a necessary evil to get orders by big customers, companies continue to compete on a traditional basis. Among them, the ones that are satisfied by the new service contracts start to consider the service business as a potential stable source of revenues and foresee to actively promote it in the future. On the contrary, companies that are unsatisfied of the service experience, declare they will not go on in that direction anymore after the end of open contracts. Passive innovators do not show satisfying performances under the financial point of view: their goal is to close positively the service contracts, but without introducing changes to company organization and supply chain. These companies are medium-big sized.
- **Proactive innovators:** companies strategically committed towards advanced service strategies that are in fact using them as the main pillar for competing in the market. They have a strong market orientation that pushed them to find proactively new ways of bringing value to customers. Business model innovation has been faced as soon as market changes were perceived and the need to differentiate themselves from competitors emerged. A strong commitment of the top management is typically present and it guides the entire company to think strategically, acting as a sponsor in fighting organizational resistance to changes. Technology is not considered the unique part of the offer but rather the enabling factor for service strategies, as proved by the evidence that these companies own a solid technical background. These companies, which are medium and big sized, report very satisfying performances about service offerings, both on the financial and marketing point of view.

The illustrated clusters of business model innovators suggest that three different paths governing this innovation phenomenon can be identified:

1. The first path is the one through which traditional product companies become proactive advanced innovators after a preliminary phase allowing to achieve a high strategic commitment through a cultural evolution and through the acquisition of the needed methodological competences and resources. Thus, the transformation from products to services is radical in the value proposition change, since companies shift from a traditional product catalogue to a very innovative services offering, but it is put in place after a cultural and methodological maturation time which prepares the company to successfully face the challenge of advanced services.
2. The second innovation path leads traditional product companies to become proactive service innovators passing through and intermediate step of "passive innovation", which is triggered by binding requests of customers having high contractual power. This innovation path is incremental in the sense that traditional companies are forced to enter a service scenario which usually does not consist in a very innovative one. Through this experience, machine builders acquire strategic consciousness and knowledge about service innovation. If this experience is positive, they start promoting actively the service business and they grow in culture and resources until they become advanced proactive innovators. This innovation path has not been fully observed in case studies, since companies passing from passive to proactive innovators have not been found. Nevertheless, the intentions of passive innovators to go towards this direction have been clearly registered.
3. The third innovation path is in fact a non-innovation route, since it represents the failure of service oriented innovation attempts. Similarly to the previous description, machine tool companies are first forced to a passive innovation, but their experience is negative or not enthusiastic. This is due to financial losses with service contracts or to unsatisfying relationships with customers asking for them. As a consequence, companies decide to stop service offerings after the end of their experience of passive innovators, returning thus to their traditional product oriented business model.

Results show that service oriented business model innovation can not be considered as an unique innovation path for all companies. Different ways to innovation are possible, determined mainly from company culture and market orientation, that allows or does not allow organizations to imagine proactively such a transition, and by the external requests of customers, that call suppliers in the arena of services without being prepared.

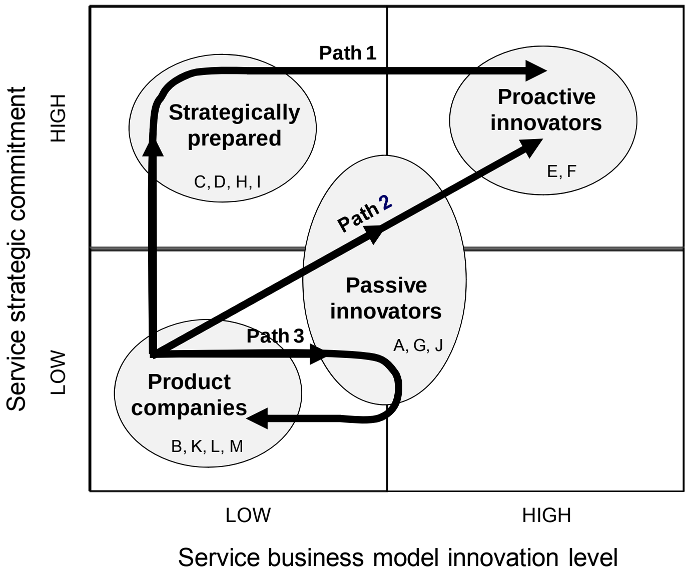

Figure 1: Companies clustering.

The performance of service innovators seem to depend on the innovation path: the service paradox [4] has in fact been observed for passive innovators and it was not for proactive innovators. Many other literature findings about service strategy enablers were confirmed in this case study research. Company culture and market orientation, proactive strategic commitment toward services, networked supply chain and the advance forecast of costs, revenues and risks. In particular, proactive innovators follow all the normative prescription of literature.

Moreover, it has been found that small and medium enterprises are out of the game of service innovation: no small and medium companies could be classified as proactive or a passive innovator. It can be argued that small companies have usually a lower market culture and a more difficult access to all type of resources (financial and human) that are needed to imagine, design and implement proactively the service business model innovation. The lack of small companies in the passive innovators segment can be interpreted on the other hand with the hypothesis that, being big customers aware of the difficulties and challenges that the supply of services imply, they select big suppliers since they imagine they can better sustain such difficulties. The evidence that business model innovators are mainly medium and big companies is worrying, being the majority of European companies small and medium enterprises.

Finally, the proposed clustering and the multiple innovation paths permit to clarify some contradiction in past literature about the incremental or radical nature of the transition form products to services [5, 7, 8, 36, 37, 47, 48]. It can be affirmed that the two type of process can be found in reality. Proactive innovators, in fact, can become radical innovators because they have the opportunity to design the innovation in advance, to develop the right culture and to acquire the needed resources. Passive innovators, on the other hand, are called to supply some intermediate services, which makes them incremental innovators in case they decide to progress in service strategy (path 2 of innovation).

4 CONCLUSIONS AND FUTURE RESEARCH

The results of a case study research in the machine tool sector presented in this paper outline that machinery suppliers are in the middle of the transition from product companies to advanced service companies. Few of them are already advanced servitizers, offering operational services to their customers on a stable basis and successfully. Other companies show the adoption of intermediate advanced service strategies not for a deliberate decision, but because they are pushed by big customers having a high contractual power. These companies do not generally experience positive performances, since they were not willing to undertake this innovation. The remaining part of companies is still adopting traditional product strategies but, among them, some are strategically thinking the transition from products to services and is currently acquiring the necessary knowledge and competences to start the process.

Based on this situation, three possible innovation paths have been identified: in the first one, companies promote a cultural change, achieve the needed resources and implement a radical innovation to their offering oriented to advanced services. In the second one, companies proceed incrementally pushed by customers, by increasing their capacity to manage service offerings while living service business in real industrial contracts. In the third one, companies renounce to proceed in service business model innovation after having had negative experiences in some attempts triggered by customers.

Literature prescription for service business success have been confirmed, as proactive innovators showed to follow them. The reasons of passive innovators for not following such suggestions, leading to the “service paradox”, have been clarified. This allowed a better in-depth understanding of innovation mechanisms.

It has been found that the transformation process can follow both an incremental and radical approach, depending on the innovation paths companies follow. This contributed to harmonize the previous literature results and to motivate existing contradictions.

Finally, it has been understood that only big companies have the potential to activate the first and the second innovation path, leading to successful service oriented business model innovation. This confirms that the potential benefits of advanced services are not within reach of small and medium enterprises yet.

Under the light of these conclusions, the following research directions can be drawn. First, the innovation theories presented in this paper should be generalized and refined through quantitative research. Second, the early innovation triggers and mechanisms determining the different innovation paths should be understood in-depth through additional qualitative research. Third, methods, instruments and other actions should be identified to involve the small and medium enterprises in these innovation paths, being them the centrepiece of European economy. Finally, the current body of knowledge about enablers of advanced service business model innovation should be referred to the different innovation paths companies may follow, in order to provide more efficacy suggestions in all innovation stages and situations.

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] www.cecimo.eu

[2] Copani, G., Molinari Tosatti, L., Lay, G., Schroeter, M., Bueno, 2007, New Business Models diffusion and trends in European machine tool industry, Proceedings 40th CIRP International Manufacturing Systems Seminar, Liverpool 2007.

[3] Mathe, H. and Portioli Straudacher, A., 2004, Innovative service that reinvent manufacturing, Proceedings of the IMS International Forum, Vol. 1, Cernobbio, Italy, pp. 162-70.

[4] Gebauer, H., Fleisch, E. and Friedli, T., 2005, Overcoming the service paradox in manufacturing companies, European Management Journal, Vol. 23, pp. 14-26.

[5] Windahl, C., Andersson, P., Berggren, C., Nehler, C., 2004, Manufacturing firms and integrated solutions: characteristics and implications, European Journal of innovation management, Vol. 7, pp. 218-228.

[6] Cohen, M. A. and Whang, S., 1997, Competing in Product and Service: A Product Life-Cycle Model, Management Science, Vol. 43, pp. 535-545.

[7] Brax, S., 2005, A manufacturer becoming service provider – challenges and a paradox, Managing Service Quality, Vol. 5, pp. 142-155.

[8] Oliva, R. and Kallenberg, R., 2003,Managing the transition from products to services, International Journal of Service Industry Management, Vol. 14, pp. 160-72.

[9] Baines, T. S., Lightfoot, H. W., Benedettini, O., Kay, J. M., 2009, The servitization of manufacturing: A review of literature and reflection on future challenges, Journal of Manufacturing Technology Management, Vol. 20, pp. 547-567.

[10] Jacob, F. and Ulaga, W., 2007, The transition from product to service in business markets: an agenda for academic inquiry, Industrial Marketing Management, Vol. 37, pp. 247–253.

[11] Pine, J. B., 1993, Mass Customization: The New Frontier in Business Competition, Boston, Harvard Business School Press.

[12] Anderson, D. M., 1997, Agile Product Development for Mass Customization: How to Develop and Deliver Products for Mass Customization, Niche Markets, JIT, Build to Order and Flexible Manufacturing, Irwin Professional Pub..

[13] Bolden, R., Waterson, P., Warr, P., Clegg, C., Wall, T.A, 1997, New Taxonomy of Modern Manufacturing Practices, International Journal of Operations & Production Management, Vol. 17, pp. 1112-1130.

[14] Dugay, C. R., Landry, S. and Pasin, F., 1997, From Mass Production to Flexible/Agile Production, International Journal of Operations & Production Management, Vol. 17, pp. 1183-1195.

[15] Koren, Y., Heisel, U., Jovane, F., Moriwaki, T., Protshow, G., Ulsoy, G., Van Brussel, H., 1999, Reconfigurable Manufacturing Systems, Annals of the CIRP. Vol. 48/2.

[16] Son, S. Y., Olsen, T. L. and Yip-Hoi, D., 2000, Economic benefits of Reconfigurable Manufacturing Systems, Proceedings of the 2000 Japan USA Flexible Automation Conference Michigan, Ann Arbor.

[17] Molinari Tosatti, L., Pierpaoli, F., Urbani, A., Jovane, F., 2002, New frontiers for manufacturing in Mass Customization, Proceedings of the 35th CIRP-International Seminar on Manufacturing Systems Seoul, Korea.

[18] Urbani, A. and Pasek, Z., 2002, Description and analysis of a possible supply chain evolution based on a service pattern, Proceedings of the 5th International Conference on Managing Innovations in Manufacturing (MIM), Milwaukee, Wisconsin, USA.

[19] Hill, T., 1977, On goods and services, Review of Income and Wealth, Vol. 23, pp. 315-38.

[20] Judd, R. C., 1964, A case for redefining services, Journal of Marketing, Vol. 28, pp. 59-65.

[21] Kotler, P., 1994, Marketing Management: Analysis, Planning, Implementation and Control, Englewood Cliffs, NJ, Pentice-Hall.

[22] Levelock, C. H., 1983, Classifying services to gain strategic marketing insights, Journal of Marketing, Vol. 47, pp. 9-20.

[23] Rathmell, J., 1974, Marketing in the Service Sector, Cambridge, MA, Winthrop Publishing.

[24] Shostack, G. L., 1977, Breaking free from product marketing. Journal of Marketing, Vol. 41, pp. 73-80.

[25] Lalonde, B. and Zinszer, P. H., 1976, Customer Service: Meanings and Measurement. Chicago, IL, National Council of Physical Distribution Management.

[26] Frambach, R. T., Wels-Lips, I. and Guendlach, A., 1997, Proactive product service strategies: an application in the European health market, Industrial Marketing Management, Vol. 26, pp. 341-352.

[27] Samli, A. C., Jacobs, L. W. and Willis, J., 1992, What pre-sale and post-sale services do you need to be competitive?, Industrial Marketing Management, Vol. 21, pp. 33-41.

[28] Homburg, C. and Garbe, B., 1999, Towards an improved understanding of industrial services: quality dimensions and their impact on buyer-seller relationships, Journal of Business-to-Business Marketing, Vol. 6, pp. 39-71.

[29] Johansson, P. and Olhager, J., 2006, Linking product–process matrices for manufacturing and industrial service operations, Int. J. Production Economics , Vol. 104, pp. 615–624.

[30] Mathieu, V., 2001, Service strategies within the manufacturing sector: benefits, costs and partnership, International Journal of service industry management, Vol. 12, pp. 451-475.

[31] Azarenko, A., Roy, R., Shehab, E., Tiwari, A., 2009, Technical product-service-systems: some implications for the machine tool industry, Journal of Manufacturing Technology Management, Vol. 20, pp. 700-722.

[32] Cook, M. B., Bhamra, T. A. and Lemon, M., 2006, The transfer and application of product service systems: from academia to UK manufacturing firms, Journal of cleaner production, Vol. 14, pp. 1455-1465.

[33] Tukker, A., 2004, Eight types of product-service systems: eight ways to sustainability?, Business Strategy and the Environment, Vol. 13, pp. 246-260.

[34] Morey, E., 2003, Product service systems: exploring the potential for economic and environmental efficiency, www.colorado.edu/Economics/morey/4535 /students/pachecod_project-ed.pdf.

[35] Lewis, M., Portioli Staudacher, A. and Slack, N., 2004, Beyond products and services: opportunities and threats in servitization, Proceedings of the IMS International Forum, Cernobbio, Italy, Vol. 1, pp. 162-170.

[36] Davies, A., 2003, Are firms moving downstream into high value services?, Ed. Joe Tidd and Frank M. Hull, Imperial College Press.

[37] Malleret, V., 2006, Value Creation through Service Offers, European Management Journal, Vol. 24, pp. 106-116.

[38] Anderson, J. and Narus, J., 1995, Capturing the value of supplementary services, Harward Business Review, Vol. 73, pp. 85-93.

[39] Lay, G. and Erceg, J., 2002, Produktbegleitende Dienstleistungen: Konzepte und Beispiele Erfolgreicher Strategieentwicklung. Berlin : Springer-Verlag.

[40] Slater, R. 1999, Jack Welch and the GE Way, New York, NY, McGraw-Hill.

[41] Mathieu, V., 2001, Product Services: from a Service Supporting the Product to a Service Supporting the Client, Journal of Business & Industrial Marketing, Vol. 16, pp. 39-58.

[42] Neely, A., 2007, The Servitization of Manufacturing: an Analysis of global Trends, 14th European Operations Management Association (EUROMA) Conference, Ankara, Turkey.

[43] Vargo, S., Maglio, P. and Akaka, M., 2008, On value and value co-creation: A service systems and service logic perspective, European Management Journal , Vol. 26, pp. 145– 152.

[44] Gebauer, H., Krempl, R. and Fleisch, E., 2008, Exploring the Effect of Cognitive Biases on Customer Support Services, Creativity and Innovation Management, Vol. 17.

[45] Cavalieri, S., Gaiardelli, P. and Ierace, S., 2007, Aligning strategic profiles with operational metrics in after-sales service, International Journal of Productivity and Performance Management, Vol. 56, pp. 436-455.

[46] Vargo, S., Lusch, R., Akaka, F., He, Y, 2008, The service-dominant logic of marketing: A review and assessment, Review of Marketing Research, p. In press.

[47] Gebauer, H., Beckenbauer, B. and Fleisch, E., 2004. How to innovate customer support services in manufacturing firms?, Service Excellence in Management: Interdisciplinary Contributions, Proceedings of the QUIS 9 Conference, Karlstad, pp. 397-406.

[48] Hildenbrand, K., Fleisch, K. and Beckenbauer, B., 2004, New business models for manufacturing companies in B2B markets, Service Excellence in Management: Interdisciplinary Contributions, Proceedings of the QUIS 9 Conference, pp. 407-416.

[49] Gebauer, H., 2008, Identifying service strategies in product manufacturing companies by exploring environment–strategy configurations, Industrial Marketing Management, Vol. 37, pp. 278-291.

[50] Biege, S., Copani, G., Lay, G., Marvulli, S., Schroeter, M., 2009, Innovative service-based business concepts for the machine tool building industry, CIRP IPS2 Conference 2009 Proceedings Cranfield University, UK.

[51] Copani, G., Molinari Tosatti, L., Groothedde, R., Palethorpe, D., 2007, New Financial Approaches for the Economic Sustainability in Manufacturing Industry, 14th CIRP Conference on Life Cycle Engineering Proceedings, Tokyo, Japan.

Value Adding Services in Packaging – A Value for all Supply Chain Actors?

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Abstract

Consumer packaging has become increasingly important as a value adding product service system, since packages shape the consumer's experience of product use as well as accelerating and affecting the first purchase decision. Recent research in food packaging has resulted in technological innovations that provide information on the real shelf life and expiration of food products as a service to users. These product-service innovations present an added value to consumers and also a clear benefit from a sustainability perspective, but are they beneficial for all actors of the supply chain?

This paper presents a study with the purpose to elaborate the value different actors' experience from the added service of one technical food packaging innovation. The paper starts by explaining the technological innovation and its potential service addition. The business opportunity of this integrated product service system is then elaborated, with a special focus on the service needs from the different supply chain actors.

Keywords

Packaging innovation, value adding service, product-package-service system, supply chain actor, consumer value

1 INTRODUCTION

Customer orientation and value added products and services are acknowledged by most organizations and regarded as prerequisites for successful business. The value added is perceived by the consumer when experiencing the fulfilment of a desired need in the use and purchase of such a product-service system. Product-service systems can be defined as made up by combined service units and physical objects. It can be regarded as innovations that focus on the value of utility of the combined product and service, rather than focusing on the value of selling the physical product [1]. The product-service view then links to the strategic direction the providing organisation takes in relation to their customers.

A product-service system that has become increasingly important as value adding is consumer packaging, since packages shape the user's experience of product use as well as accelerating and affecting the first purchase decision. Löfgren et al. [2] point out the importance of a package to add value to the consumer in the first moment of truth, i.e. in the purchasing situation, and in the second moment of truth, i.e. in the usage of the product at the point of consumption and recycling. With this value adding perspective, there is strategic evidence that viewing packaging as a central value carrier and as a product service system, from the perspective of the users, will benefit producers [3].

From a company perspective, food packaging can be regarded as such a strategic product service system since it adds value to consumers both in the first and the second moments of truth. In the food industry, the package is the interface between the product and the consumer and adds values in terms of information, usability, marketing, functionality and recyclability, among others. With the role of food packaging as a value adding element and interface to the product, the package also has a function of adding values to other actors of the food supply chain. Such values could be information, handleability, stackability, etc., in the different parts of the chain.

One example of value added services is related to food consumers' quest for assurances that the food they buy and eat is safe, i.e. being able to trust the food companies along the supply chain [4]. The trend among consumers for fresh products has resulted in chilled food, particularly prepared chilled food, now competing more and more with their frozen counterparts. These new trends and lifestyles place strict requirements on new food products for a safe and quality controlled distribution. In order to highlight safety and quality, temperature control is an important issue in chilled food distribution [5]. Good temperature control from production to retail sales is the basis for maintaining quality and safety in chilled foods. The issue in distribution of temperature sensitive food is to store, handle and transport products at a minimal charge by keeping as much as possible of the original quality and shelf life [6]. In order to succeed in this, all activities have to take place under temperature-controlled forms, referred to as "the chill chain". Being the interface between the product and the consumer, the package relates to both marketing and logistics, while at the same time serving the functions of protecting and preserving the product in for example the chill chain [7].

Some value adding service functions of food packaging systems for securing food quality, especially for the chilled food category, have lately been introduced as concepts. These concepts are derived from recent research in food packaging. The research has come up with technological innovations that provide information on the real shelf life and expiration dates of food products as a service to consumers and other supply chain actors. But is the value delivered to all actors of the supply chain and how is this added value perceived?

The purpose of this paper is to present a study that elaborates the value different actors experience from the added service, in a product-service system based on a technical food packaging innovation for securing food quality throughout a food chill chain. The paper starts by elaborating on theory on food packaging, supply chain, service value, and food quality aspects. Thereafter the technological innovation and their potential service additions are explained. The business opportunities of this integrated product service system are then elaborated, with a focus on the service needs from the different supply chain actors.

2 PACKAGING; A PRODUCT- SERVICE SYSTEM

In the user perspective, food products and its' packaging are perceived as integrated systems, throughout the life-cycle from production, consumption to recycling [3]. The system view of consumer products and its packaging is highly relevant, since the package is the bridge between products and the supply chain environment. Even though the product and the package usually are regarded as artefacts, these integrated product package systems provide value to the users during the entire life-cycle. The product and its' package can therefore be regarded as a product-service system. Product- service systems are defined as the combined service units and physical objects, and are innovations that focus on the value of utility of the combined product and service [1]. A service-centred view is according to Vargo and Lusch [8] inherently customer oriented and results in service provisions, rather than in economic exchange, as with traditional sales of product artefacts. In a product service system the service is embodied in the utility of artefacts, and the service is dependent on the artefact to enable the service delivery [9].

From a value adding perspective, packaging plays a central role in the marketing and sales of consumer products and has an equally important role in the handling and transportation of the same [10]. Thus the package can be regarded as the interface between the product and the different users in the supply chain from production to consumption and recovery. According to Johnsson [11], a more dynamic integration between packaging and logistics also has a potential for major advantages. When the package and logistics systems support each other, it is possible to influence costs and effectiveness in the whole logistics process by considering the package as a prime element. In the development of consumer packages, companies thus need to consider the needs of the different actors of the supply chain in order to create solutions that meet these needs and provide added services, and regard the product and its' package as a product-service system. This requires the developers to work differently from those who develop conventional products, in the way that they need to take into account the entire organisation of the system when developing a product-service system, such as food packaging [1].

2.1 Packaging and service development in the food supply chain

The primary consumer packaging is the most vital extension of a company towards the consumer and therefore a strategic tool for producers in the marketing, sales and brand recognition of food products [12; 13]. It has been shown that packaging solutions that attract retail outlets and end users will create a “demand-pull” effect, which leads to a change in market position and market segment value [14; 15]. In the development of consumer packages it is a matter of creating ones that attract the consumer and draw attention to the retail shelf, for the first moment of truth, while providing superior functionality and convenience in the second moment of truth, in order to make the consumer repeat the purchase [2;16]. Consumer purchasing decisions are strongly influenced by the consumer's attitudes and perceptions of the brand security and safety. Value adding services in the area of food safety and control contribute to producer and consumer welfare. Since all food items are packaged, the package serves as the interface between the consumer and the product and thus also becomes the carrier of the added values that the producers want to put forward to the consumer, in for example food safety and quality concerns.

In addition to food safety concerns, consumer demands on food products have driven the market towards more convenience and differentiation in a market with widely spread consumption patterns [3]. This differentiation and convenience have driven development towards more mixed foods and also toward more chilled foods. Mixed and chilled food place higher demands on food safety since these products are more sensitive to microbiological deterioration. The process of guaranteeing food safety is a challenge but also an opportunity to deliver an extra service to actors of the supply chain, through the package.

2.2 Food supply chains

When it comes to food products, packaging is a valuable aid in providing safe food to consumers. Food supply chains are both time critical due to temperate storage requirements and dynamic due to variance in raw material supply and quality. Even though food safety has a high priority on the food producers' agenda, the food industry has become global and more complex. This means that there are longer distances from the production of food to the consumer. This certainly places higher demands on food safety matters and on the process of guaranteeing safe food to consumers.

Although complex, food supply chains can be generalised into certain steps from crop, to production and consumption. Typical steps in these complex food supply chains are agriculture, food manufacturing, food wholesaling, food retailing and, food service and catering, as illustrated in Figure 1.

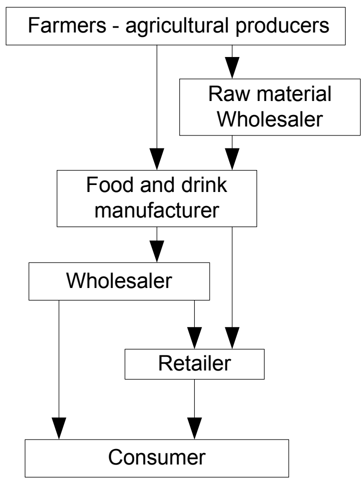

Figure 1: A generic food supply chain based on scheme from [17] and from input in the study

The generic supply chain in Figure 1, shows the different steps in a supply chain, but supply chains differ depending on the number of actors in the different steps. They also differ in the balance of power between different actors of a supply chain. In the UK, for example, the retailers have great power and in Sweden the power has shifted from a tradition of having very strong producers to a strong and powerful oligopoly on the retail level.

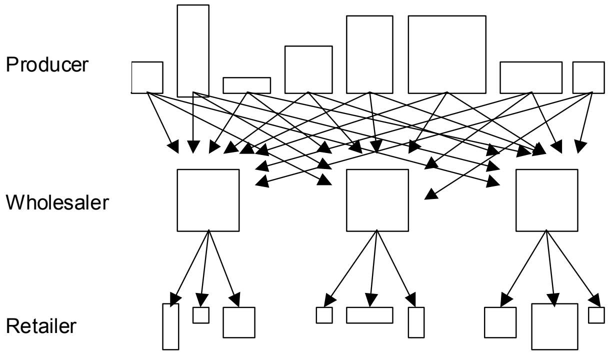

Figure 2: Swedish food chain

Figure 2 shows a generic view of the Swedish food industry and how it can be characterised as having many producers, very few wholesalers and many retail outlets. The retailers however are linked to the wholesalers and are usually under the same ownership even though there are some small independent retail stores still. The producers deliver to all wholesalers, while the wholesalers deliver to only a few retailers [4].

2.3 Food quality and shelf life

The shelf life of food products is an indicator of the level of quality. All food products in Sweden have to be marked with either "best-before date" or "last date for consumption". The latter is used for more sensitive food like fresh meat, fish and chicken [18]. The best-before date is set so that the food, if stored under the right conditions and in an unbroken package, will be possible to consume some additional time after the set date [19].

Since food producers have to add a safety margin to the best-before date, this results in an unnecessary waste of food, both by the consumers in their home and at retail locations. The majority of consumers tend to throw away food when the best-before date has expired, irrespective of if the food has gone bad or not [20]. Consumer behaviour in retail stores also creates waste. Since consumers buy products with the longest remaining shelf life irrespective of whether the product is going to be consumed the same day or not. This generates waste of products with shorter shelf life since they remain on the shelves.

The two most important factors concerning the shelf life of a product are time and temperature. Most of the deteriorating changes that take place in food are temperature dependent and occur at a slower rate at lower temperatures [21]. When temperature is infringed upon, the shelf life is affected leading to an uncertainty of the quality and food safety.

There have been some initiatives on the market to make indicators for detecting products that have been exposed to higher temperatures than stipulated. These indicators, however, have only been able to indicate if a product has been exposed to higher temperatures, but not how long. They usually shift in colour if the product has been exposed, but they really do not say much since the exposure is also dependent on time.

3 INNOVATION DESCRIPTION

The method used in this study, is to describe a packaging innovation for temperature control that was invented and launched by a start up company. This packaging innovation can be regarded as a product-service system, since the innovation is made up of a combined physical object and a service unit providing value to different actors of the food supply chain [1]. The innovation was based on an idea from one entrepreneur and one investor. They both had extensive previous experience from the food and packaging industry. The investor further saw a business potential in this idea, which is why he got involved from the very beginning.

The research approach in this study is explorative and based on interviews with the innovators and the actors throughout different food supply chains, observations and document studies. The company and the ideas have been followed from a research perspective over the years from its start up in 2002, until the present state when the company has been put on hold.

Even though the company is on hold, there is an ambition for a restart most likely in another industry, such as the pharmaceutical one. The approach of study has been from a service perspective in relation to the value the package innovation has added to the different actors in the supply chain.

3.1 The packaging innovation

The packaging innovation is a tag originally aimed for application on food packaging. The idea from the inventor was to develop an active tag for food quality measurements that could be used for chilled distributed food.

The tag consists of an electrical circuit combined with an enzymatic liquid solution that can be activated when applied to a package. This combined enzymatic solution and electrical circuit is seen as a biosensor. After application the active tag accumulates the temperature and time exposure data of the product in temperatures above the one stipulated for the chill chain.

The tag can then be read by a handheld scanner and the measurements show the accumulated time and temperature exposure for a product from production to consumption. This tag is able to measure the "real shelf life" of a chilled food product, rather than the fictive shelf life stamped on the package as a best-before date by a food producer. It can help actors of the supply chain to measure the temperature exposure the product has had from production to retail, which assists the actors in identifying products that need to be taken off the shelf or sold earlier due to an expiring shelf life.

Since the sticker is also based on an RFID circuit and a bar code, it can help companies with traceability matters in addition to temperature exposure control, which is yet another added value of the tag. The tag has the biosensor hidden under the RFID and bar code sticker as shown in Figure 3.

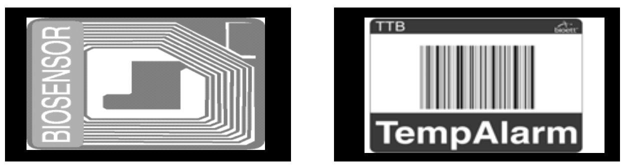

Figure 3: Temperature circuit and tag.

3.2 The innovation process and actor involvement

In the idea phase, prior to starting development, initial discussions with producers and retailers proved the innovation's business potential, since these actors could see the added value in having this type of intelligent sticker on a package.

The producers appreciated the added value of being able to secure temperature at storage right after production. They also saw an opportunity to trace the supply of products throughout the food supply chain by being able to get information about all temperatures from production to retail via an internet portal. The RFID tag with the bar code was also seen as value adding due to its properties to store all relevant data for the product in addition to the temperature data from the active circuit.

The distributors also saw the value of detecting products that have been exposed to a higher temperature than stipulated: by this detection they could redirect the orders and start distributing the products with the least shelf life first.

On the retail level the added value was considered to be the knowledge about the temperature exposure of products resulting in knowing when to take products off the shelf if their exposure was too high. The added service could also be used to put products on the shelf in another order than when they need to rely on the best-before stamp only.

During the development of the tag, all actors from producers, distributors to retailers acknowledged the potential value of better chill chain control; it was clear that the Swedish food industry was eager to engage in the development of this innovative product for increased packaging value in the supply chain. In the development phase, they all shared information among each other and to the innovators in order for them to better meet the needs of the different actors.

The actors were greatly involved in the test phase and three food producers on the consumer market participated in field trials. The producers received tags to put onto their packages and also received handheld scanners at their production facilities, at distribution centres and at the retail level. All actors engaged in the gathering of data from the different locations and all were positive about the added service the tag provided. They were also satisfied with the internet interface where they could follow up on their batches and transports.

Several actors benefitted from the trial period and new knowledge about the supply chains of chilled food was gained throughout the chain. Prior to the ability to measure temperature exposure over time, knowledge about the weak points of the chain was limited for all actors.

The tag was never exposed to final consumers, since the value added to them was a point of debate among the actors involved. It was not clear to them how knowledge among consumers would affect business and the trust in different brands, retail stores and producers.

3.3 The implementation phase

After the successful trial period, the project came into the implementation phase. During the trial period the actors had chosen products that were easy to control, since they were easy do demarcate. The products in general constituted only a small portion of the portfolio, but on the other hand they constituted a high value and were therefore selected due to their sensitiveness to temperature exposure.

The critical phase of the project started when the implementation was to commence and the actors were asked to put this into operation on a larger portion of the assortment. Suddenly, the interest from the actors disappeared. The investor tried with the producers (i.e. the starts-up company's potential immediate customers) to identify the value to the other actors of the supply chain. This co-operative effort aimed to find a way for the distributors and retailers to contribute to the investment in such a system. However, these actors could not see enough potential to invest and relied heavily on the producer to take on the entire investment. This resulted in the engaged actors withdrawing from the project when the system was supposed to be implemented. The main arguments were that they could not justify the added cost for the system.

4 ANALYSIS

The added service from this packaging innovation showed clear acceptance from the involved actors of the supply chain from producer to retailer. Thus, from the different users this was regarded as a product-service system. All actors could foresee the added value of the application during the innovation process up until the trial period. But when the implementation phase started and costs were incurred for this added value, no actor of the chain was willing to continue.

It was clear that all the actors involved had benefitted considerably from the knowledge gained in the test phase, but when the implementation was to start there was a clear expectation that the next actor in the chain should take on the extra cost and thus responsibility of securing food safety throughout the chain.

In order to get the involvement from all actors in the implementation phase, the innovator company tried to make estimations of the amount of food wasted in the supply chain due to temperature failures and exposure of packaged food. This was done to enable the calculation of possible gains by adding the sticker and thus reducing waste. However, no actor wanted to share their waste numbers in this stage of the innovation process, since it was regarded as a business secret and a risk to share among the other actors. It proved to be easier to share values on the selected trial products since they constituted such a small part of the entire portfolio. The trial products were also easy to control, which made it quite harmless to share information about from a business perspective. Even though all actors could agree that they had increased their knowledge about food waste related to temperature exposure in the tests and that they saw a need and benefit from being better informed in the area, they still showed reluctance to the system on a larger scale.

The problems identified in the implementation phase indicate a problem of sharing risks, costs and also potential value among supply chain actors. It further indicates a problem of taking overall responsibility for a chain problem. The power aspect is relevant in the analysis of this discussion. Comparing the Swedish food industry with other industries denotes the oligopoly in the food industry as a hindrance for co-operation, while other industries with several actors in each step show greater ability to co-operate in order to create customer value as a common ground and shared responsibility throughout the chain [22]. The transfer of power from the several producers in the Swedish food industry to the few wholesalers and retail chains has further intensified the difficulties of sharing problems as well as business opportunities along the chain. The investor in the innovating start-up company certifies that the innovation exposed the insufficient overall chain responsibility in the important area of securing safe food and reducing waste of non-expired food.

Another problem identified with the innovation is that it consists of an extra item that has to be placed on the package. This result in an extra direct cost per package which in isolation might not be a main problem and could also be defendable related to the added value it gives to the actors. But it also results in indirect costs of machinery, handling time, and time for reading the values at different locations in the supply chain. The added service as such is certainly requested from the different actors and its value is appreciated, however the cost is hard to justify for an individual actor. If the tag was integrated in the package, the indirect costs would be less and the added service would be of higher value in relation to the investments. Compared to an applied tag that might be seen just as an extra object, an integrated tag might be regarded as a product-service system with a value added service integrated to an already existing and needed object.

Neither the consumer nor consumer organisations were part of this project. The actors involved had different opinions whether the packaging innovation and its added value to consumers could be beneficial from a business point of view or not. However, the innovation as such surely gives an added value even to consumers, since increased knowledge about the product quality would certainly add value to a consumer. Since the temperature measurements from the stickers were readable from a handheld scanner, potential business opportunities for integrating this method into handheld scanners that already exist in larger retail chains are obvious. By scanning the tag the consumer could potentially obtain information about the real shelf life rather than the fictive shelf life stamped in the best-before date. Another opportunity would be to get the information on the receipt when the products are scanned at the cashier. In relation to such an implementation it would also be good to inform consumers about the amount of food that is wasted due to consumer behaviour in relation to the best-before date. If consumers were more informed and had more knowledge they might buy products with a shorter shelf life depending on when the products were supposed to be consumed. This proves the potential environmental benefits of the product-service system described in this case. Furthermore, consumers who have knowledge about the real shelf life through the sticker information might be better off because they will not be throwing away edible products in their homes.

5 CONCLUSIONS

It can be concluded that the added service from the presented packaging innovation showed clear acceptance from the involved actors of the supply chain from producer to retailer. The different actors appreciated a value addition from and the application was regarded as a product-service system. It can further be concluded that the Swedish food industry and the actors in such a supply chain all are eager and interested in participating in the development of new innovations for added value in the entire food packaging supply chain. However, when the innovation comes to the phase of implementation and commercialisation, none of the actors are willing to take an overall responsibility to share the costs or the risks of implementing a new innovation for value added services. Rather they rely on the next actor of the chain to take on responsibility. Thus, there is no system for sharing costs, risks and potential value gains among the actors of the food supply chain.

Even though there are obvious potential values in introducing a system all the way to the consumer, the actors are hesitant unless they can see a clear business potential for the own business.

The innovation presented shows apparent benefits from an overall supply chain and food distribution perspective in the way it can help identify product failures early in the chain and thereby decrease product waste through better logistical planning (i.e. products with the least shelf life should be first off the shelves). The system also provides value added services to all actors of the chain in the way it increases the knowledge among actors to handle shelf-life issues in another way, which also will reduce product waste.

6 REFERENCES

[1] Maussang, N., Zwolinski, P. and Brissaud, D. 2009, Product-Service System design methodology: from PSS architecture design to product specifications, Journal of Engineering Design, 20, 4; 349-366

[2] Löfgren, M. 2005, Winning at the first and second moments of truth: an exploratory study, Managing Service Quality, 15, 1; 102-115

[3] Olsson, A. and Larsson, A.C. 2010, “Value Creation in PSS Design through Product and Packaging Innovation Processes”, Introduction to Product/Service-System Design, 93-110, Springer Verlag

[4] Olsson, A. and Skjöldebrand, C. 2008, Risk Management and Quality Assurance through the Food Supply Chain – Case Studies in the Swedish Food industry, The Open Food Science Journal 2; 49-56

[5] Woolfe, M. 1992, Temperature control legislation in the UK, British Food Journal, 94, 9;14-19

[6] Björklund, M. 2002, Distribution av temperaturkänsliga livsmedel, Master thesis, Packaging Logistics, Design Sciences, Lund University, Sweden

[7] Prendergast, G. and Pitt, L. 1996, Packaging, marketing, logistics and the environment: are there trade offs? Journal of Product and Brand Management, 9,1; 56-70

[8] Vargo, S.L. and Lusch, R.F. 2008, Service-Dominant Logic: continuing the evolution, Journal of Academy of Marketing Science, 36;1;1-10

[9] Cook,M.B., Bhamra, T.A. and Lemon, M. 2006, The transfer and application of product service systems: from academia to UK manufacturing firms, Journal of Cleaner Production, 14; 1455-1465

[10] Olander-Roese, M. and Nilsson, F. 2009, Competitive advantage through packaging design – propositions for supply chain effectiveness and efficiency, International Conference of Engineering Design, Stanford; USA 24- 27 August

[11] Johnsson, M. 1998, Packaging Logistics - a Value Added Approach, Doctoral Thesis, Lund University, Sweden

[12] Gerding, T. K., Rijk, M. A. H., Jetten, J., van den Berg, F., and de Kruijf, N. 1996, Trends in food packaging: Arising opportunities and shifting demands. Packaging Technology and Science, 9; 153-165

[13] Sonneveld, K. 2000, The Importance of Integrated Product and Packaging Development, AIP National Packaging Conference

[14] Olsson, A., Petterson, M., and Jönson, G. 2004, Packaging demands in food service industry, Food Service technology, 4; 97-105

[15] Olsson, A. and Györei, M., 2002, "Packaging Throughout the Value Chain in the Customer Perspective Marketing Mix", *Packaging Technology and Science - An International Journal*, vol. 15, pp. 231-239.

[16] Sherwood, M. 1999, Winning the Shelf Wars – Unique packaging gives marketers a real selling advantage, Global Cosmetic Industry, 164,3; 64-67

[17] Bourlakis, M. and Weightman, P. 2003, Introduction to the UK food supply chain: In: The Supply Chain Management for Food, M. Bourlakis, ed., Blackwell, Oxford

[18] Livsmedelsverket. 2004, Hur länge håller varan? Available at: www.slv.se, accessed 040315

[19] Livsmedelsverket. 2004, Livsmedel transporteras vid för höga temperaturer – konsumenter vilseleds. Available at: www.slv.se, accessed 04-03-15

[20] WRAP, www.wrap.co.uk accessed 09-11-27

[21] Hernandez, J. 2001, Food Safety. Food Management 36,6; 84-86

[22] Wikström, L. 2009, Bristande konkurrens gör handeln lat, Svenska Livsmedel, 2; 6-7

Session 6A:
Production Management

Joint Framework for Product Service Systems and Life Cycle Management

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Abstract

The introduction of Product Service Systems (PSS) fosters the shift from the traditional focus on the sale of products towards the offer of a function of product-service-combinations to customers. The development and management of PSS is an interdisciplinary task and various aspects have to be taken into account. To avoid local optimisation and problem-shifting, Life Cycle (LC) thinking is required in the context of PSS. Existing approaches for Service Life Cycle (SLC) aim at the development and management of services and distinguish LC phases such as idea management, development, production and displacement. Approaches for Life Cycle Management (LCM) generally apply LC thinking to products. As a result, SLC- and LCM-approaches are not well connected with each other and synergies for PSS are often not obvious. Against this background, this paper proposes a concept how service can be integrated into an existing framework for so-called Total LCM. The framework is demonstrated based on the example of mobility concepts.

Keywords

Total Life Cycle Management, PSS, Service Life Cycle

1 INTRODUCTION

Production companies are confronted with an increasing demand to offer (industrial) Product Service Systems (PSS), to cope with the decreasing relevance of secondary market sectors and an increasing influence of the service market [1]. As PSS in general and industrial PSS in special consider a socio-technical system, solutions for PSS need to cope with increasing complexity and interdisciplinary issues. These challenges are addressed by various scientific disciplines like engineering technology, information technology, economics or psychology [2] [3].

The complexity of PSS results in a variety of challenges and production companies need to adopt themselves from product orientation to PSS orientation. Thus, the active adaptation in terms of changes in organisational structures, activities, and behaviours is a challenging task for the management of production companies [4] [5]. To cope with these challenges, a framework is required to structure the life cycle of PSS, classify and depict the mode of action of concepts, methods and tools and to help acting persons to understand engineering and management functions [5]. For that, the Total Life Cycle Management (TLCM) approach provides a framework for production companies that fulfil these requirements. To support companies offering services or PSS, an enhancement of the TLCM framework is required that integrates the specific characteristics of services.

2 PRODUCT RELATED LIFE CYCLE MANAGEMENT

Executive managers of companies face a highly complex and turbulent environment with social, political, economic, technical and ecological interdependencies. They need to cope with life cycle phases of products and services with respect to a sustainable development as well as to the internationalisation of markets, the development towards an information society and the change of values of employees and customers. Within this context, Life Cycle Management (LCM) frameworks have been developed in order to link different disciplines, to uncover interdependencies and to promote the integration of disciplines and methods [4] [5].

2.1 Requirements on Total Life Cycle Managements

The framework of TLCM is meant as a holistic LCM framework that aims at supporting management towards a sustainable development. It therefore has to meet requirements that can be summarised as follows:

- It generates transparency by structuring management activities with regard to product life cycle phases.
- It supports the understanding of general correlations between management disciplines of a life cycle management on the one hand as well as structures, activities and behaviour of involved actors on the other hand.
- It integrates various disciplines into a holistic approach with the following characteristics:
  - Life cycle spanning perception on products and processes
  - Integration of the statement for a sustainable development as part of the management philosophy with its ecological, economic and social goal dimension
  - Integrative consideration of strategic, operational and normative management
  - Consideration of attitudes, convictions and values of involved actors
  - Interdisciplinary consideration of different actors within the value chain
- It provides the opportunity for linking the life cycle of a primary product with used secondary products.

It facilitates the classification of existing and new management concepts, methods and tools.

2.2 Framework for Total Life Cycle Management

The framework is based on the ideas of the Viable System Model [6] and the St. Galler 'concept of integrated management' [7] [8]. The TLCM is a systemic and life cycle oriented framework for a life cycle phase comprehending point of view on products and the corresponding processes [9] [4] (Figure 1).

Figure 1: Framework of Total Life Cycle Management [4].

The centre of the framework is formed by the life cycle phases of a product – from *product idea* to *disposal*. Start of the entrepreneurial acting is the statement of a sustainable development as a super-ordinate philosophy. It is part of the normative management level that can be distinguished from the strategic and operational management levels. Thereby, the normative and strategic management have a rather forming function with regard to the development of the company [10]. Furthermore, the fields of action are classified into structures, activities and behaviour. Activities in the individual product life cycle phases lead to the output of the company. The activities take place according to the organisational structures and the behaviour of management and employees. These fields of action are part of all sectors of the concentric management rings.

In addition to management fields of action, the TLCM framework is divided into different LCM disciplines. These are classified in *life cycle spanning disciplines* (process management, information- and knowledge management, social life cycle evaluation, economic life cycle evaluation, ecological life cycle evaluation) and *life cycle phase related disciplines* (product management, production management, after-sales management, end-of-life management). The disciplines aim at a life cycle oriented design of products and processes and are based on the organization structures and the behaviour of involved actors.

As the term ‘total’ in TLCM refers to the holistic view on all company activities with respect to sustainability and life cycle orientation, the framework should be applicable for all types of companies and all types of products including products as well as services. Due to specific characteristics of services, the applicability of TLCM needs to be enhanced. As the main focus of TLCM was on products, service characteristics have not been considered in an adequate manner. Thus, the framework for TLCM will be enhanced for services in the first step and for PSS in the second step.

3 LIFE CYCLE MANAGEMENT FOR SERVICES

The relevance of the service sector, also called tertiary sector, has increased significantly in industrial countries during the last century. Today, in many industries, services are the most important business sector amounting to more than 70% of the national economy. Thereby, services are specified on the basis of an enumerative definition [11]. However, no distinct definition of the term “service” has been established in the scientific literature [12] [13].

3.1 Service characteristics

With reference to scientific literature, constitutive approaches provide the most distinct definition of services. These are defined on the basis of service-specific characteristics to determine the main core of services. Thereby, services are defined as independent, competitive performances that are connected with the preparation and/or the use of capabilities (potential orientation). Internal and external factors are combined within the process of provisioning services (process orientation). The combination of factors of the service provider is applied with the aim to achieve useful effects for the external factors such as people or objects (result orientation) [14] [2] [15].

Referring to this definition, it can be distinguished between a potential-, process-, and result-oriented dimension of services. This differentiation is widely accepted in literature and can be ascribed to [16] [17]. In addition to this, a fourth dimension, the market dimension, becomes consent and is found in literature as well. Thereby, the profitability of services from economic point of view is an essential characteristic and can be achieved by customer orientation within potential-, process- and result-oriented dimension [18].

Beside these four service dimensions five service characteristics have been identified [19]. These are suitable for defining services on the basis of constitutive characteristics (figure 2).

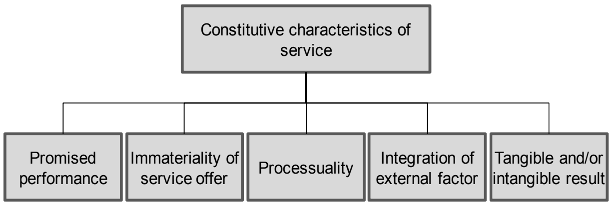

Figure 2: Constitutive characteristics of services [19]

- *Promised performance:* This characteristic applies to the willingness to perform and the potential needed to provide a service (e.g. buildings, technical equipment or employee and employer skills). In this context, the description of services takes place on the basis of the potential dimension.
- *Immateriality*: The immateriality view on services focuses on the promised performance offered on the market by the service provider. Based on this understanding, services are regarded as intangible. Therefore, the constitutive characteristics immateriality and offer of a promised performance are directly associated.
- *Process orientation*: Services are based upon an interaction process between a service provider and a service consumer. Thus, this service characteristic focuses on the process dimension of services.
- *External factor*: Due to the interaction process of services, the integration of an external factor, i.e. people, objects, or information is necessary. This results in the uno-actu-principle, meaning the simultaneous production and sale of services. The integration of external factors also refers to the process dimension of services.
- *Tangible or intangible result*: This characteristic refers to the outcome of the service provision process. In contrary to a product, the result can be tangible as well as intangible and has to meet the demands and

perceived benefits of the customer. Therefore, the centre of interest is the change of the condition of the service consumer or his objects.

3.2 Service Life Cycle

Besides the consideration of service characteristics, the specification of the Service Life Cycle (SLC) is also necessary in order to enhance the existing framework for TLCM with respect to services.

For the description of SLC different approaches have been developed. They intend to describe the single phases of services. The objective of SLC approaches is to illustrate the service life cycle in terms of sequent phases in which the interaction of required methods and tools is coordinated.

Existing SLC approaches vary in their description as they define different phases in the life cycle and use different terms for the phases [15]. Generally, they are based upon a development-oriented view, e.g. the "procedure model for systematic service development" from [18]. These approaches are characterised by defining SLC phases with a focal point on the time period previous to the service production and utilisation. Another group of existing approaches consider life cycle phases of "service production" and "usage" as well as phases subsequent to the usage. Examples are the "Bio-Inspired Service-Life-Cycle" [20], the "Service Design and Management Model" [21], and the "Phase Model for Service development" [22].

Although existing SLC approaches are mostly based upon the specific characteristics of services, they do neither include a management perspective nor integrate various disciplines into a holistic approach as described in chapter 2. In addition to this, most SLC approaches neglect single service characteristics as described in chapter 3.1. Except the approach developed by Bullinger [18], other approaches do not consider the characteristics of promised performance for service development. Moreover, the majority of existing approaches do not integrate the provision of potential factors needed for the service performance within the service life cycle phases. In conclusion, it can be stated that existing SLC approaches are not suitable for being used as a basis for a framework for Service LCM.

3.3 Service-related LCM

If service shall be described within a framework for Service LCM, service-specific characteristics and life cycle phases need to be considered simultaneously within the context of life cycle management. Thus, a framework for Service LCM has been developed within the TLCM approach with regard to existing SLC approaches. It is illustrated in figure 3 and will be described from inside to outside.

Life cycle phases

The centre of the framework illustrates the service life cycle phases – from *service idea* to *recycling*. Thereby, the traditional life cycle phases from TLCM have been consolidated with those taken from existing SLC approaches [22], [21] and [18].

Starting point for all services is a *service idea* that is detailed and designed within the *service development* phase. Service specific characteristics explicitly have to be considered, as the *provision of potentiality*, i.e. required resources, is part of the SLC. Furthermore, the immateriality is respected by integrating the *service production and service usage* as one isochronous phase. Thereby, its disjunction into two parts reflects the integration of the external factor. One part represents the service provider's processes; the other process part refers to the external factor that needs to be integrated. Finally, the *recycling* phase of SLC considers the need for utilisation and recycling of the provided potential factors as well as the possibly required adaptation of provided services with respect to new customer requirements.

Management perspective

As Service LCM integrates a management perspective into the depicted framework, it distinguishes between a *normative*, *strategic* and *operational management* level as well as *structures, activities* and *behaviour* as fields of action. Again, the management fields of action have to be considered in all sectors of the concentric arranged management levels. The strategic management has a rather forming function with regard to the development of the company, here the service company. An important difference between the framework for Service LCM and the existing TLCM framework is the integration of the external factor, depicted as the customer in figure 3. A private or industrial customer, has its own normative, strategic and operational management understanding as well as own structures, activities and behaviours. Structures, activities and behaviours of the service provider and of the customer need to match to each

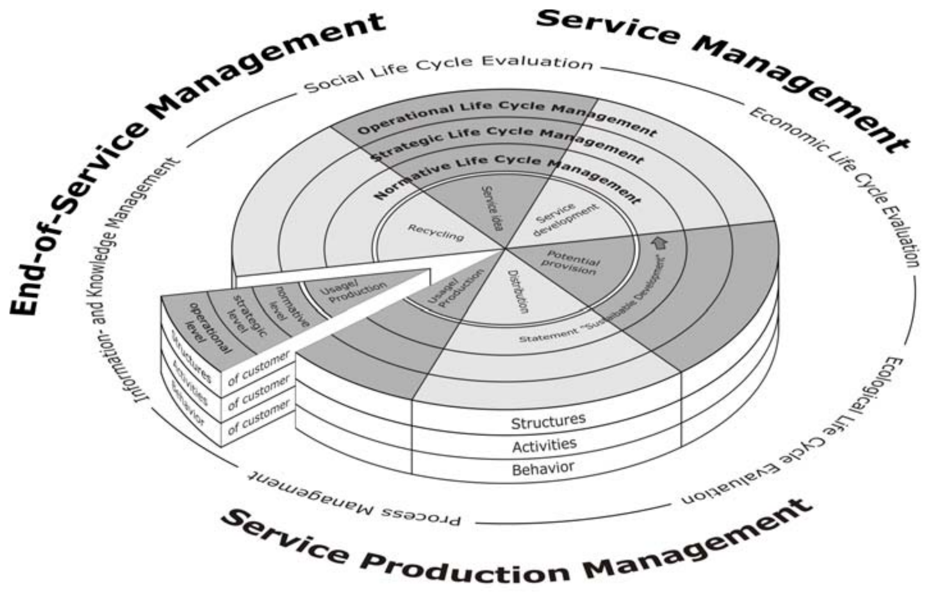

Figure 3: Framework for Service LCM

another in order to efficiently organise the phase of service production and usage. For instance, if a specific production process of a car manufacturer (e.g. assembling) has been outsourced to a service provider, the operational management within the production phase of vehicles (see figure 1) needs to be aligned with respect to the operational management of the service production phase of a service provider (figure 3).

Life cycle disciplines

According to TLCM, the framework for Service LCM is divided into *life cycle spanning disciplines* and *life cycle phase related disciplines*.

Within the *Service Management*, the service life cycle strategy and design need to be considered in all four service dimensions, i.e. the product, process, potentiality and market dimension. Thereby, the market dimension aims at developing a service that is compatible to the management levels of the customer (operational, strategic and normative).

The *Service Production Management* refers to the management of required resources for offering a service on the one hand. On the other hand it implies the management of providing services itself. This contains e.g. management guidelines for employees and their behaviour as well as service process descriptions within the operational life cycle management. In addition to this, an explicit consideration of the customer within the production and usage phase is required. Thus, the task for harmonising the management fields of action of the service provider and the customer is also part of the production management.

Finally, the *End-of-Service-Management* implies the planning and controlling of all activities at the end of service life. This contains the utilisation and reuse of service elements for new service ideas as well as the recycling of material results of the services.

As the framework for Service LCM is derived from the TLCM framework, a management perspective is explicitly included. Furthermore, it integrates the various disciplines into a holistic approach as described in chapter 2. Starting with the statement of a sustainable development it deepens the understanding of the general correlations between management disciplines and structures, activities and behaviour of involved actors within Service LCM. Thereby, service characteristics are explicitly regarded.

4 PRODUCT-SERVICE SYSTEM (PSS)

In contrast to the traditional philosophy of manufacturing and with the focus on manufacturing and selling products, the PSS-approach requires a shift towards offering a (specific) function to the customer. This requires the provision of a whole range of product and service combinations. Thus, the described framework for Service LCM should be part of TLCM and result in an integrated framework for PSS LCM.

4.1 PSS characteristics

A PSS is a bundle of products, services, networks of actors and the supporting infrastructure with the aim to be competitive by satisfying the customers' needs and at the same time to have a lower environmental impact than traditional business models [23]. Product and service are equally important for the function fulfilment [24] but the relation between services and products [25] and consequently the characteristics of PSS varies.

As the PSS concept shifts the relationship between manufacturer and customer, new business models with changing ownership structures emerged [26]:

Product-oriented business models provide additional services to sold products (e.g. financing, consultation),

- Use-oriented business model focus on the use of products that are sold, not the product itself (e.g. product renting and leasing),
- Result-oriented business model focus on a provider that guarantees satisfaction of customer needs, regardless of disposed products (e.g. facility management, mobility).

For the management of PSS the integrated and life cycle-oriented management of a product in combination with a service is necessary. Characteristics of services need to be regarded as well as characteristics of products.

Because services have only been integrated into the framework for TLCM in terms of a product-oriented business model (i.e. After-Sales-Management), it is not suitable for being used for PSS. A framework for PSS LCM needs to be an integration and combination of Service LCM (cf. chapter 3.3) and the TLCM framework (cf. chapter 2).

4.2 PSS Life Cycle Management

Within a PSS neither the product nor the service is solely important, but the required function of the total system as a result of the product and service combination. As to this, suitable PSS LCM approaches are necessary for the management of this multi-disciplinary, socio-technical system. As PSS is a new field of research, holistic approaches for the integration of a product view and a service view do rarely exist [27]. By integrating the framework for TLCM and Service LCM into one consistent framework for PSS LCM this drawback shall be addressed. Thereby, the integration of life cycles as well as the continuative management disciplines of TLCM and Service LCM can be implemented in diverse depths.

The first integration step is presented in figure 4. The Service LCM and the TLCM are connected in the usage phase of the product and the usage and production phase of the service. Thereby, TLCM and Service LCM are still represented separately, but interdependences are considered.

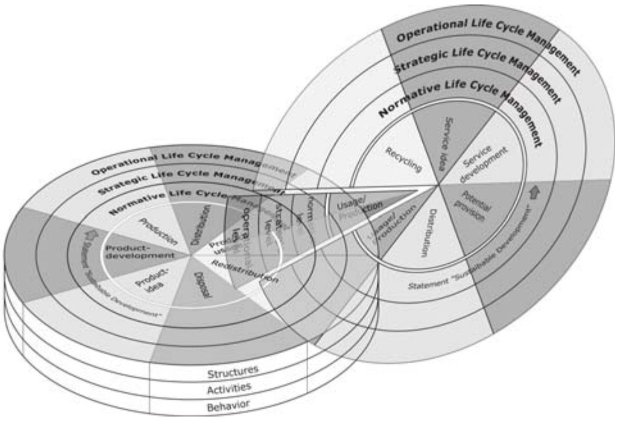

Figure 4: Connected framework of TLCM and Service LSM

In various life cycle phases an exchange and coordination between the life cycles of offered services and related products are needed. Between the levels of management, there has to be a link as well. The levels act independently but in close coordination. With this first integration step PSS requirements coming from its definition are only partly achieved. Thus, a product-related service is rather shown here, which frequently occurs in the economy.

Within an overall framework for PSS LCM, the management of services and products is combined in a unit that deals with the required function and regards the needs of the embedded services and products as equally important. To achieve this, an integration and connection of the life cycles of services and products to a common life cycle is needed. The management levels must rely on an integrated management for the common life cycle. For better understanding a mobility concept of car-sharing is used as an example (see figure 5). It meets the definition of a PSS. With this example, a mobility concept allocates the function mobility to the customer. This function is realised with an integrative combination of a mobility-enabling product (e.g. car) and a mobility-providing service [28].

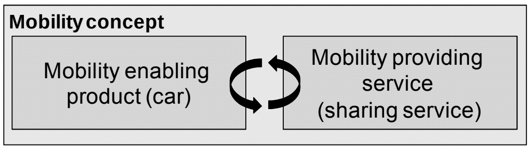

Figure 5: Mobility concept for car sharing [28]

Using the example figure 6 represents the integrated PSS LCM framework for a mobility concept.

Life cycle phases

The PSS life cycle is in the centre of the framework and starts with the *PSS idea* for the joint PSS (e.g. the idea for a car-sharing offer). The *PSS development* implies the integrated development of product parts and service parts. Within the context of car-sharing this corresponds to the development of a car as well as the services that enable the process of sharing (business processes, workflows, rules etc.). A particular attention is needed for the development of the interfaces between the car and the service.

The *PSS development* phase is followed by the *production* of the product component (car) and the parallel *provision of the required potential* for the service part of the PSS (e.g. a booking system, entry requirements, specific parking space, employer's skills, etc.). Here, a division into the life cycles of the product and the corresponding service takes place. This division is ascribed to the different characterisation of services and products. While the product needs to be manufactured before using, the immateriality of services is linked to the subsequent usage and production phase and the potential provision phase.

Within the *distribution* phase the PSS is marketed and the product as well as the physical portion of the available potential is prepared. Following the example of car sharing, the developed car sharing concept is offered to the customers, the car is shipped to its basic position and contracts and entry requirements are sent to the customers.

In the next phase, the *usage* of product and services takes place, simultaneous to the *production of services* to the customer. As described with the Service LCM in chapter 3.3 the customer and the customer's processes need to be a part of the service provision and use, in figure 6 illustrated by the separate representation of the customer in the phase of usage and production. E.g. the customer books a car by using the booking system and starts on the parking space. By starting to drive the car, the function of mobility is achieved. The integration of the external factor is needed even though a product is part of the PSS due to the immateriality of the service part (the mobility).

The last phase of PSS life cycle is *recycling* of the immaterial service and *redistribution and disposal* (or recycling) of the product. This phase considers the need for disposal of the provided potential factors and physical parts as well as the possibly required adaptation of provided services. For the PSS "car sharing", this can be divided into three scenarios.

First scenario: The car is redistributed and disposed, whereas the service or service characteristics are recycled to be used with another product or new car (car generation) starting a new life cycle of another PSS.

Second scenario: The service is suspended. The provided potentials are reduced and, if necessary, recycled. The car needs to be redistributed and can be reused in a different mobility concept (a new PSS).

Third scenario: The car is redistributed, disposed and the service is suspended. The provided potential factors are disposed or reduced.

The integrated PSS life cycle takes into account the

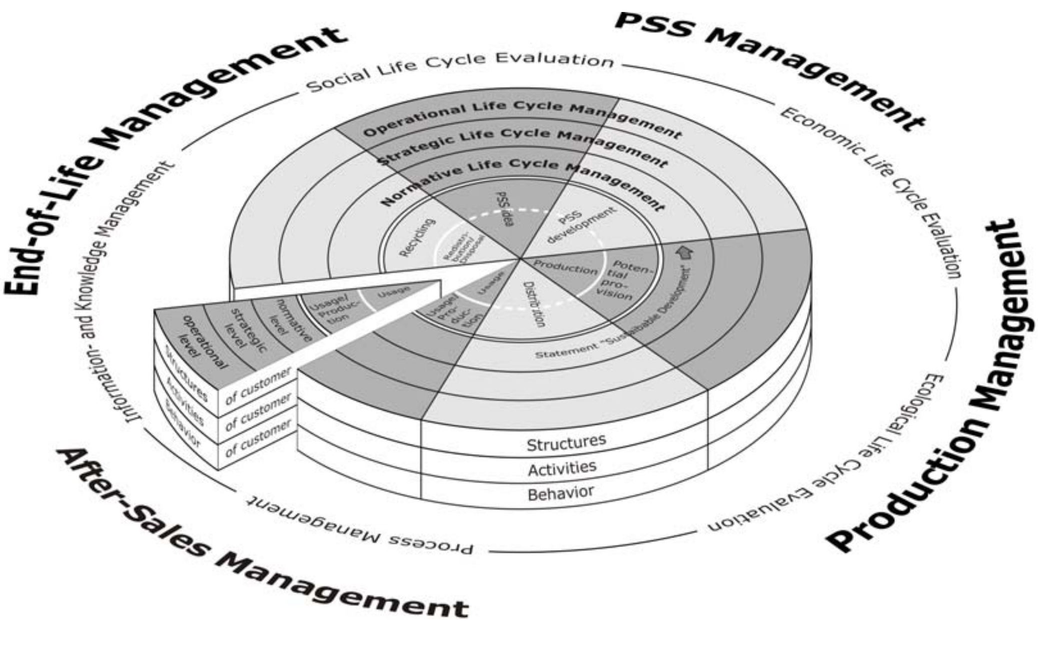

Figure 6: Framework for PSS Life Cycle Management

service characteristics (according to the depicted life cycle for Service LCM), while the requirements for the life cycle of the product are considered as well. The life cycle can be applied regardless of how distinctive the service part or the product part is in the PSS.

Management perspective

The framework for PSS LCM integrates a management perspective with a *normative*, *strategic* and *operational management* level as well as *structures*, *activities* and *behaviour* as fields of action. The management perspective of PSS LCM refers to the fulfilment of functions of PSS and therefore equally to both parts, service and product parts. Regarding the PSS "car sharing", the management perspective integrates the car as well as the sharing services. In analogy to Service LCM, PSS LCM explicitly considers a customer part. Herewith, the integration of the external factor with its own normative, strategic and operational (management) level as well as own structures, activities and behaviour in the service production and usage is displayed. Within the example, the car sharing customers' structures, activities and behaviours and its valuable mindset, strategies and plans should be taken into account for the providers' management fields of action in order to efficiently go through the phase of PSS production and usage. For example, if a customer target group is characterised by "green attitudes", this has to be addressed by an environmentally friendly car.

Life cycle disciplines

Likewise TLCM and Service LCM, PSS LCM is divided into *life cycle spanning disciplines* and *life cycle phase related disciplines*. Life cycle spanning disciplines are invariant to the regarded product (product, service or PSS) and differ only in terms of the system boundaries. Life cycle phase related disciplines however adapt to the PSS.

The *PSS Management* aims at the development of a PSS idea and the design that considers the PSS as a function fulfilment of equal parts of a product and service. Thereby, properties of products need to be regarded as well as all four service dimensions.

Within the *PSS Production Management*, processes for service and product production are simultaneously regarded. This implies the required production of resources and potentials for the service production as well as the management of product production. Furthermore, the harmonisation of the management fields of action of the PSS-customer and PSS-provider becomes a central element of the PSS Production Management. The life cycle phases product production and potential provision as well as product usage and service production/ usage are connected within this life cycle phase related discipline.

In the *After-Sales Management* the usage of the product and its related processes are regarded. However, this discipline focuses more on the harmonisation of after sales activities of the physical part and the usage and production of the service part of the PSS so that the promised performance can be fulfilled.

Finally, the *End-of-Life Management* comprises the processes and activities at the end of the PSS life. This contains structures, activities, and behaviours that are required for the redistribution and disposal of physical components as well as the adaptation or removal of services and acquired resources.

5 CONCLUSION

The framework for PSS LCM is an integration of the existing TLCM framework and a Service LCM framework. It generates transparency by structuring management activities with regard to PSS life cycle phases. It integrates various disciplines into a holistic approach and therefore fosters the understanding of correlations between management disciplines and structures, activities and behaviour of involved actors, i.e. the regarded company and the customer. Service and product related characteristics are simultaneously regarded and a common life cycle for PSS is integrated.

The framework for PSS LCM complies with the requirements for a Life Cycle Management framework as well as the requirements coming from the definition of PSS. Irrespective to the ratio of product part and service part in the PSS, the management of the PSS can be described with this framework.

6 REFERENCES

[1] Statistisches Bundesamt (ed.) 2007, Statistisches Jahrbuch 2007 für die Bundesrepublik Deutschland, Wiesbaden.

[2] Fähnrich, K.-P., Opitz, M., 2006, Service Engineering – Entwicklungspfad und Bild einer jungen Disziplin, in: Schneider, K., Bullinger, H., Scheer, A., (ed.), 2006, Service Engineering, Berlin.

[3] Torney, M., Kuntzky, K., Herrmann, C., 2009, Service Development and Implementation - A Review of the State of the Art, in: Proceeding of the 1st CIRP IPS2 Conference, Cranfield, pp. 24-30.

[4] Herrmann, C., Bergmann, L., Thiede, S., Zein, A., 2007, Total Life Cycle Management – A Systems and Cybernetics Approach to Corporate Sustainability in Manufacturing, in: sustainable manufacturing V: Global Symposium on Sustainable Product Development and Life Cycle Engineering, Rochester.

[5] Herrmann, C., 2009, Ganzheitliches Life Cycle Management - Nachhaltigkeit und Lebenszyklusorientierung in Unternehmen, Heidelberg.

[6] Beer, S., 1995, The Heart of Enterprise, London, New York.

[7] Ulrich, H., Krieg, W., 1974, St. Galler Management-Modell, 3rd edition, Bern.

[8] Bleicher, K., 1995, Das Konzept Integriertes Management, 3rd edition., Frankfurt a. Main.

[9] Herrmann, C., Mansour, M., Mateika, M., 2005, Strategic and Operational Life Cycle Management – Model, Methods and Activities, in: 12th International CIRP Seminar in LCE 2005, Grenoble.

[10] Herrmann, C., 2006, Ganzheitliches Life Cycle Management, in: Herrmann, C.; Leitner, T.; Paulesich, R. (ed.), Nachhaltigkeit in der Elektro(nik)industrie, Düsseldorf, pp.1-29.

[11] Statistisches Bundesamt (ed.), 2006, Statistisches Jahrbuch 2006 für die Bundesrepublik Deutschland, Wiesbaden.

[12] Kleinaltenkamp, C., 2001, Begriffsabgrenzungen und Erscheinungsformen von Dienstleistungen, in: Bruhn, M., Meffert, H. (ed.), Handbuch Dienstleistungsmanagement - Von der strategischen Konzeption zur praktischen Umsetzung, 2nd edition, Wiesbaden.

[13] Haller, S., 2005, Dienstleistungsmanagement – Grundlagen – Konzepte – Instrumente, 3rd edition, Wiesbaden.

[14] Bruhn, M., 2008, Qualitätsmanagement für Dienstleistungen - Grundlagen - Konzepte - Methoden, Berlin, Heidelberg.

[15] Klein, R., 2007, Modellgestütztes Service Systems Engineering - Theorie und Technik einer systemischen Entwicklung von Dienstleistungen, Wiesbaden.

[16] Donabedian, A., 1980, Definition of quality and approaches to its assessment (Explorations in quality assessment and monitoring), Ann Arbor.

[17] Edvardsson, B., Olsson, J., 1996, Key Concepts for New Service Development, in: The Service Industries Journal, vol. 16, No. 2, pp. 140–164.

[18] Bullinger, H., Schreiner, P., 2006, Service Engineering - Ein Rahmenmodell für die systematische Entwicklung von Dienstleistungen, in: Bullinger, H., Scheer, A., Schneider, K. (ed.), 2006, Service Engineering - Entwicklung und Gestaltung innovativer Dienstleistungen, Berlin.

[19] Gill, C., 2004, Architektur für das Service Engineering zur Entwicklung von technischen Dienstleistungen, Aachen.

[20] Linner, D., et al., 2007, Biology as Inspiration Towards a Novel Service-Life-Cycle, in: ATC 2007, LNCS 4610, pp. 94-102, Heidelberg.

[21] Ramaswamy, R., 1996, Design and Management of Service Processes – Keeping Customers for Life, Reading.

[22] Deutsches Institut für Normung e.V. (ed.), 1998, Service Engineering: Entwicklungsbegleitende Normung (EBN) für Dienstleistungen, Berlin.

[23] Mont, O. K., 2004, Product-Service System - Panacea or Myth?, Disseration, KFS AB, Lund University.

[24] Goedkoop, M.J., et al., 1999, Product Service Systems - Ecological and Economic Basics, Den Hag.

[25] Ölundh, G., 2003, Environmental and Developmental Perspectives of Functional Sales, Licentitate Thesis, Department of Machine Design, Stockholm.

[26] Hockerts, K., Weaver, N., 2002, Towards a Theory of Sustainable Product Service Systems – What are the Dependent and Independent Variables of S-PSS?, INSEAD-CMER Research Workshop “Sustainable Product Service Systems”.

[27] Meier, H., 2006, Hybride Leistungsbündel im Maschinen- und Analgenbau, in: wt Werkstatttechnik online, vol. 96, No. 7/8, p. 428

[28] Herrmann, C., Stehr, J., Kuntzky, K., 2009, Automotive Life Cycle Engineering: Understanding the Interdependencies between Technology and Market of Environmentally Conscious Mobility Concepts, in: Eco Design, 6th International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Sapparo

Organizational changes in connection with IPSO

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Abstract

Integrated product service offerings (IPSO) have the potential of obtaining better margins, profitability and less environmental impact. Becoming a service provider implies significant changes in the way companies do business, considerable changes within the organization and changes with the relationships to external actors. This paper aims to contribute to the research concerning these changes when companies start to provide IPSOs. Changes within the organizations have been necessary for all the companies studied and especially the sales staff since trust, transparency and long-term relationships with the customer is crucial. Support from the top management is also of importance as well as working in cross-functional teams. Changes are also needed in the service organization and amongst the retailers. Apart from the change in the provider-customer relationships little has been done in including other external actors, but the companies see potential in doing so in the future to expand and develop their IPSOs.

Keywords

Integrated product service offerings organization, IPSO, organizational change, external actors

1 INTRODUCTION

The business climate is becoming more and more competitive and manufacturing companies can experience difficulties in receiving acceptable margins on their products as well as competing with standardized products. One way of continuously receiving revenue for manufacturing companies is to provide services throughout the whole life cycle of the products [1] and lowering environmental impacts at the same time as fulfilling customer needs in a better way [2]. Other beneficial outcomes of this so called Integrated Product and Service Offerings, IPSO, are the possibility of a larger market or more control over the product value chain [3]. With this change from product focus to becoming a service provider as well significantly affect the way the companies do business [1].To become a service provider considerable changes have to be made within the organization, the capabilities and the management of the firm, but not enough information concerning these challenges is available and more research is needed in this particular area [4]. The role of the supplier organizations have not yet been sufficiently assessed [1]. This is particularly interesting since the extent to which a firm should become a service provider is determined by the properties of the organization [4].

More information concerning the challenges and implications of the IPSOs is therefore needed, especially concerning the organizational changes since there are ongoing processes within the companies and an update is needed. This paper is a part of the KIPTES (Swedish: Kartläggning av Integrerade Produkt- och TjänsteErbjudanden i Sverige) project which has the purpose of collecting and establishing knowledge concerning the activities of Swedish companies and researchers within the area of integrated product service offerings and subsequently to spread this knowledge. The study was divided into four parts; a literature review, mapping of Swedish researchers within the area as well as their research projects, mapping Swedish companies and their activities within the area and finally in-depth case studies using e.g. LCA and LCC which can be studied in [5]. This paper is based on the third study but is focused on a smaller area, namely the companies' organizational changes associated with IPSO.

1.1 Objective

The objective of this paper is to investigate what has changed for the organization of the companies internally and externally since they started to provide IPSOs. The specific research questions that evolved from this objective were the following:

- How and why has the organization within the companies changed when starting to provide IPSOs? *The structure, competence and management of the organization of a company providing IPSO plays a significant role in the success of the IPSO.*
- How and why have the relationships and co-operations with external actors changed when starting to provide IPSOs?
  With internal changes come external changes and relationships and cooperation with external actors, e.g. customers and suppliers will change when starting to provide IPSO.

2 METHOD

In order to find answers to the research questions and subsequently the objective of the paper firstly an explorative survey was performed to identify interesting companies for further interviews. The purpose of the survey was also to identify areas in which changes had occurred in the organization and the networks. These areas were later investigated further in interviews with selected companies to give answers to how and why the changes had occurred. The process of selecting companies for interviews is illustrated in Figure 1.

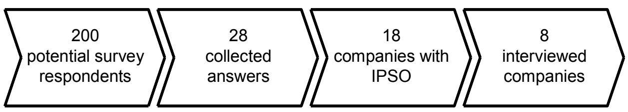

Figure 1: The process of selecting companies for interviews.

2.1 Survey

From the previous literature review [6] in the KIPTES project important factors and areas were identified and these were used to construct the survey. In total the survey consisted of 19 questions divided into three main sections. The first questions were concerned with the name and size of the company as well as contact details. Thereafter a screening question was conducted to separate the respondents into two groups; companies currently providing integrated product service offerings and those who do not offer them. The companies who did not provide these kind of offers where asked to explain why, while the ones who did provide the offers were asked more specific questions concerning their offers as well as more general questions such as profitability and drivers for the development.

The process of identifying respondents/companies included several different steps. Some companies were identified in the literature review that preceded this study, while others were found through the survey that had been sent out to Swedish researchers within the area. Organizational networks were also contacted as well as an advertisement in the popular science newspaper called "Ny Teknik" in Sweden encouraging companies to participate in the survey. None of these attempts were successful and instead company networks established in earlier research at Linköping University were used to reach respondents. Four different networks were used reaching a total of just over 200 companies.

2.2 Interviews

The following step in the study was the process of interviewing selected companies who had participated in the survey to provide a greater understanding of the companies and their offers. Criteria were set for selecting the companies for interviews to achieve a view as versatile possible. The following criteria were used:

- A completed survey
- The size of the company
- Type of industry
- How long the company had offered IPSO
- The percentage of the total sales consisting of IPSO
- The interviewee's position in the company

The nine companies selected were the ones to meet the criteria and where the respondents accepted to participate. The interviews were performed over the phone, lasting in average 30 minutes. They were all recorded and a semi-structured interview guide was used.

2.3 Evaluation process

The results from the survey were collected and analyzed for similarities and differences. A split between large and small companies was made but no differences were discovered concerning the focus of this paper.

The information from the nine companies interviewed was gathered in individual descriptions to acquire a deeper overview of the companies. Thereafter similarities and differences were analyzed and compared to the literature review. Finally results and analyses were condensed to give answers to the objectives of this paper.

3 ORGANIZATIONAL CHANGES

The total number of respondents completing the survey was 20 and 8 of them were selected for interviews. Characteristics concerning the interviewed companies can be found in Table 1. Respondents working with business development, service development or with market responsibility were the most frequent. The departments within the companies that participated most in developing the IPSOs were product development, market and aftermarket. Concerning the small companies, the aftermarket department was not marked as one of the participating departments probably due to the size of the companies and them not needing a separate department for the different market activities and aftermarket. Most of the participating companies have only recently started to provide services but these types of offerings have existed for a longer time though under another name and among fewer companies.

3.1 Restructuring and the customer relationship

For almost all the companies, changes within the organization have been necessary in connection with providing IPSOs. For Company G which has provided IPSOs since the 1970s the new way of working has been adopted in the organization over time and the organization has grown into the role it has today. Other companies, such as Company E, who started providing IPSOs in 2008, has not made any major changes in the organization to date. In general, however most of the companies have made changes and the respondents especially emphasize the changed way of which they do business in combination with the increasing importance of the role of the sales person. Company D has completely changed the way in which they approach the customers. Instead of waiting for the customers to contact them the company has become more proactive in their sales process. The main focus for Company F has been the people in the organization since the working processes and the attitudes needed to change.

> *"The adaptation internally went good and when the co-workers realized the benefits with the new offers and thereby became more involved and committed, it then led to even more advantages".*

The change was necessary according to the CEO since the employees now work closer to the customers in the process of providing services.

Table 1: Characteristics of interviewed companies.

Name	Employees	Industry	IPSO share of total sales	Started providing IPSO
Company A	500	Logistics and material handling	20-30 %	1970s
Company B	2300	Aerospace-industry (Volvo Aero Corporation)	40 %	1970s
Company C	1800	Healthcare	10 %	2004
Company D	1300	Mining industry (Atlas Copco Rock Drills)	20 %	2000
Company E	800	Vehicle industry	5 %	2008
Company F	60	Subcontract work and logistics (EDC)	50 %	2000
Company G	30	Plastic industry (Plastema)	100 %	1978
Company H	50	Graphic industry	25 %	2003

The one company that differs significantly from the others is Company H since it is a service providing company that has started to integrate products in their offers. Problems within its organization are e.g. the lack of a product manager and the fact that new suppliers had to be found to be able to deliver the product parts. The company did have people within the organization who had experience from manufacturing companies and the respondent considers this the reason for why no specific changes have yet been made within the organization.

The companies claim that the relationships with the customers have become closer and more frequent and the goal has been to create more long-term relationships. Company G states that "the offer has spread from the current customers to new customers by word of mouth". The respondent for Company F emphasizes the important of having a good partnership with the customers, but states it goes both ways; the customer too has to make an effort and become more transparent to make the IPSOs possible. And the level of transparency among the customers varies greatly according to the respondent, which makes it more or less difficult to provide the offerings.

Each of the interviewed companies claimed that their IPSOs are more profitable than the traditional ones. However, there have been difficulties arguing the value of the offers both internally as well as in convincing the customer due to the traditional mindset. Company E developed a calculation tool to avoid the risk of the retailers to misestimate the value of the offers and thereby avoid the cost for the company to be stuck with a non profitable deal. Still most of the companies base the pricing on physical products.

3.2 Coordinating activities and competences

All interviewed companies have had a typical product focus except one that started off as a service provider and recently began to add product to the offer. Constantly reoccurring during the interviews was the opinion that coordination of corporate activates and competences are required to succeed in the transition. Company B, which earlier put together a team when there was a need in the development process, now has identified the need for more structure in the organization to be able to transfer similar offers to other customer segments. Furthermore, competence and knowledge from other parts of the company group have been used in developing and realizing the IPSOs, e.g. IT-logistics. Mostly the work at Company B is focused on the service development and the knowledge concerning the customers and it is therefore required to better cooperate with the local markets since they work close to the customer. Another important change is the way in which the company measures success and now a longer perspective is needed than when only products were included in the offer.

Company C started the IPSOs in 2004 and is still struggling with the needs within the organization when developing services.

> *"To even out the skewed balance between product development and service development more focus in required towards services to increase sales and thereby prove that the concept is functioning."*

The work is still very much divided and based more on a product logic than a service logic.

In Company A, B and C there have been difficulties in changing the mature organization where the employees believe that the current way of working is the right way. Company D has also experienced this according to the respondent.

> *"The IPSOs have not run into any strategic obstacles but have experienced certain resistance in some regions where the sales organizations have a mature structure and therefore have been less inclined to changes."*

Furthermore, the dilemma of competing against the traditional offer can occur, which happened in Company D. The solution was to set criteria for when the IPSOs were to be sold, namely when a new product was sold and if the customer currently did not have a service agreement with the company.

3.3 Service organization

Changes in the service organizations have been necessary as well as changes in the work routines of the service technicians. In Company A the service technicians are provided with detailed information concerning the product at the customer plant before they leave the company. This is possible due to a wireless solution that sends operation information which the company can use both for maintenance work and development of the offer. Company A has realized that a back-office function will be needed to be able to make use of the information sent from the products.

> *"The plan is to redirect the quality history to the sellers and product development and thereby make improvement s within the offers."*

Not all of the companies have their own sales or service organization like Company E which instead uses retailers who work with the guidelines set by the company. The retailers did already sell IPSOs but now the difference is that it is supported from the management.

3.4 External actors

Apart from the change in customer relationships changes in the supplier networks are consequences of the new IPSOs. Company B has started to involve the suppliers to a greater extent. Furthermore, Company C sees a potential in involving more external actors to create new offerings. Another external change is the education given to retailers by some companies who have organized their sales organization in that way. The education has included the way of selling and the actual offers themselves. However, some retailers have already sold these kinds of offerings but the difference is now that the procedures are centralized.

4 DISCUSSION

In this section the results from the survey and interviews are discussed following the procedure described section 2.3. The discussed information is mainly retrieved from the interviews. Figure 2 aims to illustrate the discussion and examples from the companies are used to concretize the chapter.

4.1 Participating departments

The departments within the companies that participated most in developing the IPSOs were product development, market and aftermarket. This is in line with the results with previous research [3] that present similar findings. This cross-functional way of working to design an IPSO is a necessity [1], meaning that representatives from technical design, commercial management and project management need to be involved. Concerning the small companies, the aftermarket department was not marked as one of the participating department probably due to the size of the companies and them not needing a separate department for the different market activities and aftermarket. Two of the smaller companies argue that with respect to the size of the company, everyone is involved in the development and that the different roles overlap.

In a gap analysis conducted by Östlin et al. [7] it was found that there is an organizational gap between the product department and service delivery department. In addition, less sharp boundaries between departments will facilitate the creation of well designed offers [8]. This has been illustrated in Figure 2 where the circle representing the cross-functional teams is in connection with all the participating departments in the company. These kind of issues are also further discussed by Östlin et al. [7] which also presents 10 key aspects that influence the performance of industrial product/service systems.

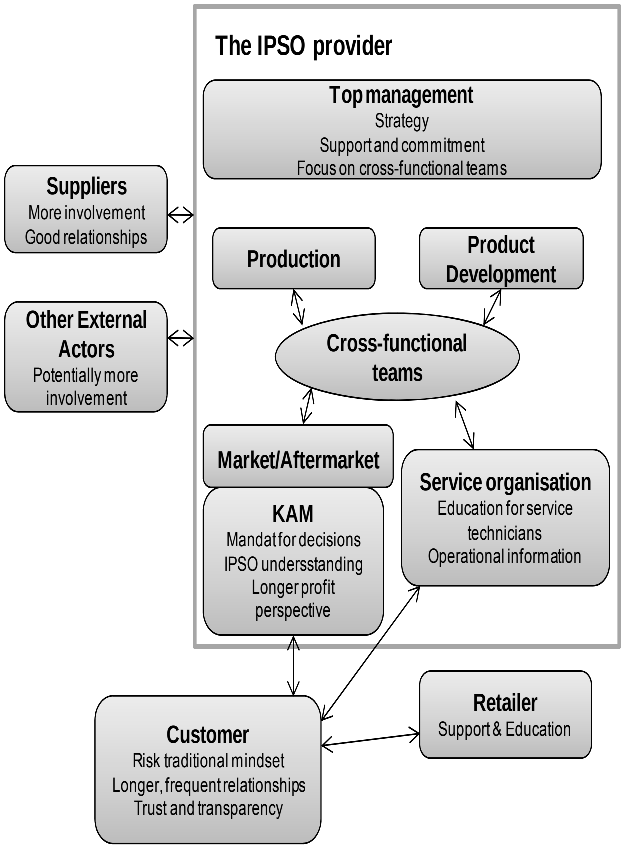

Figure 2: Relationships and co-operations between the departments and functions within the IPSO provider and with the external actors.

4.2 Centralization vs. decentralization

The top management support is a critical success factor [9] and several companies have understood the importance of this. In Figure 2 the importance of the role of the top management is shown by representing it on the top of the figure. No arrows were needed here to show the flow of the influence, instead arrows to all the participating departments as well as to external actors could be imagined. Examples of this includes e.g. Company E being the retailers which are supported in a centralized way and Company B having a more structured way of putting teams together from different departments to be able to transfer the offer to other segments. This is an example of a more cross-functional way of working which has been suggested to be successful [10]. This means that external changes such as the increased interaction with the customer to create an offer modifies the relationships between the departments [11]. This can be exemplified by Company A where a wireless solution is used to retrieve operational information about the product at the customer. This information is then sent from the service organization back to the development department and used to make improvements. This flow has been illustrated in Figure 2 by the arrow from the customer to the service organization and then further to the product development via the cross-functional team. This information loop will hopefully help to improve the product in a way that it lasts longer, both through structural improvements and maintenance improvements. Routines for feedback from parts of the organization working close to the customer has been recommended in earlier research [12] . The need for more structure in some parts of the company collides with the increased interaction between the company and the customers and the need for more decisions taken in a more decentralized way [11] to win the trust of the customer. This means that there is a need for top management commitment in the strategy but individual customer decisions need to be more decentralized, creating a delicate balance between these two critical factors.

4.3 Traditional mindset

The pricing of the IPSOs needs to be done properly [13] but there is a lack of knowledge in this area [14]. Other Swedish IPSO providers have also found this to be a great challenge in order to achieve a win-win situation [15]. Despite this all the interviewed companies consider their IPSOs more profitable than their traditional offers. This indicates that the companies at least have managed a pricing that makes it profitable to provide IPSOs. However, several of the companies experience difficulties in convincing the customers of the value of the offer. The pricing is still mainly based on the physical products probably due to that both the companies and their customers still have a traditional mindset and the customers prefer paying in a traditional way. In addition, using traditional mindset when designing the physical products have also been found to be an obstacle for success of industrial product/service systems [7, 16]. Earlier research has also pointed out the difficulties with a traditional mindset among the customers [17]. There is a need for models and tools that in a simple way can illustrate the economical benefits of the offers [18]. This has been done by Company E which developed a calculation tool for the retailers.

The issues with the pricing show how important it is for the companies to win the trust of the customers to be able to convince them of the benefits and value of the IPSOs by e.g. the role of a Key Account Manager, KAM. However, this requires a person with an understanding of IPSOs and who has the willingness to work in the new way. The driver for the sales person has traditionally been to sell as much as possible to generate profit. The profit was realized at short-term whilst now the profit realization period is longer and at the point- of- service [19]. Therefore a new way of thinking of the business is required of the sales persons. The role of the KAM has been illustrated in Figure 2 as part of the market/aftermarket department, but has been given a box of its own to emphasize the importance of this role.

In Company A, B and C there have been difficulties in changing the mature organization where the employees believe that the current way of working is the right way. This traditional mindset within the organization is an obstacle for developing IPSOs [14]. This is also in line with the findings of a previous study of IPSO providers in Sweden [15]. Furthermore, the dilemma of competing against the traditional offer might occur [18] , which happened in Company D. The solution was to set criteria for when the IPSOs were to be sold, namely when a new product was sold and if the customer currently did not have a service agreement with the company. Not only the company and the customer can have a traditional mindset, this also applies to retailers who prefer the traditional way of selling products [18]. The companies then need to support the retailers and provide concrete help such as the calculation tool Company E developed. This traditional mindset is not always an issue, which has been illustrated by that the retailers for one of the companies already sold IPSOs. In most cases, however, education for the retailers has been needed.

4.4 Customer relationship

The change of the way the companies approach and interact with the customers has been emphasized by most of the companies. This is something that has been frequently discussed in previous research in the area [1, 14]. The relationships have become longer and more frequent, but there is also a requirement of transparency, both from the provider and the customer and here the openness of the customers varies according to one company. The lack of trust makes the customer unwilling to provide the information needed to realize a great offer [20]. This has for some companies made it difficult to provide the offerings since mutual cooperation is of importance. To achieve cooperation and transparency the customers need to trust the provider and this is why the sales person is of utmost importance. This role has changed significantly and must now be more of a customer advisor than a salesperson [21]. The role of a Key Account Manager could be the way of handling both service and products. This is also one of the skills needed to be acquired by companies when starting to sell IPSOs [1]. The important relationship between the provider, the KAM and the customer is highlighted with the double arrow between the two actors. The customer relationships are of high importance when combining industrial product/service systems with product remanufacuting in order to retrieve used products that are in good conditions [22].

4.5 Increasingly more involvement of external actors

A few of the interviewed companies have made changes concerning their suppliers, Company B involves them to a greater extent and Company C emphasizes the importance of a good relationship to the supplier. The increased involvement of suppliers is shown as a double arrow between the IPSO provider and the supplier box. Furthermore, Company C sees potential in involving more external actors to create new offerings. Previous research has highlighted the need for changed or new networks needed to develop and provide IPSOs such as new distribution channels [4], research networks and regional and sectorial networks [23]. The main focus for the interviewed companies has been internal changes and the changed relationship with the customer. This is probably related to the fact that most of them have not yet been an IPSO provider for more than a few years and they are still focusing on developing and selling their current offer. When they have become more mature in their new role it is likely that they will include more external actors to be able to expand their offers or develop new ones. Therefore the arrow between the IPSO provider and the box for other external actors in Figure 2 has been dashed in the progress of the companies to develop these relationships more.

5 CONCLUSIONS

This paper aims to answer what has changed for the organization of the companies internally and externally since they started to provide IPSOs. This section describes how the paper specific research questions have been answered:

5.1 How and why has the organization within the companies changed when starting to provide IPSOs?

Changes within the company organizations have been necessary for all the interviewed companies. A critical factor has been the need for a change in the role of the sales person. The new type of sales requires a new competence, namely knowledge of how to sell IPSOs since it is more complex. The need for Key Account Manager positions responsible for the customers is advisable. These persons need understanding of IPSOs, a longer profit perspective than for traditional sales and also mandate to make customer decisions.

The importance of management support for the new way of doing business and for the service focus within the organization have also been discussed as important factors as well as a focus on cross-functional teams to develop and improve the offers, both services and products.

Changes have also been made within the service organization in the companies. New routines for the service technicians and more access to operational information are examples of these changes. The operational information is used by the companies to improve and develop the offer and also make improvements in the maintenance work. This makes the life cycle of the product longer, which is both economically and environmentally beneficial.

5.2 How and why have the relationships and the co-operation with external actors changed for the companies when starting to provide IPSOs?

The networks around the companies have changed, mainly through longer and closer relationships to the customer. Building long-term relationships with the customer is needed to be able to develop and implement the IPSOs in a satisfying way. This requires transparency and to achieve this transparency trust has to be built between the provider and the customer. In general, customers of manufacturing companies have a traditional mindset and trust is also needed to convince the customer of the new way of selling, i.e. the IPSO way. For organizations using retailers the needs for support and education concerning the new offers and the way they are sold have been required.

Other changes including external actors are primarily still in the planning stage. A few companies have started to involve the suppliers to a larger extent and they see potential in those types of co-operations and argue the importance of having good relationships with the suppliers.

The next step is to further involve external actors e.g. suppliers and other external actors such as other companies or organizations. The way of using external actors to expand the offers and develop them even further is a potential development indicated by several of the companies but for now it is not much more than an indication. The interviewed companies have in general only been IPSO providers for a few years and so far the main focus has been on internal changes needed and the relationship with the customers. The companies are starting out with changes in their internal organization and the external relationships that already exist. On the other hand, more internal changes will have to be made if a new external actor becomes involved since all parts are connected and work together to be able to provide IPSOs.

5.3 Future research

It would be of interest to keep following the companies on their way to become full-fledged providers of IPSOs. To return to the companies to e.g. see how the potential relationships and co-operations between the providers and external actors are developing. So far there have only been vague indications of these possibilities, but the ideas are there.

6 ACKNOWLEDGEMENTS

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7 REFERENCES

[1] Brady, A., A. Davies, and D.M. Gann, Creating value by delivering integrated solutions. International Journal of Project Management, 2005. 23(5): p. 360–365.

[2] Lindahl, M. and G. Ölundh. The Meaning of Functional Sales. in Life Cycle Engineering: Challenges and Opportunities: 8th International Seminar on Life Cycle Engineering. 2001. Varna, Bulgaria: CIRP.

[3] Lindahl, M., T. Sakao, E. Sundin, and Y. Shimomura, Product/Service Systems Experiences – an International Survey of Swedish, Japanese, Italian and German Manufacturing Companies, in CIRP Industrial Product-Service Systems (IPS²) Conference. 2009, Cranfield University: Cranfield, The United Kingdom.

[4] Oliva, R. and R. Kallenberg, Managing the transition from products to services. International Journal of Service Industry Management, 2003. 14(2): p. 160-172.

[5] Sundin, E., M. Lindahl, and L. H., Environmental and Economic Benefits of Industrial Product/Service Systems, in CIRP IPS2 Conference. 2010: Linköping, Sweden.

[6] Calminder, T., Genomgång av svensk litteratur inom området Integrerade Produkt- och TjänsteErbjudanden. 2009, Institutionen för Ekonomisk och Industriell Utveckling, Linköpings Universitet, LIU-IEI-R-- 09/0071--SE: Linköping. p. 61.

[7] Östlin, J., M. Lindahl, and E. Sundin. Managing Functional Sales Systems - Important Aspects for Making Functional Sales an Effective Business System. in Proceedings of 10th International Conference of Sustainable Innovation. 2006. Farnham, UK.

[8] Lindahl, M., T. Sakao, and A. Öhrwall Rönnbäck, Business Implications of Integrated Product and Service Offerings, in CIRP Industrial Product-Service Systems (IPS²) Conference. 2009: Cranfield University, Cranfield.

[9] Mont, O., Drivers and barriers for shifting towards more service-oriented businesses: Analysis of the PSS field and contributions from Sweden. The Journal of Sustainable Product Design, Kluwer Academic Publishers. Printed in the Netherlands, 2002. 2: p. 89-103.

[10] Edvardsson, B., A. Gustafsson, M.D. Johnson, and B. Sandén, New Service Development and Innovation in the New Economy. 2000, Lund, Sweden: Studentlitteratur AB.

[11] Heiko, G., E. Fleisch, and T. Friedl, Overcoming the Service Paradox in Manufacturing Companies. European Management Journal, 2005. 23(1): p. 14-26.

[12] Lindahl, M., E. Sundin, Y. Shimomura, and T. Sakao, An Outline of an Interactive Model for Service Engineering of Functional Sales, in International Design Conference - Design 2006. 2006: Dubrovnik.

[13] Ölundh, G. and S. Ritzen, Funktionsförsäljning och produkters miljöaspekter – en studie i tre svenska tillverkningsföretag. 2002, Naturvårdsverket, ISBN 91-620-5234-9: Stockholm. p. 40.

[14] Söderström, J., Från produkt till tjänst - Utveckling av affärs- och miljöstrategier i produktorienterade företag, in Handelshögskolan. 2004, Stockholm University: Stockholm.

[15] Sundin, E., G. Ölundh Sandström, M. Lindahl, A. Öhrwall Rönnbäck, T. Sakao, and T. Larsson, Challenges for Industrial Product/Service Systems: Experiences from a learning network of large companies, in CIRP Industrial Product-Service Systems (IPS²) Conference. 2009: Cranfield University, Cranfield, The United Kingdom.

[16] Sundin, E., M. Lindahl, and W. Ijomah, Product Design for Product/Service Systems : design experiences from Swedish industry. Journal of Manufacturing Technology Management, 2009. 20(5): p. 723-753.

[17] Alonso-Rasgado, T., G. Thompson, and B.-O. Elfström, The design of functional (total care) products. Journal of Engineering Design, 2004. 15(6): p. 515-540.

[18] Berggren, C. and M. Björkman, Funktionsförsäljning/funktionsupphandling för hållbar tillväxt - Idépromemoria och kunskapsöversikt. 2002.

[19] Sakao, T., G. Ölundh-Sandström, and D. Matzen, Framing Design Research for Servicification through Extending PSS-Design Research. Journal of Manufacturing Technology Management, 2009. 20(5): p. 754-778.

[20] Mont, O., Introducing and developing a Product-Service System (PSS) concept in Sweden. 2001, Financed by Nutek: Stockholm, Sweden.

[21] Stahel, W., The functional economy: Cultural and organisational change, in The Industrial Green Game. 1997, National Academy Press: Washington DC. p. 91-100.

[22] Östlin, J., E. Sundin, and M. Björkman, Importance of closed-loop supply chain relationships for Product Manufacturing. International Journal of Production Economics, 2008. 115(2): p. 336-348.

[23] Mont, O.K., Clarifying the concept of product-service system. Journal of Cleaner Production, 2002. 10(3): p. 237-245.

Towards Adaptable Industrial Product-Service Systems (IPS²) with an Adaptive Change Management

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Abstract

Compared to single physical products or services, IPS² are characterized by a very high degree of dynamic changes not only during their planning, but throughout their entire life cycle. These changes have to be managed, tracked and documented by a change management process and supported by a change management system. As IPS² changes and change processes are very difficult to plan during the IPS² development phase, existing static and deterministic change management solutions are not appropriate to be used for IPS². This paper describes a new concept of an adaptive change management for IPS². The concept described allows for appropriate redesigning, adaption and execution of change processes of IPS² throughout its entire life cycle to carry out an IPS² change most efficiently with regard to time and costs.

Keywords

Industrial Product Service Systems (IPS²), Engineering Change Management (ECM), Adaptive Processes, Adaptability

1 INTRODUCTION

Industrial Product Service Systems (IPS²) is defined as "an integrated industrial product and service offering that delivers value in use" [1]. In this respect, it is the lasting satisfaction of the customer benefit that constitutes the central aspect of the IPS² approach. Dynamic adaptability and changeability of IPS² throughout the entire IPS² life cycle are hard to plan deterministically during the development phase. Yet they are a basic requirement for its successful implementation and application. To fulfil these conditions, change management processes have to possess a high degree of adaptability and flexibility, i.e. they have to adapt appropriately and respond promptly to new situations during their runtime.

This paper describes the concept of an adaptive Engineering Change Management (ECM) for IPS² which allows for appropriate redesigning, adapting and executing of change processes of IPS² throughout its entire life cycle in order to carry out an IPS² change most efficiently with regard to time and costs.

The concept presented in this paper has been developed in the research project Transregio 29 "Industrial Product-Service Systems – Dynamic Interdependency of Product and Service in the Production Area", which is funded by the German Research Foundation (DFG).

2 CURRENT SITUATION

Competitive IPS² providers must be able to adapt their share of products and services within an integrated IPS² to quickly respond to unforeseeable changes in their environment throughout its lifecycle. Various factors, the so called *change drivers*, can cause such changes. They can be technological (e.g. emergence of new technologies), environmental (e.g. increasing shortage of resources), political (e.g. legislation amendments), social (e.g. new customer demands), or economic (e.g. decrease in customer demand due to the current economic crisis). Hence the prompt reaction to these unpredictable changes along the overall IPS² lifecycle has a significant impact on the economic success of the companies involved in the IPS² network. This challenge can only be met by an adaptive engineering change management.

In the last decades, several methods and standards such as part 4 of DIN 199 (Technical Product Documentation), ISO 10007:2003 (guidelines for configuration management) and Release Management and Recommendation VDA 4965 (Engineering Change Management) have been developed for the management of technical changes. The focus of these methods and standards is the management of technical changes of physical products (not of services), which is why they are strongly geared towards the life cycle processes of these products.

However, the life cycle processes of IPS² are much more complex than those of technical products. For instance, IPS² producers, as a rule, are also responsible for the delivery of IPS² and have to optimize it and to dynamically and promptly adapt it to customer needs during the use phase. Therefore, current change management methods and standards can only consider specific characteristics of IPS² to a small extent and support an efficient implementation of IPS² change management processes in a limited way. The following points serve as examples for the most important weaknesses of current change management methods and standards with regard to IPS² change management:

- Existing change management methods focus exclusively on the development and manufacturing phases and neglect the delivery and use phases.
- Existing change management methods cannot sufficiently consider the complexity of IPS², which arises from the networking and mutual influence of technical products and services as well as change dynamics during the delivery and use phases.
- Previous change management methods do not provide a fast reaction to changes that occur within the delivery and use phases of IPS².
- Existing change management methods only support or provide static and deterministic change processes and do not provide an appropriate adaptation during the process runtime.

- Existing change management methods do not allow an integrated view of the product and service share of an IPS².
- Existing change management methods limit corporate innovation skills and the responsiveness to unpredictable changes.

3 REQUIREMENTS

Current obstacles to IPS² adaptability are deterministic and fix-planned static change management processes, which serve as a basis for the implementation of all activities within an Engineering Change Management (ECM).

Such processes limit corporate innovation skills and the responsiveness to unforeseeable changes. Within a given scope, adaptive change processes can make an important contribution to IPS² adaptability. They automatically respond and immediately adjust to new conditions. Thus ECM process buildup and implementation priorities of the process activities must be determined automatically in real time and be adequate to and in accordance with the conditions that apply at that time.

Adaptive change processes enhance IPS² adaptability through:

- an integrated consideration and analysis of the technical products and services as a hybrid performance package (IPS²) during ECM process implementation.
- a continuous and prompt optimization of the various interacting IPS² modules (i.e. technical product and service) to grant the best possible customer benefit.
- enhancement of the real time responsiveness of the IPS² provider (fast and adequate to the situation) to the unpredictable and permanently changing customer requirements during IPS² delivery and use phase.
- real time definition of executable ECM process activities and their execution priorities depending on ECM contents, context, objectives, and the current conditions (i.e. adaptive process design and management).
- prompt configuration and immediate startup (e.g. continuous real-time plan-and-execute rather than static plan-the-execution) [2].
- management of changes during IPS² development and delivery phases.
- taking into account all aspects of the complexity of IPS² during the change management, which arise through strong networking and IPS² modules interdependency and which are thus not directly visible to IPS² developers.
- taking into consideration the great uncertainties which arise in IPS² development and delivery phase during ECM process execution.
- ascertaining the effects and determining the spread of IPS² module change on the whole IPS² and its environment throughout its lifecycle.
- auto-ascertaining ECM process variations in the implementation of IPS² changes and adaptations.
- integration and close interaction of all IPS² network partners during IPS² change (product manufacturers, service providers, IPS² providers, IPS² customers, etc.).

4 RELATED WORK

In recent years, numerous pieces of work have been carried out with the focus on change management. In the following, the outcomes of the crucial projects that are related to this work project are listed and briefly discussed:

The work of Burmeister et al. [3] is among the important works that deal with the issue of developing agile process modeling methods. For this, they have combined the agent technology and the goal-oriented modeling method to model und implement agile business processes. The developed approach has been applied and validated in line with a case study in the domain of Engineering Change Management of technical products. The demands arising due to the high complexity and the permanent changeability of IPS² have not been taken into account in this work.

In several research projects, Eckert et al. [4, 5, 6] have addressed the question of how designers can be made aware of the impact of a proposed change before they carry it out. The main result of these projects is the implementation of a tool to evaluate change proposals during ongoing design processes where the state of the development of parts is taken into account. This presents an extension of the Cambridge Change Prediction Method, which assesses the risk of changes propagating between two parts. The research works have only concentrated on the change of technical products arising during the design phase and they have not considered those that arise during the delivery and use phase of technical products relating to the added services.

Conrad et al. [7] also propose an approach to support the processes of analyzing and assessing the effects of changes in the product development process. This approach is based on the CPM/PDD theory (Characteristics-Properties Modelling/Property-Driven Development) and the FMEA method (Failure Modes and Effects Analysis). The proposed approach only deals with the effect of changes in the CAD models during the design phases of technical products.

Amaral et al. [8] suggest an NPD model (New Product Development) named PDNet, the singular characteristic of which is the integration between a business process reference, a maturity model and a change management model in order to support the full product development change cycle. This work also focuses on the development phase of technical products and does not consider the special requirements of the IPS² change management.

In order to investigate the behavior of change management processes in practical work and to develop a practice close change management approach, several case studies [9, 10, 11] have been carried out in various industrial sectors. However, the aspects of the adaptive change management for IPS² have not been in the focus of these approaches.

5 CURRENT PROCESS MANAGEMENT METHODS

Since the nineties, several process management approaches and methods (e.g. ARIS, SA, OMEGA, SADT) have been developed to design, manage, execute and control ECM processes and related data. They are commonly known as BPR (Business Process Reengineering), BPM (Business Process Management) or CPI (Continuous Process Improvement).

These methods have been implemented into various IT tools (e.g. ARIS Design Platform, PAVONE ProcessModeler, Bonapart) to support companies with the carrying out of company specific ECM processes. In view of ECM process adaptability and thus also company adaptability, however, current process management methods show the following weaknesses among others:

- The processes can only be mapped as fixed and static sequences or as a concatenation of activities.
- Existing Continuous Process Improvement (CPI) methods aim at improving adaptation of process models to changing boundary conditions in order to optimize business processes [12]. However, these methods only allow the presentation of fixed sequences of activities. Thus, the adaptation to changed boundary conditions must be made a priori. This is a very time-consuming process, as the process manager does not receive systematic support in their solution determination.
- Objectives and goals of a business process are not defined and modeled explicitly and are thus not always visible. Hence, adaptations and changes to processes evoke the necessity to ascertain that, in the end, the original aim of the process is indeed reached.
- Process flexibility can only be achieved by defining additional process variants. That way processes become ever more extensive, unclear and complex.
- In most cases the executed processes do not correspond to those planned a priori, as the implementation of change processes is rather elaborate and expensive ("shadow processes" may arise).

Adaptive ECM processes are important prerequisites for IPS² adaptability. To design ECM processes, adaptively new process management methods are required. These methods are supposed to warrant systematic process design and control. On the other hand, they need to leave enough space for creativity and permanent changeability. ECM processes must thus be designed and executed in a way that ensures the continuous IPS² adaptability to new and unpredictable situations.

The new process management methods need to be goal-oriented, not activity-oriented. Thus, ECM processes are to be defined and modeled in real time, i.e. during process runtime whilst taking into account newly occurring conditions and requirements. They should no longer be defined a priori as fixed processes. This will also render the entire process clearer and more intelligible, which is a prerequisite for a fast adaptation, change and transformation of ECM processes.

6 GOAL-ORIENTED PROCESS MANAGEMENT METHOD

This section introduces a new goal-oriented process management method for modeling adaptive processes. The method is based on the Business Process Management approach by [3], which was defined by Daimler AG and Whitestein Technologies.

The aim of this new goal-oriented management method is to replace those processes that are planned in a fixed and sequential way and a priori, with dynamic and adaptive processes. When executed, the latter allow for near-independent, real time responses in specified situations.

To reach these goals, the processes are defined and modeled by the new method according to the following principles (Figure 1):

- First and foremost, the processes are intended to capture and characterize the defined business goal, independent of the solution. Goals can be construed into further sub goals.
- Each goal is assigned a generic implementation plan, which is merely made of independent tasks or activities without any predefined execution sequence or priorities.
- The specifications of and the order in which tasks or activities are carried out are determined during process execution, in real time, and depending on the main process issues and the current situation (rules) of the process.

Within the process, the tasks or activities are defined as intelligent agents. They represent the appropriate road to the (sub) goal, appropriately, independently, and subject to the rules. They also provide the process manager with recommendations for decision-making in view of the occurrence of further process steps.

These agents are modeled as modular, intelligent services according to the BDI principle (Belief-Desire-Intentions) [13]. The services are fitted with assumptions about their environment (Belief), knowledge of the target issue (Desire), and the purposes of how that issue can be reached (Intentions). To possess the required knowledge (Belief, Desire and Intentions) during process runtime, the intelligent services need access to process ontology. The process ontology then serve as a common basis for process data management and as a source of knowledge generation for real time process control (Figure 2).

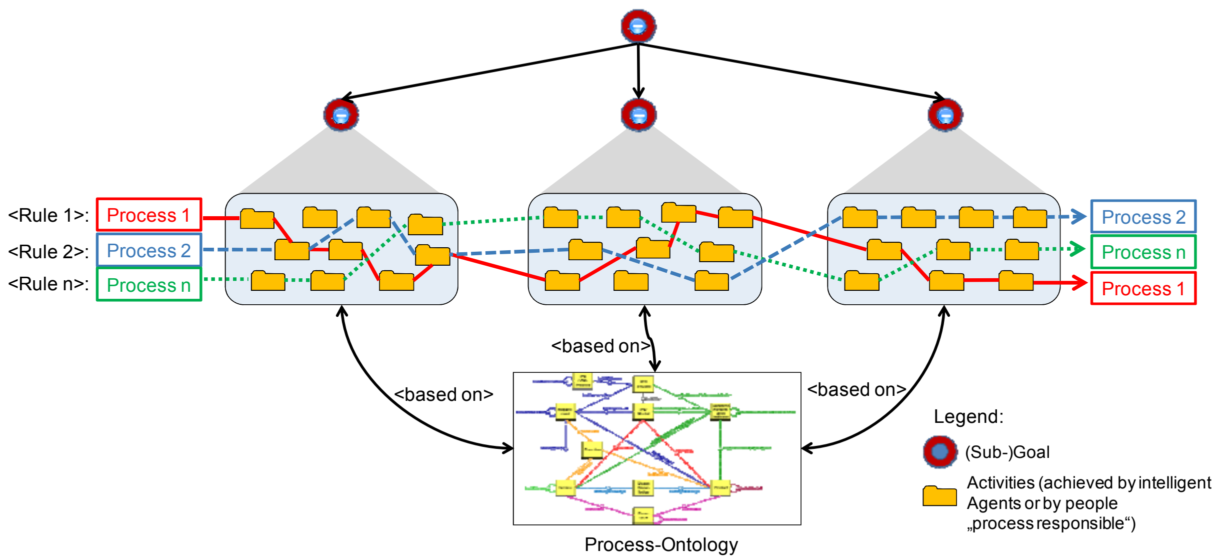

Figure 1: Goal-oriented process management method

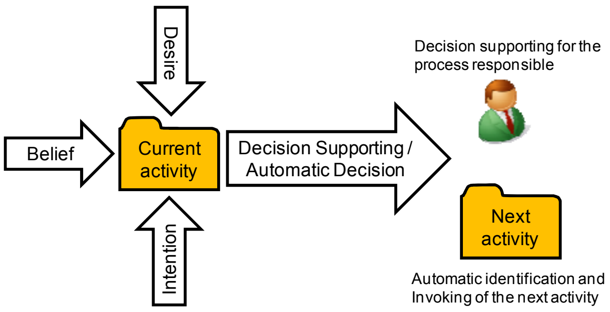

Figure 2: Intelligent agents (process activity) according to the BDI principle

The main differences between current process management methods and the new goal-oriented method are summarized in Table 1.

Characteristics	Current Methods	New Method
process modelling	fixed sequence of activities	goals, activities, rules
process optimization	in the design phase	in the execution phase (real time)
process control	central	decentralized / autonomous
IT technology	Rigid Workflow Management System	Adaptive Service Oriented Architecture
Separation Process Definition/ Execution	yes	no
Sequence of Process Events	fixed (in the design phase: fixed process chain)	adaptive (in the execution phase: real time sequence definition)

Table 1: Comparison of current process management methods and the goal-oriented method.

Based on the new defined process management method, process execution and control resemble a GPS system: Once the goals and sub goals as well as any further boundary conditions have been entered, the route is calculated dynamically in real time taking into account all possible disturbances. Divisional routes are chosen autonomously, or they are presented to the driver's assistance.

7 ADAPTIVE CHANGE MANAGEMENT APPROACH FOR IPS²

This section introduces an approach to an adaptive change management that supports and enhances IPS² changeability and adaptability. At the core of this approach stands an adaptive ECM process (Engineering Change Management Process) that maps the activities of an IPS² change order based on the goal-oriented principle (as described in section 6). In addition, this paper defines a top level IPS² ontology as a knowledge source of real time ECM process execution and control.

7.1 Adaptive ECM Process for IPS²

The adaptive ECM process for IPS² has been developed by means of the defined goal-oriented management method. The basis for ECM process definition is VDA recommendation VDA4965 Part 1 "Engineering Change Management" (ECM). This recommendation supplies a standard and a generic description of change processes of technical products along the entire supply chain in the automotive industry [14]. In this work, the ECM-process (Engineering Change Management process) of VDA4965 has been extended by further IPS²-specific aspects in order to enable an integrated change management of a whole IPS².

The main goal of the adaptive ECM process „IPS²_ECM_Managed" is management, i.e. the execution and control of an IPS² change order. The accomplishment of this main goal presupposes the accomplishment of several sub goals (Figure 3). First of all, the requirements or wishes for an IPS² change are registered and their relevance and priority are checked: „IPS²_ECM_Inquired". Based on the results of the preceding goal, a Change Request is made which specifies all the details of the change: „IPS²_ECM_Created". The next ECM process goal is a comprehensive and profound technical, logistical and economic analysis of IPS² change: „IPS²_ECM_Analysed". Subsequently, IPS² change is evaluated and commented by various experts (e.g. development, production, logistics and service): „IPS²_ECM_Commented". Finally, based on the evaluation and comments, a decision regarding the execution of IPS² change is made: „IPS²_ECM_Decided".

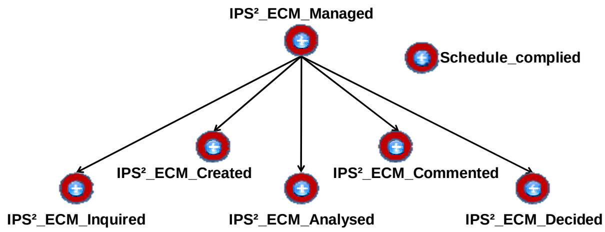

Figure 3: Overview of the adaptive Engineering Change Management (ECM) for IPS²

At the beginning of an ECM process, organizational restrictions, e.g. the maximal processing time, can be defined: „schedule complied". To accomplish this organizational goal, ECM process control automatically determines the optimal process path.

The above-mentioned goals are accomplished by invoking intelligent, modular services, which are mapped as modular, isolated tasks or activities in this ECM process. Tables 2 and 3 show examples in excerpts of the activities to achieve the goals "IPS²_ECM_Inquired" and "IPS²_ECM_Analysed" respectively.

Several process parameters have been defined for real time execution and control of the ECM process. These can be set at the beginning of or during process execution on the (sub) goal and activity level. Operators (e.g. AND, OR, XOR, If, Then) define a priori and in real time rules. By use of these rules the required (sub) goals and activities as well as their execution sequence and process runtime can be determined to ascertain optimal ECM process flow. Table 4 shows excerpts from the process parameters defined in this work including their possible parameter values.

Activities	Description
change registration	register requirements and wishes for IPS² change
change classification and prioritization	• classify changes to be performed (e.g. product change, service change, technical change) • prioritize changes to be performed (e.g. high, medium, low)
condition for ECM creation checking	check requirements for the initiation of an ECM process (e.g. customer relevance, manufacturer relevance, security relevance, competition relevance)
concerned parties determination	determine areas or parties concerned by the changes (e.g. development, service, manufacturer, customer, logistics service provider).
change- responsible determination	determine areas or parties responsible for the execution of the changes (e.g. development, service, manufacturer, customer, logistics service provider)
next goal determination	based on the results of the individual activities the next ECM process goal is determined

Table 2: Excerpts from the activities to achieve the goal "IPS²_ECM_Inquired"

Activity	Description
new IPS² requirements identification	identify change-related new IPS² requirements
new IPS² function identification	identify change-related new IPS² functions
concerned IPS² function identification	identify change-related concerned IPS² functions
concerned IPS² modules identification	identify change-related concerned IPS² modules (products and services)
next goal determination	Based on the results of the individual activities, the next ECM process goal is determined.

Table 3: Excerpts from the activities to achieve the goal "IPS²_ECM_Analysed"

7.2 Top Level IPS² Ontology

To manage the entire IPS² life cycle, a top level ontology has been developed within the research project Transregio 29 "Industrial Product-Service Systems – Dynamic Interdependency of Product and Service in the Production Area". It is based on the STEP reference model "AP 214" and consists of several classes and relations mapping and describing the various IPS² modules (e.g. technical product, service, function, requirement), the entire IPS² structure as well as IPS² life cycle management processes (e.g. change management, release management). In addition, the top level IPS² ontology has been augmented by axioms that automatically generate knowledge, conclusions, and relations based on IPS² data. This ontology has been used throughout this work as a source of knowledge to provide all necessary information regarding process parameters and rules of real time ECM process execution and control.

Parameter	Parameter Value
ECM_Activator	• IPS²_Provider • Product_Manufacturer • IPS²_Customer • Service_Provider
ECM_Reason	• IPS²_Enhancement • IPS²_Optimization • Product_Optimization • Service_Optimization • Customer_Wish • Quality_Problems • legislation amendment
Change_Complexity	• High • Medium • Low
Design_Relevance	• Product_Design • Service_Design • IPS²_Design • No
Cost_Relevance	• Product_Change_Cost • Service_Change_Cost • IPS²_Change_Cost • No
Safety_Relevance	• Product_Safety • Service_Safety • IPS²_Safety • No
Quality_Relevance	• Product_Quality • Service_Quality • IPS²_Quality • No
IPS²_Use_Model	• Result_Oriented • Function_Oriented • Availability_Oriented
Necessity	• High • Medium • Low
Technical_Risk	• High • Medium • Low
Financial _Risk	• High • Medium • Low
Schedule_Risk	• High • Medium • Low

Table 4: Excerpt from the ECM process parameters

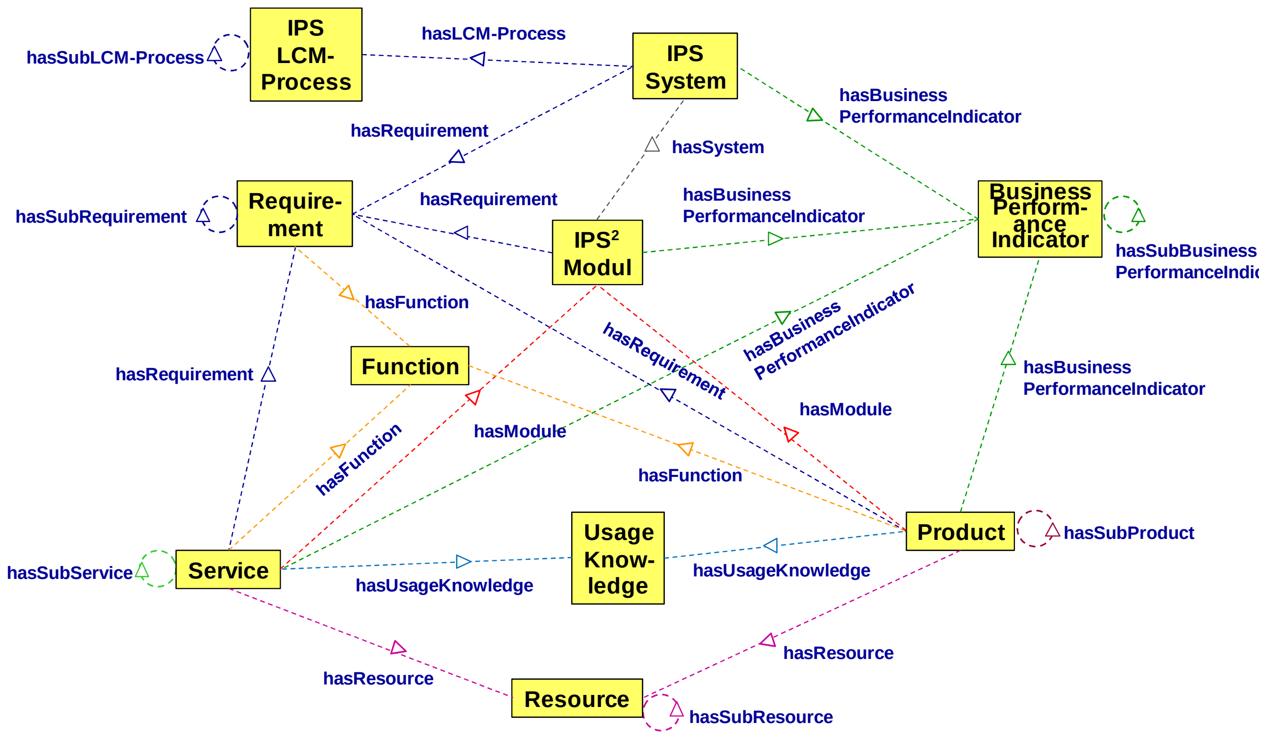

Figure 4: Overview of the top level IPS² ontology

Figure 4 shows the top level class structure of the developed IPS² ontology, which is an extract of the complete ontology model. A comprehensive description of all IPS² ontology elements and the respective opportunities for generating knowledge, conclusions and relations has already been presented in a previous paper [15].

8 IMPLEMENTATION OF THE CHANGE MANAGEMENT APPROACH FOR IPS²

The standard process description language WS-BREL4People (Web Services – Business Process Execution Language for People) has been used for the modeling and prototypical implementation of the developed change management approach for IPS². WS-BPEL4People is an XML-based language that describes business processes the individual activities of which are implemented by modular, isolated web services [16].

As of late, WS-BPEL4People has been implemented into many IT tools, so called BPEL editors. By use of these BPEL editors, a process and its activities can be described and mapped graphically. However, this can also be done using different workflow modeling techniques. Unlike other techniques, it can generate an executable XML process code from the graphically modeled business process directly and in real time.

Figure 5 shows the prototypical realization of the goal “IPS²_ECM_Inquired” and the related activities, which have been implemented as modular web services.

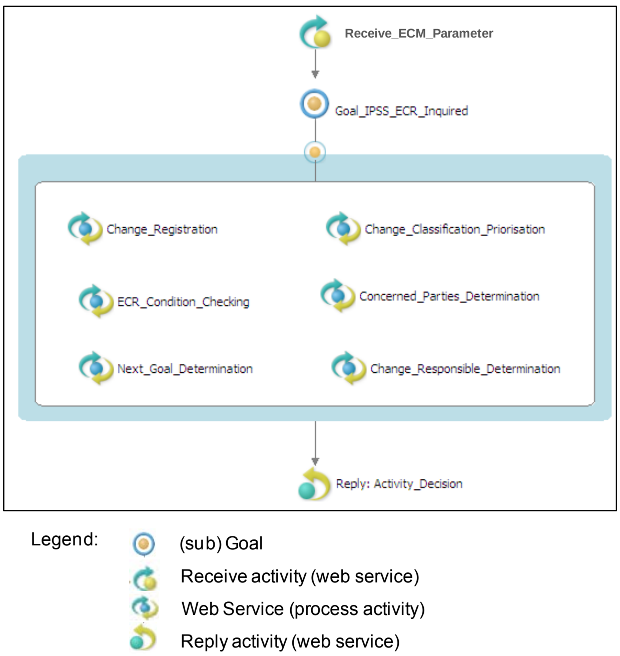

Figure 5: Modelling of the goal “IPS²_ECM_Inquired” by using of the WS-BPEL4People

9 CASE STUDY

A case study has been carried out to validate the approach developed in this work. The IPS² treated in this case study is an Electrical Discharge Machine (EDM) [17]. These machines are mostly used in the manufacturing of micro-structured work pieces by using electroerosion techniques. The customer (IPS²_Customer) who owns the EDM machine gives the supplier of the EDM machine (IPS²_Provider) the task to upgrade the existing machine to also manufacture rotational-symmetric µm work pieces such as, for instance, clock spindles [18, 19]. While executing these changes the following boundary conditions must be adhered to:

- Additional customer employees training is necessary to produce µm parts.
- Both customer and IPS² provider employees must be deployed to produce µm work pieces.
- The change estimate does not exceed €100,000.
- The upgraded machine possesses a minimal technical availability of 90%.
- The IPS² change is implemented within a maximum of 6 months.
- Annual maintenance by the IPS² provider does not exceed €10,000 and does not use more than 4 working days.
- The entire ECR process is carried out within a maximum of 4 weeks.

In view of the description of the change and the boundary conditions, the ECM process parameters (see Table 5) have been defined. These parameters have partly been concluded from the IPS² ontology and partly been input (acquired from the change context or from experience) by the process user.

Parameter	Parameter Value
ECM_Activator	IPS²_Customer
ECM_Reason	IPS²_Enhancement
Change_Complexity	High (basic IPS² structure is changed)
Design_Relevance	• Product_Design • Service_Design
Cost_Relevance	IPS²_Change_Cost ≤ 100;000 €
Safety_Relevance	No
Quality_Relevance	IPS²_Quality
IPS²_Use_Model	Availability_Oriented ≥ 90%
Necessity	High
Technical_Risk	High
Financial _Risk	High
Schedule_Risk	High

Table 5: Excerpt from the ECM process parameter for EDM machine enhancement

In this case study the execution of the ECM process has lead to the following main decisions [18, 19] (Figure 6):

- Enhancing the EDM machine by an additional portable rotary spindle.
- This rotary spindle is mounted on the machine table of the EDM system by means of an adaptive clamping system.
- This rotary spindle is incorporated into the production process by an integrated IT control system.
- The entire maintenance concept of the EDM machine is adjusted.
- The entire training concept of the EDM machine is adjusted.

10 CONCLUSION AND OUTLOOK

IPS² is developed to permanently meet the demands of the customer through the synergy of technical products and industrial services. Its prerequisites are integrated planning, development, delivery, and use of both service quotas, as well as their dynamic adaptability throughout the entire IPS² life cycle.

To support this approach, this paper has treated the development of a new goal-oriented process management method. Contrary to the classical process management methods it allows for an adaptive process design. By applying this new method an adaptive change management approach for IPS² has been developed. This approach enables adaptive responses in the ECM process, i.e. during their execution ECM processes can, to a certain degree, respond and adapt to specific situations autonomously and in real time.

In the course of this work, the developed adaptive change management approach for IPS² has been prototypically implemented by means of the standard process description language WS-BPEL4People. A case study of an IPS² (EDM machine) change management has validated the approach.

In the future, further case studies will be conducted in various other business sectors. Their aims are to enhance ECM process parameters, rules and the axioms of the IPS² ontology to increase the self-adaptivity of ECM processes and the transferability of the solutions to other branches.

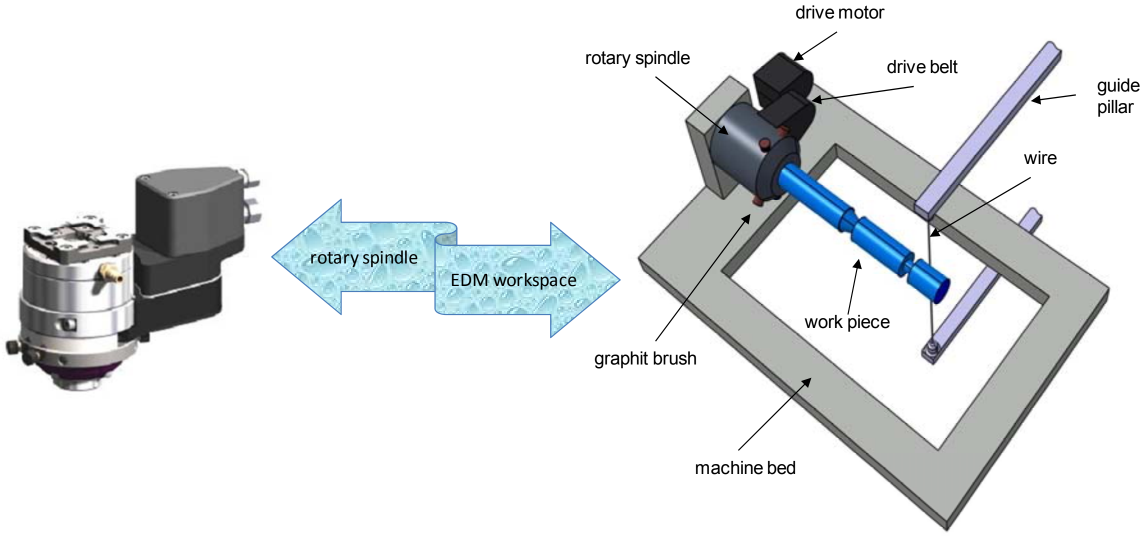

Figure 6: Illustration of the enhancement of the EDM machine.

11 ACKNOWLEDGMENTS

We express our sincere thanks to the Deutsche Forschungsgemeinschaft (DFG) for financing this research within the Collaborative Research Project SFB/TR29 on Industrial Product-Service Systems – Dynamic Interdependency of Products and Services in the Production Area.

12 REFERENCES

[1] Datta, P. P., Roy, R., 2009, Cost Modelling Techniques for Availability Type Service Support Contracts: A Literature Review and Empirical Study, Proceedings of the 1st CIRP IPS² Conference, Cranfield, UK, 216- 223.

[2] Kernland, M., Hoeffleur, O., Felber, M., 2008, The Agility Challenge in Business Process Management, in Product Data Journal, Vol 1/2008, ed. by Prostep iViP e.V., Darmstadt, Germany, 40-42.

[3] Burmeister, B., Arnold, M., Copaciu, F., Rimmassa, G., 2008, BDI-Agents for Agile Goal-Oriented Business Processes, Proceedings of the 7th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2008), Estorial, Portugal.

[4] Ariyo, O., Keller, R., Eckert, C. M., Clarkson, P. J., 2007, Predicting Change Propagation on Different Levels of Granularity: An Algorithmic View, Proceedings of the International Conference on Engineering Design (ICED 07), Paris, France.

[5] Jarratt, T., Eckert, C., Clarkson, P. J., 2004, The Benefits of Predicting Change in Complex Products: Application Areas of a DSM-Based Prediction Tool, Proceedings of the International Design Conference (DESIGN 2004), Dubrovnik, Croatia.

[6] Eger, Tido, Eckert, Claudia M., Clarkson, P. John, 2007, Engineering Change Analysis During Ongoing Product Development, Proceedings of the International Conference on Engineering Design (ICED 07), Paris, France.

[7] Conrad, Jan, Deubel, Till, Köhler, Christian, Wanke, Sören, Weber, Christian, 2007, Combining the CPM/PDD Theory and FMEA-Methodology for an Improved Engineering Change Management, Proceedings of the International Conference on Engineering Design (ICED 07), Paris, France.

[8] Amaral, D. C., Rozenfeld, H., 2007, Integrating New Product Development Process References with Maturity and Change Management Models, Proceedings of the International Conference on Engineering Design (ICED 07), Paris, France.

[9] El Hani, M. A., Rivest, L., Fortin, C., 2007, Propagating engineering changes to manufacturing process planning: does PLM meet the need?, Proceedings of the International Conference on Product Lifecycle Management (PLM07), Milan, Italy.

[10] Pulkkinen, A., Riitahuhta, A., 2009, On the relation of business processes and engineering change management, Proceedings of the International Conference on Product Lifecycle Management (PLM09), Bath, UK.

[11] Tavcar, J., Duhovnik, J., 2004, Product Life Cycle Management in a Serial Production, Proceedings of the International Design Conference (DESIGN 2004), Dubrovnik, Croatia.

[12] Scheer, A.-W., 2002, Vom Geschäftsprozess zum Anwendungssystem, 4. Auflage, Springer Verlag, Berlin, Germany

[13] Roa, A. S., Georgeff, M. P., 1995, BDI Agents: From Theory to Practice, Proceedings of the 1st International Conference on Multi-Agent Systems, San Francisco, USA.

[14] Verband der Automobilindustrie (VDA), 2006, VDA 4965: Engineering Change Management (ECM) – Part 1 Engineering Change Request (ECM), Frankfurt, Germany.

[15] Abramovici, M., Neubach, M., Schulze, M., Spura, C., 2009, Metadata Reference Model for IPS² Lifecycle Management, Proceedings of the 1st CIRP IPS² Conference, Cranfield, UK, 268-272.

[16] Abramovici, M., Bellalouna, F., 2008, Service Oriented Architecture for the Integration of Domain-Specific PLM Systems within the Mechatronic Product Development, Proceedings of the 7th International Symposium on Tools and Methods of Competitive Engineering, (TMCE 2008), Vol. 2, Izmir, Turkey, 941-953.

[17] Abramovici, M., Neubach, M., Fathi, M., Holland, A., 2009, Knowledge-Based Feedback of Product Use Information into Product Development, Proceedings of the International Conference on Engineering Design (ICED 09), Stanford, USA.

[18] Richter, A., Sadek, T., Steven, M., Welp, E.G., 2009, Use-Oriented Business Models and Flexibility in Industrial Product-Service Systems, Proceedings of the 1st CIRP Industrial Product-Service Systems (IPS²) Conference, Cranfield, UK.

[19] Sadek, T., 2008, Ein modellorientierter Ansatz zur Konzeptentwicklung industrieller Produkt-Service Systeme, Dissertation, Ruhr-Universität Bochum, Bochum, Germany.

An Innovative Service Business using a Holistic Availability Management System

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Abstract

As a result of constantly growing market requirements and an increasing complexity of machining systems, rising demands emerge on machine productivity, as well as the need for flexibility and availability of production processes. Furthermore, this calls for an innovative and holistic availability management system, which ensures an availability increase by using a significant, process-accompanying and rule-based condition information system. In this information system all condition-relevant data, received from heterogeneous sources, is brought together on a homogeneous platform. Besides, a holistic solution is supported by the cooperation of manufacturers, suppliers and operators which guarantees the consideration of all possible availability losses regardless of their causes. This paper describes the technical challenge and a first holistic approach to develop such a system that ensures an optimized maintenance and production planning based on a reliable and convincing analysis of the actual condition of machines or production systems. With regard to this, chances arise to evolve different business models.

Keywords

Availability Management, Maintenance, Business Model

1 INTRODUCTION

Nowadays, production systems are either extremely versatile or highly productive. But market requirements and industry force a balance of those two divergent demands. Both aspects increase a company's dependence on the availability of their machines and systems, which is directly connected with the functional efficiency of several machine components. The demand to gain high productivity comes along with an increasing complexity of machining systems. In this context the availability of production processes is a crucial factor of success, especially for small- and medium-sized enterprises. [1], [2], [3]

Considering high purchase costs for production systems, a need arises for solutions to reduce downtime and therefore to avoid an economic loss. Furthermore, the impact of a downtime is much higher due to the growing complexity of production systems and also because of the increased coupling of production processes of multiple companies in a supply chain. In addition to that, the risk that seemingly small causes of malfunction are going to cause significant damage is also going up. To ensure the availability and furthermore increase it, there is a need for a significant evaluation - a reliable and convincing analysis - of the current condition of machines or production systems. This analysis coevally forms a basis for the optimisation of the maintenance activities. [1], [3]

The paper motivates and describes the technical challenge to develop a holistic rule-based, process-accompanying availability management system. This management system is not only consisting of condition monitoring tools, but involves also organisational aspects and machine control-data. The main task therefore is to connect both sensor- and machine control-data near real-time on the technical side and organisational data from the production planning. In this information system all condition-relevant data, received from the already mentioned heterogeneous sources, is brought together on a homogeneous platform. For this aim, the holistic solution has to be supported by the cooperation of manufacturers, suppliers (sensor producer, IT-specialist), service providers and operators, which guarantees the consideration of all possible availability losses regardless of their causes. [2], [3]

Following this concept, the holistic availability management builds up an innovative business model as a whole, as well as there are chances arising to evolve different business models for each participating partner in the availability management system. The paper thus also focuses on the systematisation of those availability-enhancing business models, which reveals a great variety of characteristics and technical possibilities to increase the availability. [4]

2 HOLISTIC AVAILABILITY MANAGEMENT SYSTEM

2.1 History of Maintenance

In recent years the basic understanding of maintenance has changed from the focus on the costs caused by maintenance activities to the costs which could be prevented by means of an efficient maintenance [5]. Furthermore, maintenance is no longer only a matter of physical machine care, inspection and repair of machines and systems. Many companies face the task of maintenance as a complex challenge. The central idea is still to maintain a machine's capability. But meanwhile also the elimination of weak spots -in a structured and systematic way-, as well as the continuous improvement of the functional reliability are taking centre stage [6]. Figure 1 shows the history and development of maintenance: starting with a quite trivial reactive maintenance (fire-fighting-strategy) beyond a preventive, acting maintenance, leading to a complex, need-based and condition-based maintenance supported by state-of-the-art technology. It is no longer reacting or preventing but monitoring, acting, adapting and optimising.

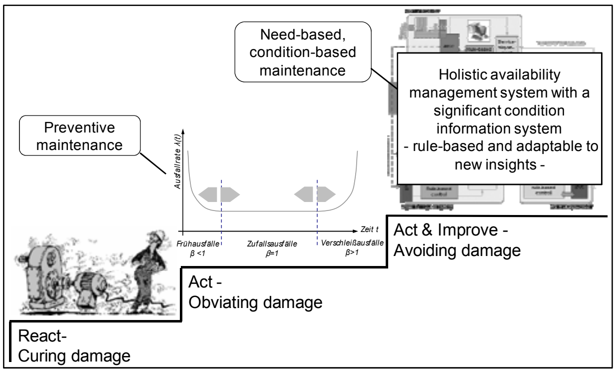

Figure 1: The history of maintenance.

2.2 Structure for an Availability Management System

Depending both on the field of application and the type of production system, there are a several different strategies to maintain a machine or a plant. As mentioned, there are, for example, reactive or preventive, in other words active maintenance strategies more or less using condition-based maintenance activities. Within the joint project VERA^{PRO}, initiated by the German Federal Ministry for Education and Research, a concept that enables a significant and meaningful assessment of the current machine condition and thus enables an optimisation for all the maintenance activities was developed. Thereby, the generation of machine data out of the field, provided by the operating company, builds up the basis for a rule-based condition analysis closely connected with process data. By the use of modern communication channels, there was a scenario developed and implemented where the machine manufacturer is able to analyse data of his already sold machines. In addition to that it is possible - particularly for the manufacturer of machines - to gain an overview across all production systems in order to detect manufacturing faults or breakdown patterns through the coupling of condition data with the data of the machine production process. By doing so, special measures, both to eliminate system defects and to adjust maintenance activities, could be initiated.

As well as there is the scope of action for the machine manufacturer, there arises a field of action for specialised service providers. With the aid of condition-based maintenance strategies the service provider guarantees a defined availability.

The realisation of the holistic availability management system with the involved and mandatory, different parties accounted for a substantial exchange of, at least in most instances, sensitive machine data. Therefore, a secure and anonymous data transfer was fundamental.

Within the availability management system a condition information system - on the basis of condition-based maintenance - was developed, which is able to combine special individual solutions (e.g. condition monitoring systems, remote services or maintenance plans) and consolidate comprehensive planning systems joined on one platform. The continual attainment of new insights about the correlation between condition data of production systems (generated by condition monitoring systems), product-related data (from production planning and control systems, quality systems or similar systems) and economic strategies as well as suitable measures to increase the availability were further aims of the availability management system. Those insights were transformed and transferred into a system of rules, located at the production system. The usage and adaptation of those rules led to continuously improved condition information. In order to implement an ideal management of availability, the cooperation of several interdisciplinary task managers as manufacturer, operator, sensor manufacturer, service provider, communication system manufacturer and maintenance management system manufacturer is necessary, which was supported by the consortium in the joint project (see Figure 2).

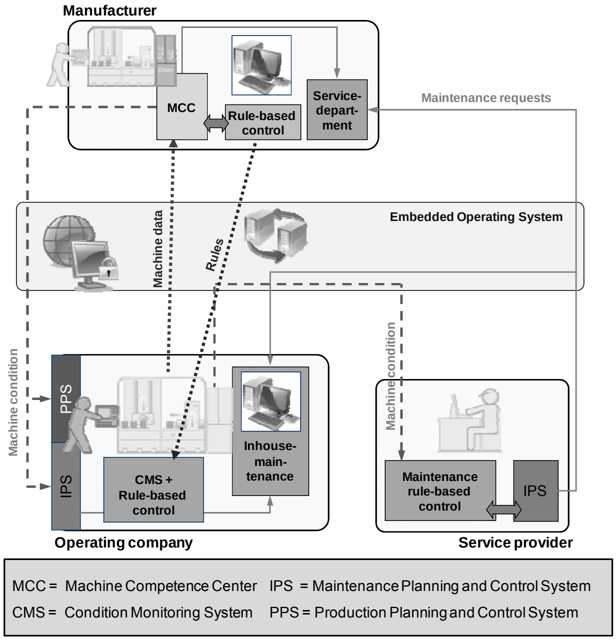

Figure 2: Overall scenario of the availability management system (joint project VERA^{PRO}). [1], [2], [3]

Thus, the individual requirements for an increase of availability could be determined corporately and then be transferred into the management system. Hence, manufacturers of production systems with their knowledge about the technical realization of highly available systems, operators with their specific data about real utilisation, abrasion and attrition ratios have defined the common purpose. [4]

Concerning the implementation of a condition information system and an adjusted maintenance strategy within the holistic availability management system, the financial aspect is very important. For the development of suitable business models, the benefit has to appear to achieve a change in the corporate culture and to guarantee a successful implementation of this concept. [1]

3 BUSINESS MODEL

3.1 Basic business model definition

The bases for entrepreneurial action are business models, which describe the fundamental aspects and architecture of the business of a company. There are several views about the structure of business models, which are reflected in various definitions of business models [7]. The systematisation of the business models, developed in this joint project, was geared to the definition of business models by Stähler [8], which focuses a high costumer orientation and customer value. Following this definition, a business model is divided into three stages: the customer value, the architecture of value creation and the turn over model (see Figure 3).

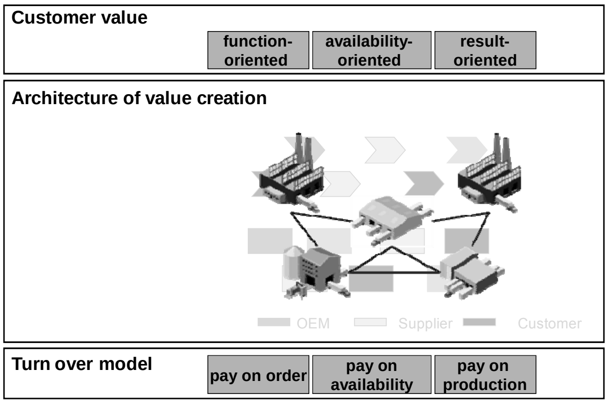

Figure 3: The architecture of business models by Stähler [8].

Based on this structure, relevant aspects are the stakeholders, the attainments and the configuration of trade-off. The customer value describes the benefit which customer or another value adding partner could reach from dealing with the company; it answers the question: which benefit does the company endow? A concept of business is an architecture of value creation at the same time by describing how the benefit for the customers is generated. This architecture gives a description of the different stages of value creation and economic agents with their special roles within the added value. It answers the question: in which configuration and how is the attainment being created? The turn over model gives an idea about which revenues the company is achieving from which sources. Then the future revenues will determine the benefit of the business model for the company. Furthermore, it could also draw a conclusion about the sustainability of the business model. In summary the turn over model answers the question: How does the company earn money?

Based on dynamic systems, the customer value could be differentiated between function-, availability- and result-orientated business models. [9] A function-oriented business model comprises, for example, a maintenance contract in order to guarantee the functionality for an assured period of time. In an availability-oriented business model, the usability of the means of production is also guaranteed. The supplier takes over business processes of the customer as his own responsibility, e.g. maintenance or repair and thus bears a part of the production risk. In a result-oriented business model, the complete responsibility of the production result is transferred to the supplier. The customer pays only for the faultlessly produced parts.

3.2 Conclusion

There is an explicitly formulated or at least an implicitly existing business model behind every valuable consideration. Accordingly, a company, which offers different services and products - thus various conditions for the customer, could be represented by different business models. Due to the various specifications of service offers, a detailed description of a business model is very considerably. Against the background of availability increasing business models, these assumptions are also valid for the mentioned availability-oriented business models and especially for the services within an availability management. This fact reflects the idea of an Industrial Product-Service System (IPS²). IPS² represent a paradigm shift in the definition of service performance in mechanical engineering by considering tangible and intangible goods in an integrated way [9]. The concept of IPS² considers the integration of products and services to enable new business models aiming to fulfill customer needs [10], [11].

4 BUSINESS MODELS WITHIN THE JOINT PROJECT

The business models developed in the joint project VERA^{PRO} contrast with other business models by having the benefit for the operator of production systems (the customer) by increasing the availability.

While dealing with a systematisation of availability-increasing business models, there arised a large variety of characteristics and technical possibilities to enhance and ensure the availability of production systems (see Figure 4). In consideration of the holistic availability management, three dimensions of action could be identified in the project. These are an operational-reactive, an operational-constitutive and a strategic dimension. The dimensions mainly differ in the space of time, which is given to execute the availability increasing measures and the therein included measures for realisation. Within the three dimensions, there are a variety of functions and actions, which are different, depending on the business model characteristics (e.g. organisational availability increase, technical availability increase, ...).

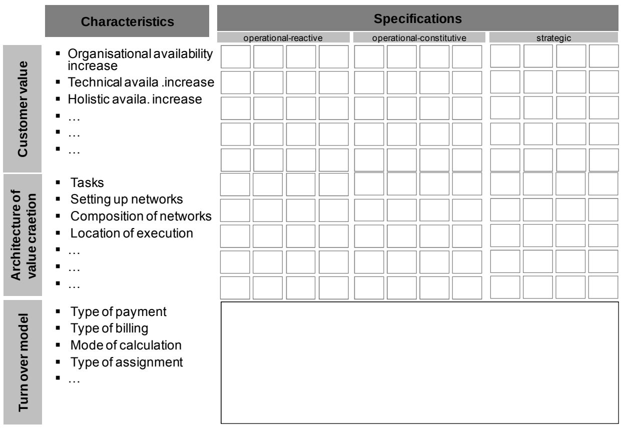

Figure 4: Structure of availability-oriented business models. [4]

In order to assign the actions to the characteristics and specifications and to structure them, there is a need for a systematic combination of the components of the business model.

An approach, which can solve this task, is the method of Quality Function Deployment (QFD). Other approaches like scoring models are too vague.

5 SYSTEMATISATION OF BUSINESS MODELS

5.1 Quality Function Deployment and house of quality

For business operations the customer orientation is an important element. In this context, the Quality Function Deployment is able to support a customer-orientated product- and process development. The QFD model consists of four phases, respectively four houses of quality (HOQ) [12]. The customer demands will be transferred into product characteristics and processes as well as into the production planning. The house of quality consists of a matrix which evaluates the correlations between demands and solution characteristics. Furthermore, an interdependency analysis builds up the roof of the house of quality. Customer requirements could be surveyed by market research, then be analysed and transferred into QFD-suitable information. In the first HOQ the production is planned by translating the customer requirements into quality characteristics. In the second HOQ the planning of the several components is focussed by assessing the relevance of each component concerning quality characteristics. The aim of the third HOQ is finally the process planning. Based on the necessary production processes and characteristics the manufacturing specifications are generated. By transferring the manufacturing specifications into production instructions the production planning is developed in the fourth HOQ.

5.2 QFD for business model development

Following the conclusion by analogy the development of business model could be based on the QFD. Therefore, QFD concretises the configuration of product-service systems and processes within the business model. Thereby the proceeding follows the development mentioned above. First of all, the customer demands were opposed to the characteristics of product-service systems for a holistic availability management. The assessment of the correlation of customer demand and the characteristics of product-service systems in the availability management is done by experts. In the next step, the characteristics of product-service systems were broken down into functions within a matrix. By doing so, it is then possible to judge which processes are necessary. The last matrix for the characteristics of product-service systems checks the requirements, e.g. the equipment characteristics for the processes. An overview of the development is given in Figure 5.

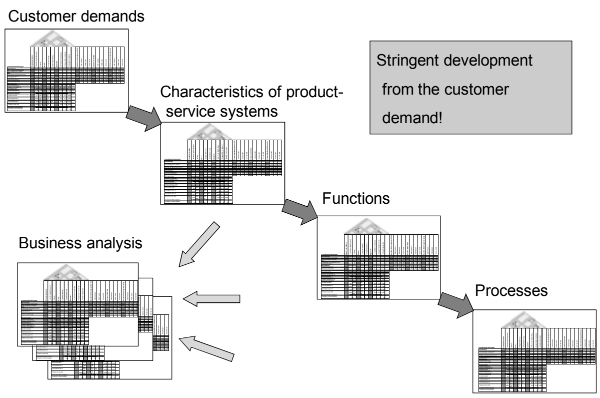

Figure 5: Customer-oriented availability-based business models.

6 SUMMARY

To establish a holistic availability management system, there is a need for a special structure or scenario based on a comprehensive information system. In this information system all condition-relevant data, received from heterogeneous sources, is brought together on a homogeneous platform. Therefore, it has to be supported by the cooperation of manufacturers, suppliers and operators, which guarantees the consideration of all possible availability losses regardless of their causes to accomplish a holistic solution.

According to the participation of the several partners, an innovative business model could be built. Furthermore, there are chances arising to evolve different business models for each participating partner in the availability management system. Based on this, there emerges a need to systematise those availability-enhancing business models, which reveals a great variety of characteristics and technical possibilities to increase the availability.

The QFD could be used for the configuration of the business model as well as for a customer-specific configuration of product-service systems. Within the business model definition by Stähler the QFD could make a considerable contribution to the structuring of marketing activity. The most striking advantage of QFD is the stringent focus of the development of business models on customer demands. The introduced approach is implementing by the project partners of the joint project VERA^{PRO} and his evaluation will generate new consolidated findings.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Meier, H., Binner, S. M., Quade, N., 2008, Availability-Management of Production Systems Using a Rule-Based In-Line Condition Information System, 6th CIRP International Seminar on Intelligent Computation in Manufacturing Engineering, Naples, Italy, Session A1.

[2] Quade, N., 2009, Verfügbarkeitsmanagement von Bearbeitungssystemen mit erweiterter Betrachtung der administrativen Prozesse in kleinen und mittleren Unternehmen, Dissertation, Schriftenreihe des Lehrstuhls für Produktionssysteme, Hrsg. Prof. Dr.-Ing. Horst Meier, Band 2009.2, Shaker Verlag, Aachen.

[3] Meier, H. (Hrsg.), 2009, Ganzheitliches, regelbasiertes Verfügbarkeitsmanagement von Produktionssystemen (VeraPro) - Verfügbarkeit von Produktionssystemen als Dienstleistung, Band 2 der Reihe, Apprimus Verlag, Aachen,1-2, 5-6, 14-15.

[4] Meier, H., Letmathe, P., Quade, N., Jacobs, J., Binner, S.M., 2009, Systematisierung verfügbarkeitssteigernder Geschäftsmodelle, wt Werkstattstechnik Online, 7/8-2009, Springer-VDI-Verlag, Düsseldorf, 526-532.

[5] Matyas, K., 2008, Taschenbuch Instand-haltungslogistik. 3. Auflage, Carl-Hanser Verlag, Munich, Vienna.

[6] Mexis, N. D., Hennig, J., 1994, Handbuch zur Schwachstellenanalyse und -beseitigung. 2. Auflage, TÜV Rheinland GmbH, Köln.

[7] Scheer, C., Deelmann, T., Loos, P., 2003, Geschäftsmodelle und internetbasierte Geschäfts-modelle-Begriffsbestimmung und Teilnehmer-modell, ISYM-Lehrstuhl für Wirtschaftsinformatik und BWL, Johannes-Gutenberg-Universität, Mainz.

[8] Stähler P., 2002, Geschäftsmodelle in der digitalen Ökonomie, Josef Eul Verlag, Köln.

[9] Meier, H., Kortmann, D., 2007, Leadership-From Technology to Use-Operation Fields and Solution Approaches for the Automation of Service Processes of Industrial Product-Service-Systems, Proceeding of the 14th CIRP Conference on Life Cycle Engineering, Tokyo, Japan, 159-163.

[10] Brissaud, D., Zwolinski, P., Maussang, N., 2007, Common representation of products and services: a necessity for engineering designers to develop Product Service Systems, In: Kraus F L (ed), The future of product development, proceedings of the 17th CIRP Design conference, Springer, 463-471.

[11] Roy, R., Cheruvu, K., 2009, A competitive framework for Industrial Product Service Systems, Accepted for International Journal of Internet Manufacturing and Services, Special Issue on Product Service Solutions in Life-Cycle Activities.

[12] Clausing, D., Pugh, S., 1999, Enhanced Quality Function Deployment. Design and Productivity International Conference, Honolulu, Hawaii.

Impact of Uncertainty on Industrial Product-Service System Delivery

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Abstract

Sufficient consideration of uncertainties is essential for successful Industrial Product Service Systems (IPS^2) delivery, due to their potential impact over cost, schedule and performance. The paper serves the purpose of structuring complexity in IPS^2 delivery by presenting the main categories and types of uncertainties and their impact on the delivery of IPS^2. Detailed description of the uncertainties and their influence on one another is explained. Additionally, the paper defines the complexity implications of these uncertainties on the IPS^2 delivery. The findings have been derived from the industrial interactions with four major organisations in the defence and aerospace industries and critically analysing the literature.

Keywords

Industrial Product-Service Systems, availability contracts, delivery, uncertainty, impact

1 INTRODUCTION

The focus of the customer in the defence and aerospace industries has been shifting from equipment purchase to functional capability [1]. This transition has typically been achieved through availability contracts, which are also known as performance based contracts. Contracting for Availability (CfA) is a commercial process which seeks to sustain an equipment/system/part at an agreed level of readiness, over a period of time, by building a partnering arrangement [2]. Fundamentally, to be able to deliver these requirements it is necessary to address the availability in terms of *what*, *when* and *where.* In academia, related research has been covered in the 'Product-Service Systems (PSS)' domain. Baines et al., [3] defines PSS as **"**an integrated product and service offering that delivers value in use". The approach takes a physical product as the initial point; a PSS is created only after the servitization of this product [4]. The specific case of a PSS, involving the business to business context, a physical product core and high net value is considered to be an Industrial Product Service System (IPS^2) [5], where CfA serves as an example.

IPS^2 delivery has progressively increased in scale and complexity. Examples range from the humble photo-copier through to major infrastructure projects (e.g. Private Finance Initiative -PFI- hospitals) and large defence projects (e.g. complete sea, air or land platforms). The shift to CfA promotes the use of performance criteria (e.g. key performance indicators) over the Product Life Cycle (PLC), which may last up to 40 years. Equipment availability, reliability and maintainability are some of the main areas of interest within these contracts. As a result, relationship between the customer and industry has been growing while co-creation of value has become a major theme across the industry [6]. CfA has become widely considered as win-win solutions for both the customer and industry. Some of the major reasons behind this include opportunities for cost reduction, incentivising flexibility in IPS^2 delivery, extending PLC through higher reliability, payment based on unit of service rather than resources, optimisation of use, postponing disposal costs, incentivisation of component re-use, and fixed income achieved over longer duration [3]. These positive outcomes have been achieved through the enhancement of the role of service in the delivery of customer needs. The significance of service arises due to its ability to ensure or to enhance the product performance expected by the customer throughout the whole PLC [7]. Services such as health checks, spares and repairs services, defect response, on-call service, performance assessment, process management and training have become widely offered across the defence and aerospace industry. Such services as part of an IPS^2 have enabled to tailor delivery to the individual customer needs [8].

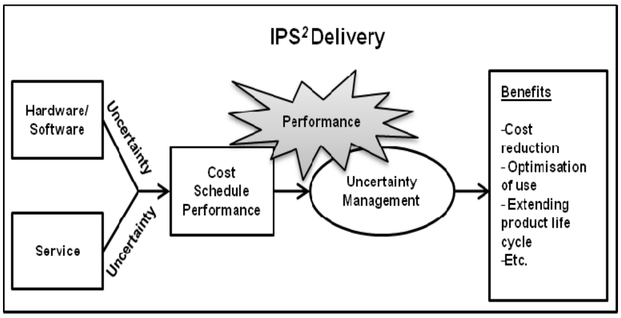

Figure 1: IPS^2 Delivery

There are a number of barriers that may hinder the possibility of benefitting from the potential advantages that CfA offers. From the industry perspective some of these aspects include difficulties in predicting costs, accuracy of concept design, and organisational issues across the service supply chain [9]. Furthermore, considerations for the IPS^2 delivery need to capture system innovation or upgrade requirements early on in order to meet profitability expectations. However, the required capabilities and knowledge in managing the delivery of services are different to managing products [9]. The challenge for industry arises from handling the balance between supply and demand, which affects the fluctuation of the delivered service quality over the long duration. On the other hand, for the customer, the barrier for adopting an IPS^2 relates to the uncertainties with regards to the offer in terms of unclear risks, costs and responsibilities [9]. Thus, both the customer and industry face challenges in agreeing these contracts, whilst the prediction of cost along with schedule and performance has proven to be challenging due to uncertainties which require the management of uncertainties that arise in achieving a targeted performance. Figure 1 represents this aspect as well as illustrating that benefits are expected from the delivery of IPS^2 (e.g. for customer, industry, and suppliers), which combines products (e.g. hardware and software) and services. In order to cope with uncertainty, flexibility needs to be built into the IPS^2 [10], however approaching this complex phenomenon requires a structured methodology. It is worth distinguishing between uncertainty and risk, where uncertainty involves the indefiniteness of the outcome of the situation and risk is considered to be the chance of loss or injury [11]. This paper focuses on uncertainties due to its broad view that encapsulates both threats/risks and opportunities.

Section 2 explains the research methodology. The paper, in Section 3, focuses on the types and categories of uncertainties that impact the delivery of IPS^2. The impact of uncertainties on IPS^2 delivery is clarified in Section 4.

2 METHODOLOGY

This research is aiming to establish a cost-uncertainty modelling methodology for IPS^2, as part of the 'PSS-Cost' project at Cranfield University. The project has been collaborated with three major defence companies and one defence customer in the United Kingdom. Initially, through literature review the state of the art in defining uncertainty and the uncertainty types that emerge in availability contracts or IPS^2 delivery was captured. This guided the research to be divided firstly to understand the nature of availability contracts, which has been studied in product-service systems. Secondly, research aimed to study the uncertainties that arise in IPS^2 delivery. This related to research in uncertainty, and uncertainty management conducted by the Ministry of Defence (MoD), Department of Defense (DoD), North Atlantic Treaty Organization (NATO) and NASA. As a last step, these two research themes were combined through the identification of the main challenges, related to uncertainties that are faced in availability contracts.

The outcomes of the literature review, led to semi-structured interviews with all four mentioned organizations. The research with the collaborators focused on understanding the challenges in cost uncertainty estimation that are present in service delivery (i.e. spares, maintenance and training). A total of over 40 hours of semi-structured interviews were conducted with cost engineers, project managers, support managers, engineering managers, and functional experts (i.e. on risk and uncertainty). In the interviews it was highlighted that the process of systematically capturing uncertainties in IPS^2 delivery is a major challenge. Thus, the research aimed to establish a list of uncertainties that typically affect an IPS^2 delivery. The list was developed based on examination of what occurred on previous programs (e.g. Work Breakdown Structure-WBS) and an overall understanding of the issues that are likely to arise on future programs. Furthermore, the list of uncertainties was generated bearing in mind their influence over cost drivers. This approach was taken due to the significant challenges that are experienced in cost estimation in CfA. The process of interaction with industry is represented in Figure 2.

Along with the pre-mentioned interviews, the list and the refinement of uncertainties was achieved through two workshops. These were attended by all four collaborators. The attendees, held positions such as project manager, engineering manager, service capability manager and cost estimators. In the first workshop the role of uncertainties over IPS^2 delivery was established. This involved considering all the uncertainties that impact the process. The contextual focus was directed towards the early phases, where information is limited for an availability contract. The second workshop validated the list of uncertainties that had been generated through interviews and the workshop. This led to the refinement of the uncertainty list and also conceptual scope of each type of uncertainty was defined.

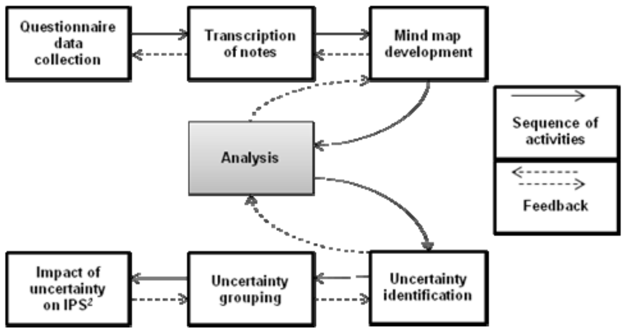

Figure 2: Research Methodology

3 UNCERTAINTIES IN IPS^2 DELIVERY

IPS^2 delivery combines product and service processes, where Figure 3 shows a comparison between the two. Conceptual similarities between these processes involve firstly identification of a need whether it be a product or a service [12]. Secondly, a plan is developed to fulfil the need and subsequently the implementation of the product delivery or service delivery takes place. Explicitly in the case of products, there needs to be an alignment between product policy formulations (e.g. defining equipment objectives), product objective finding (e.g. ideas generation and selection), product development (e.g. development, production, design and marketing), and product realisation [13]. The focus of traditional contracts centred on all of these aspects as well as the distribution and sales. The uncertainty in service delivery was distinguished from the product requirements. Whilst in the IPS2 context the integration of product and service is essential in order to achieve the performance requirements. This can be considered the basis of the shift in types of uncertainties when moving from a traditional contract into availability. As a result, the ranking of various uncertainties, for the Original Equipment Manufacturer (OEM), change as a proportion to the overall uncertainty level. For instance, with the increasing control/responsibility of the OEM in service and support activities uncertainty in maintainability (i.e. better handling of mean time between failure) is reduced while uncertainty related to service provision has grown (i.e. co-creation of value). Thus, in the case of service, all phases of the service processes including service creation (e.g. solution analysis, objectives, strategy), service engineering (e.g. generation of requirements, development, and implementation), and service management (e.g. delivery of service) need to be aligned with one another [13]. The implementation of product and service processes faces a different set of challenges arising from a different set of uncertainties.

The impact of uncertainty arising from the service delivery process may originate from many sources, which require the identification of uncertainty to be conducted systematically. There are a number of ways to identify the types of uncertainties including semi-structured interviews, brainstorming techniques, the nominal group technique, the Delphi technique, identification tools (e.g. systems dynamic models), identification aids (e.g. checklists), UML diagrams, SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis [14]. The identification of uncertainty is typically driven by expert judgment and experience [15]. To start with, in order to identify uncertainties it is necessary to recognize and document all associated uncertainties that are known. Though, the process is challenged by the dynamic nature of uncertainties over the life cycle of IPS^2. In order to systemically conduct an uncertainty analysis a generic list of uncertainties across IPS^2 can be considered. Taking a systematic approach facilitates the elimination or reduction of personal bias. Furthermore, this provides the opportunity to improve the chance of accurately assessing uncertainties (e.g. level of technical uncertainty) and to subsequently deliver an IPS^2. Through interviews in the defence and aerospace industry, uncertainties have been categorized into commercial, affordability, performance, training, operations and engineering areas, which the list has been referred to as CAPTOE. Figure 4 illustrates the uncertainty categories and types in each category, while also discussing their relationship with one another. This representation is in line with Roy and Cheruvu [16], which defines a competitive framework for IPS^2.

- Commercial uncertainty, considers factors that affect the contractual agreement, which is driven by certain requirements set by the customer. However, industry takes responsibility in defining these requirements based on its capability constraint. Responsibilities are driven by both the customer and industry
- Affordability uncertainty, considers factors that affect the ability to predict the customers funding for the given granularity of a project. Responsibility is driven by the customer
- Performance uncertainty, considers factors that affect industrial achievement in reaching the performance goals (Key Performance Indicators-KPIs) for the given project granularity level
- Training uncertainty, considers factors that affect industrial achievement in reaching customer needs for the delivery of training
- Operation uncertainty, considers factors that affect industrial achievement in reaching the required level of service and support delivery. It focuses on equipment level activities (i.e. onshore, maintenance) to deliver IPS^2
- Engineering uncertainty, considers factors that affect industrial achievement in managing strategic decisions with regards to the future service and support requirements (i.e. offshore, obsolescence management) to deliver IPS^2

The categories of uncertainties can be classified into strategic and operational level influence over the IPS^2 delivery. From a strategic view, the customer has a major role in commercial and affordability uncertainty categories, whilst the other areas are driven by industry. From an operational view the delivery of the IPS^2 is driven by training, engineering, and operation activities. In the case of training, along with uncertainties arising from delivering training, the process also has a knock-on effect on system performance. This is driven by the skill level of equipment users, which affect the failure rate and subsequently the availability level. On the other hand, engineering decisions can influence operational activities. For instance, planning for obsolescence will reduce problems that arise in finding spares, and this can enhance the efficiency of operations. In an IPS^2 delivery the focus is on performance, which is determined by strategic and operational level uncertainties, which for industry there are internal capabilities and external influences that affect the delivery processes (e.g. customer misuse). For the customer the scope of the requirement is constrained by its budget, which affects the affordability of an IPS^2.

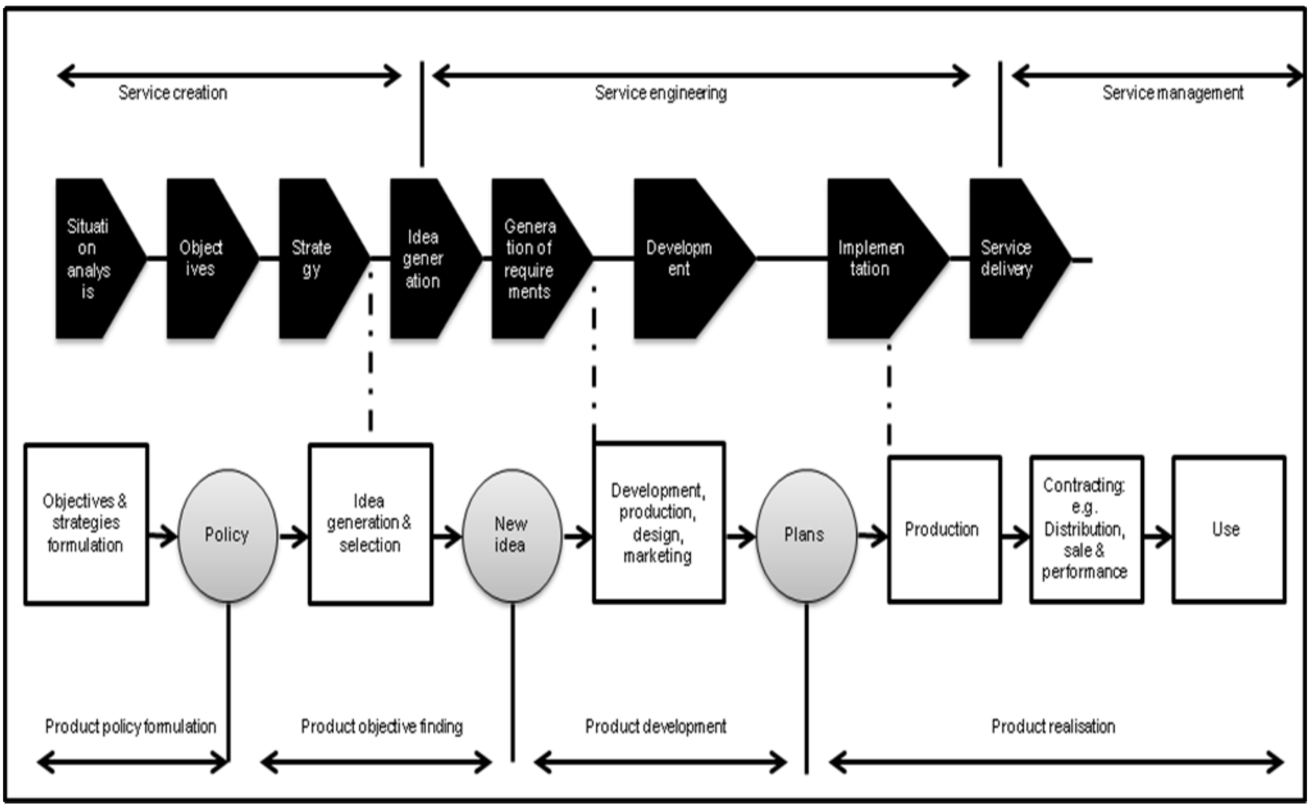

Figure 3. Comparison of product and service processes [Adapted from 13]

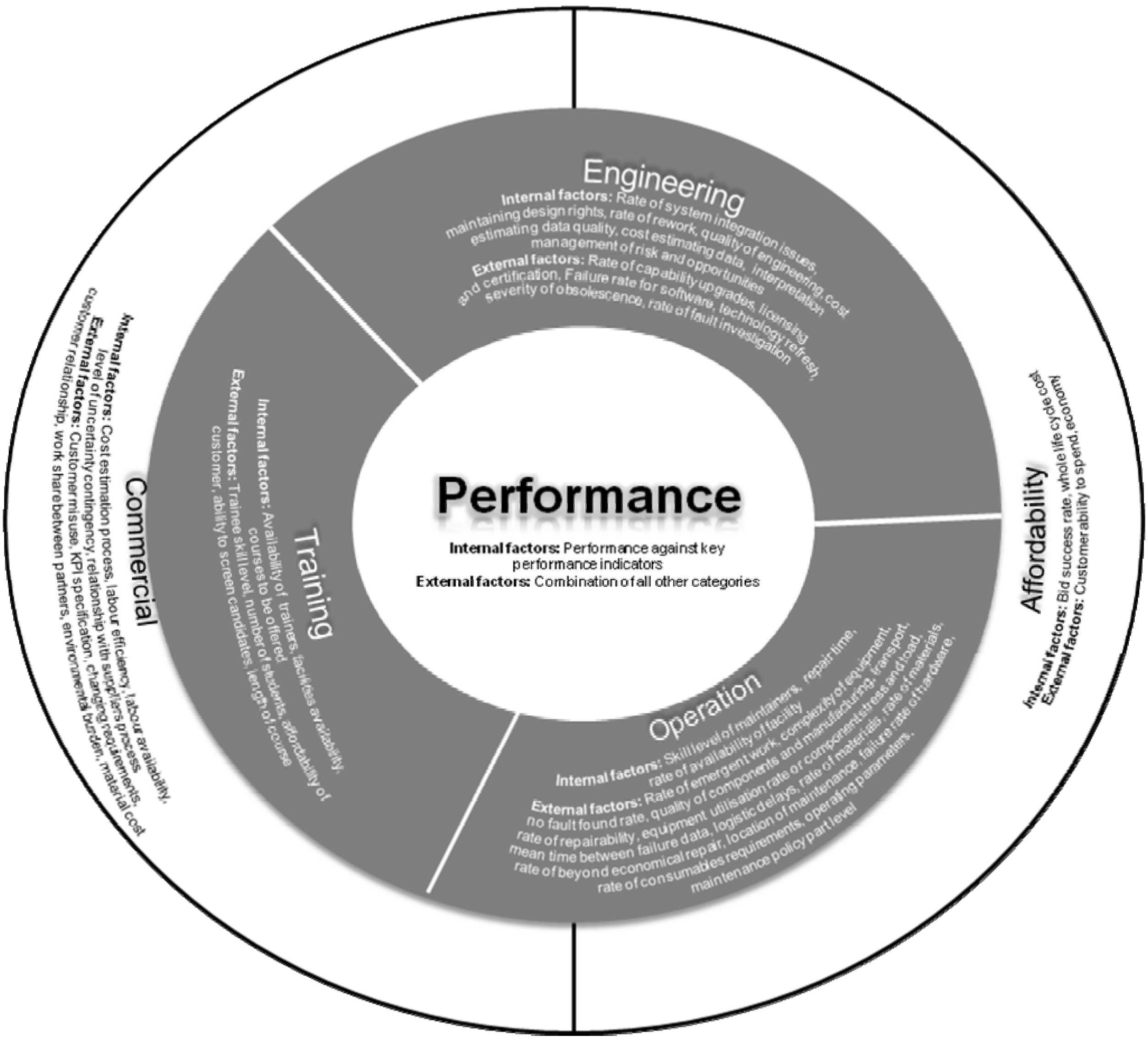

Figure 4. Categories and types of uncertainties in IPS^2 delivery

Each of these categories contains a number of relevant uncertainties, which influence IPS^2 delivery. In total 76 types of uncertainties have been captured. The list, which can also be interpreted as a risk register or a checklist, serves as the concepts that need consideration in developing an IPS^2. Although, the study was conducted specifically within the defence and aerospace industry, due to the focus on the early stages, driven by the level of available information, concepts are fairly generic and the list can be considered to be a starting point in order to develop an IPS^2 across other industries. For each category of uncertainties internal and external uncertainty drivers are explained in the following section. Internal factors take the view of industry, where capabilities are the driving force behind uncertainties that arise. On the other hand, external factors take a view of factors that originate outside of industry, which includes the customer or supply chain.

3.1 Commercial Uncertainty

The internal factors are driven by the capabilities of industry. This firstly involves a cost dimension, which includes uncertainties that may arise from the cost estimation process, and the ability to define the uncertainty contingency for the given project. Secondly, it requires consideration of labour requirements. Uncertainties may arise in the process of allocating labour for responsibilities, and achieving labour availability. The level of relationship set with suppliers is also considered as a capability that may influence the quality of the delivered service. On the other hand, external factors consider uncertainties that arise from the customer, supply chain and environmental burden. The customer may create uncertainty in the process of specifying KPIs, by equipment misuse, by changing requirements. The customer is also, to a large extent, responsible for the relationship with industry, which may influence the delivery of service. From the supply chain perspective, various uncertainties include material cost (e.g. spares), and the output of the collaboration with peer groups which involves a common goal (e.g. PFI initiatives). Finally, environmental burden refers to the uncertainty in the environmental requirements that needs to be adhered to.

3.2 Affordability Uncertainty

The internal factors are classified into two areas. Firstly, with IPS^2 delivery a life cycle view of cost is necessary and there are uncertainties within this process that industry needs to take responsibility for. Secondly, driven by the organisations' bid success rate across projects, opportunities to reduce cost may arise, which may be reflected in the price negotiations. In turn this may influence the affordability level of a project. As for external factors, customer ability to spend which is determined by budget constraints is an influential factor over customer affordability. The progression of the economy is another factor that influences customer affordability. The implications may arise from a supply (e.g. increasing prices, due to diminishing supply) or demand (e.g. decreasing budget) perspective.

3.3 Performance Uncertainty

Achieving required performance is an internally driven process that is measured based on KPIs. Performance being the main goal of the IPS^2 delivery is driven by many factors that concern the process of delivery (e.g. activities). Elements covered in affordability, commercial, training, operations and engineering feed in to the level of performance delivered. Thus, managing performance requires a multi-dimensional approach in order to encapsulate the affects of many uncertainty sources.

3.4 Training Uncertainty

Uncertainties that can be managed internally, relate to the availability of trainers, facilities availability (e.g. computers, lecture rooms), and the number of courses that are likely to be offered. The external factors are driven by the customer and trainees that attend the courses. For instance, the main uncertainties include trainee skill level, number of trainees to attend courses, ability to screen candidates (e.g. examining trainee skill level). Finally, the length of the course will be determined based on the customers' requirements and the skill level of the trainee in order to achieve the performance level.

3.5 Operation Uncertainty

The internal factors are driven by the skill level of maintainers, repair time, rate of availability of facility (e.g. for maintenance). The external factors that contribute to uncertainty are classified based on equipment originating factors, customer and supply chain. Equipment originating uncertainties include rate of emergent work (e.g. additional work needed to conduct repair), complexity of equipment (e.g. based on knowledge requirements to maintain), quality of components, and failure rate of hardware. On the other hand, customer originating uncertainties that affect the operational level of IPS^2 include equipment utilisation rate or component stress and load, rate of repairability, operating parameters (e.g. temperature, moisture), and maintenance policy part level (e.g. defined maintainability level). The final factor relates to supply chain originating uncertainty. This includes transport (e.g. degree of logistics as a result of spares/maintenance requirements), location of maintenance (e.g. distance to travel), mean time between failure data (e.g. uncertainty with the data), no fault found rate (e.g. no need to replace/repair), beyond economical repair (e.g. need for new part), logistic delays (e.g. originates from transportation), rate of consumables requirements, rate of materials (e.g. spares requirements).

3.6 Engineering Uncertainty

Engineering uncertainties, internally, capture skill and cost related capabilities. Skill considers the ability to handle system integration issues, rate of rework (e.g. refitting spare), quality of engineering, management of risk and opportunities (e.g. devising appropriate strategies). Also, uncertainty exists in retaining design rights, which is driven by the customers' satisfaction of delivered services. From a cost perspective estimating data reliability or quality, cost estimating data interpretation emerge as the main uncertainties with regards to engineering activities. The external factors relate to uncertainties that arise from the rate of capability upgrades, licensing and certification (e.g. customer driven), failure rate for software (e.g. considered as an engineering activity), technology refresh, severity of obsolescence, and rate of fault investigation (e.g. equipment driven requirements).

4 IMPACT OF UNCERTAINTY ON IPS2 DELIVERY

The different sources of uncertainty including incomplete information, inadequate level or understanding of information, and undifferentiated alternatives [17] may create major impacts on IPS^2 delivery. Furthermore, consideration of uncertainties enables more effective project planning. The impact, typically, on cost, schedule or performance requires attention. Table 1 presents the potential impact of the uncertainty categories shown in Figure 4. This list is not exhaustive and illustrates some of the potential impacts for each category.

Table 1. Impact of uncertainty on IPS^2

Category	*Source*	*Impact*
Commercial	Internal	Low availability level, penalties, inadequate flow of material across supply chain, bad cost estimates
	External	Too ambitious KPIs, high cost from supply chain, inadequate collaboration with partners
Affordability	Internal	Too ambitious cost estimates, and price reduction (when in competition)
	External	Downfall of the economy, diminishing budget
Performance	Internal	Unsuccessful in reaching KPIs, penalty
	-	-
Training	Internal	Inadequate training service, penalty
	External	Low trainee skill level causing longer courses, unprofitability
Operation	Internal	Low equipment availability, penalty
	External	Higher than expected cost, re-negotiation of utilisation rate, penalty to customer
Engineering	Internal	Inefficiency in design which reduces ability to achieve customer needs, inadequate cost estimates
	External	Equipment failure above expectations, equipment upgrade above expectation

Improper planning may cause decisions to be based on distorted foundation- 'propaganda' and 'lies' [18]. This in essence will impact the project through threats or unrealised opportunities. Thus, appropriate uncertainty management strategy needs to be implemented in order to reduce or prevent the impact of uncertainty on IPS^2 delivery.

5 DISCUSSION

IPS^2 delivery needs flexibility in order to respond to opportunities and threats that uncertainties create over a given time scale. CfA take a long life view, which uncertainties are exposed to growth due to the complexity of IPS^2 delivery. Morelli [19] stresses that complexity arises due to the complex exercise of interpretation during interactions between various actors and the unpredictability of their behaviours. It is the uncertainties that create complexity in IPS^2 delivery. This may be driven by a number of factors, (1) lack of understanding of systems by all stakeholders, (2) lack of predictability of system behaviour, (3) lack of control of functions in particular environments [20]. Complexity is an inherent feature of IPS^2, and is characterised by:

- Typically, a large number of interacting individual components of the system, which do not have a static interaction between the system and its environment
- System adaptation is necessary, but system usefulness and functionality must not be undermined within this process

There are three levels of responses to uncertainties; operational, tactical and strategic. Operational level response involves correcting an uncertainty within the equipment. Tactical response, involves controlling operating parameters such as temperature, pressure, and humidity. Finally, a strategic level response involves continuous improvement of quality and cost by collaborating and guiding employees and suppliers. This paper has presented the types of uncertainties that arise in IPS^2 delivery, which responses can be at all three of these levels.

For future work, uncertainties that arise in various forms of IPS^2 delivery needs to be examined. Whilst the focus of this paper has been on CfA, trends suggest that the defence and aerospace industry will adopt the capability contract approach in the future. This will further enhance industry's' responsibilities within the operational phase, while focusing on providing required outputs by the customer. The challenges that are faced within such a model, due to uncertainties will require consideration from industry.

6 SUMMARY

Uncertainty emerges as the main barrier in delivering IPS^2, because it encapsulates many factors that are prone to variability or unpredictability. For this reason there is a need to understand types of uncertainties and their potential impact over delivery. This paper contributes in this area by providing a list of uncertainties and their potential impact on IPS^2, collated from literature review and interaction with the MoD and three major companies in the defence and aerospace industry. The contextual focus has been the bidding stage of availability contracts, which are considered to be a form of IPS^2. In total 76 types of uncertainties have been classified into six categories: commercial, affordability, performance, training, operation and engineering. It is envisaged that awareness of these uncertainties and their impact, when designing the delivery of an IPS^2, will enhance capability in project planning, where customer affordability, required profitability for industry and the sustainability of the supply chain is facilitated.

7 ACKNOWLEDGMENTS

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8 REFERENCES

[1] Erkoyuncu, J. A., Roy, R., Shehab, E., Wardle, P., 2009, Uncertainty challenges in service cost estimation for products-service systems in the aerospace and defence industries, *Proceedings of the 1st CIRP IPS^2 Conference*, Cranfield, pp. 200-206.

[2] Ng, I., Williams, J., Neely, A., 2009, Outcomebased contracting: Changing the boundaries of B2B customer relationships, *AIM Executive Briefing.*

[3] Morelli, N., 2002, Designing product/service systems: A methodological exploration, *Design Issues*, 18(3), pp. 3-17.

[4] Baines, T. S., Lightfoot, H. W., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy R., Shehab E. et al., 2007, State-of the-art in product-service systems, *Proceedings of the Institute of Mechanical Engineers*, 221(B10), pp. 1543-1552.

[5] Aurich, J.C., Fuchs, C., Wagenknecht, C., 2006, Life cycle oriented design of technical Product-Service Systems, *Journal of Cleaner Production*, 14, pp.1480-1494.

[6] Ng, I., Yip, N., 2009, Identifying risk and its impact on contracting through a benefit based model framework in business contracting: Case of the Defence industry. *Proceedings of the 1st CIRP IPS^2 Conference*, Cranfield, pp. 207-215.

[7] Takata, S., Kimura, F., van Houten, F.J.A.M., Westkamper, E., Shpitalni, M., Ceglarek, D. and Lee, J. 2004, "Maintenance: changing role in life cycle management", *Annals of the CIRP*, 53(2), pp. 1-13.

[8] Aurich, J.C., Wolf, N., Siener M., and Schweitzer, E. 2009, Configuration of product-service systems, *Journal of Manufacturing Technology Management*, 20(5), pp. 591-605.

[9] Mont, O. K., 2002, Clarifying the concept of product service system, *Journal of Cleaner Production*, 10, pp. 237-245.

[10] Richter, A., Sadek, T., Steven, M., Welp, E.G., 2009, Use-oriented business models and flexibility in Industrial Product-Service Systems, *Proceedings of the 1st CIRP IPS^2 Conference, Cranfield*, pp. 186-192.

[11] United States Government Accountability Office (GAO), Cost Estimating and Assessment Guide, Best Practices for Developing and Managing Capital Program Costs, March 2009, [Online] Accessed from: http://legislative.nasa.gov/hearings/3-5-09%20CostEstimatingAssessGuide.pdf Access date: 02/09/09

[12] Alonso-Rasgado, M. T. & Thompson, G. (2007) A Rapid Design Process for Total Care Product Creation, *Journal of Engineering Design*, 17, pp. 509-531.

[13] Brezet, J.C., Bijma, A.,S., Ehrenfeld, J., Silvester, S., 2001, The design of eco-efficient services: Methods, tools and review of the case study based 'Designing Eco-efficient Services' project, Design for Sustainability Program, Delft University of Technology

[14] Erkoyuncu, J.A., Roy, R., Shehab, E., Cheruvu, K., 2009, Managing Uncertainty in Service Cost Estimation for Product-Service Systems, *Proceedings of the 7th International Conference on Manufacturing Research (ICMR 2009),* Warwick University, Warwick, UK, 8-10 September 2009

[15] Boussabaine A., Kirkham R., 2004, Whole Life-cycle Costing: Risk and risk responses, *Blackwell Publishing*, 1st Edition, pp. 56-81

[16] Roy, R. and Cheruvu, K.S, 2009, A competitive framework for industrial product service systems, *International Journal of Internet Manufacturing and Services*, 2(1), pp. 4–29.

[17] Grote, G., 2009, Management of Uncertainty-Theory and Application in the Design of Systems and Organisations, *Springer*, pp. 29-35.

[18] Smithson, M. 1989, Ignorance and uncertainty, *New York: Springer-Verlag,* pp. 54-72.

[19] Morelli, N., 2009, Service as value co-production: reframing the service design process, *Journal of Manufacturing Technology Management*, 20(5), pp. 568- 590.

[20] Molloy, E.M., Siemieniuch, C., Sinclair, M., 2009, Decision-making systems and the product- to-service shift, *Journal of Manufacturing Technology Management*, 20(5), pp. 606-625.

A Methodology for Adopting Product Service Systems as a Competitive Strategy for Manufacturer

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Abstract

This paper presents the overview of a research program of the development of a new Product-Service Systems Evaluation (PSSE) methodology. The aim of the PSSE Methodology is to assist manufacturer to asses whether the adoption of a PSS is a good competitive strategy. The paper briefly reviews existing literature related to Servitization and PSS. It describes the competitive elements of a PSS competitive strategy and its performance criteria. Results of the case studies conducted in Singapore to understand the awareness of PSS concept and the requirement sets of the delivery mechanism of the new PSSE methodology are presented. The structure of the new PSSE methodology is briefly outlined at the end of the paper.

Keywords

Servitization, Product-Service Systems, PSS, Competitive Strategy, Manufacturing Operation Methodology

1 INTRODUCTION

PSS, Product-Service Systems, is an integrated combination of products and services that delivers value in use [1]. For manufacturers whose products are undifferentiated and commoditized, or with a wide installed base, going downstream represents significant opportunity to create a new competitive strategy to sustain further business growth and generate more profits [2]. Manufacturing capability and processes now represent opportunities to create more value via the provision of a PSS [3-6]. Although the concept might not be new [7], Servitization, 'the innovation of an organisation's capabilities and processes to better create mutual value through a shift from selling product to selling PSS' [4, 5], provides a possibility to shift traditional product focused manufacturing to a new servitized manufacturing paradigm with the support of advanced ICT and manufacturing and maintenance infrastructure. The surge of research papers in recent years reflects the level of intensity in interests from academia in this subject[see references 1-17], albeit conducted under different research themes like Servicising [11], Product to Service Transition [8], Service Engineering [10, 12] and Industrial Business Service [13] etc.

The assumption that manufacturers are being able to create more value in use via PSS lies in the fact that manufacturers are in a position of being able to effectively exploit the synergies of products and service combination. Manufacturers possess the ability to design "serviceability" into a product, be it servicing the products itself in operation or delivering the intended services to customers. For example, as manufacturer is likely to be responsible for the entire product life cycle support, special features are likely to be designed and developed onto the product itself to monitor the usage of the products and to prolong its operating life span.

Although expanding into services offers manufacturers opportunities to exploit more values from the products, the move to Servitization, however, generates new uncertainty, game rules and challenges [4, 14, 16]. Servitization requires significant organizational changes in language, values, design process, and organization structure [3, 8]. Manufacturers need to develop new competence profile and core competency base and undergo organisational changes, both structurally and infrastructurally [3]. To a certain extent, competences, resources and capabilities which may be so new to the manufacturer that it resulted in new collaboration with other partners [15], or formation of a decentralized new service unit with different metrics and performance measures to support the new service activities [18].

To date, despite the fact that many companies are moving towards Servitization, services have yet to be successfully integrated into the corporate competitive analysis and strategy formulation process. Hence, to develop tool and methodology to help manufacturing firm to effectively design PSS within the manufacturing context is important. In particularly, when a manufacturer decided to go for Servitization, an effective tool or methodology to help evaluating whether such a decision is a competitive move is also essential [5]. As pointed out by Wilkinson et al., traditional operations management tools, techniques and frameworks, were basically developed for traditional product manufacturing [19]. As the traditional manufacturing firms servitized, the models and methodologies used by the operations management community may need to be modified and enhanced [19]. Furthermore, Baines et al. stress the needs to develop new methodology to support the transition to servitized manufacturing [5].

Although currently there are some PSS methodologies developed for designing and implementing PSS, their approach is biased towards attaining sustainability and reducing environmental impact [20, 21]. In view of this, this paper sets out to present a methodology aims at assisting manufacturer in evaluating whether the adoption of a PSS is a good strategy from the point of view of competitiveness.

The paper commences by first describing the research programme, which includes research background, aim and research questions. Literature in the areas of Servitization and PSS is then reviewed. The central sections of the paper focus in discussing the value preposition of a PSS competitive strategy. The later sections present the results of the exploratory case studies conducted in Singapore and the structure of the PSSE methodology. Future research is briefly described at the end of the paper.

2 RESEARCH PROGRAMME

2.1 Research Background

Singapore, like many other developed countries in the West, is gradually shifting from low value labour intensive manufacturing to high value manufacturing. Proposal put up by the Economic Review Committee in 2002 has recommended Singapore manufacturers to move downstream to capture values generated from additional service activities to maintain their competitive edge [22]. Although the concept of providing services to support customers and products are not new to most of the manufacturers, the concept of Servitization and PSS, which currently capturing the attention of policy makers in Europe and USA, still remain relatively a unknown one in Singapore.

2.2 Research Aim and Questions

The aim of this research is "to design and evaluate a methodology that will enable the manufacturing companies in Singapore to assess whether the adoption of PSS is a good competitive strategy".

The following research questions have been formulated to address the research aim:

1. What are the competitive elements of a PSS competitive strategy?
2. How can a manufacturing firm assess whether the adoption of a PSS is a good competitive strategy?

A 5-phased research programme has been established to achieve the research aim:

- Phase 1: Establishing the requirements set of the PSSE Methodology
- Phase 2: Identification & evaluation of existing methodologies against the requirements set
- Phase 3: Formation of pilot PSSE methodology
- Phase 4: Validation of the pilot PSSE methodology
- Phase 5: Refinement and development of the final Methodology

Section 3 to 5 of this paper present the background work of the research programmes that led to the establishment of the requirements set in phase 1 and the formation of the pilot PSSE methodology in phase 3 which is briefly discussed in Section 6.

3 LITERATURE REVIEW

3.1 General Definitions of Product and Services

As stated in the beginning of this paper, PSS is an integrated combination of products and services that deliver value in use. It includes both the tangible product and the intangible service as its basic elements. Although the term of "product" and "service" appeared to be easily understood by common laymen, its definition varies from the literature of marketing to manufacturing [1, 24]. Thus, it is important to provide a clear definition of "product" and "service" at the beginning of this paper before we discuss on the competitive elements of a PSS strategy and the methodology developed to evaluate its competitiveness.

Product

The term "product" is well understood in the world of manufacture. A product is typically referring to a material artefact, for example, a car, an engine or even small component parts being manufactured like screws and nuts. Goedkoop et al. describe it as "a tangible commodity manufactured to be sold, and of capable of falling on your toe and fulfilling a user's needs" [23]. The term "functional product", on the other hand, is not necessarily referring to a physical artefact, and can be consisting of any combination of hardware, software and services [17]. In the context of manufacturing, product is usually regarded as something tangible, and certainly do not contain any intangible service elements. The definition of the "product" adopted in this paper is shown in Table 1.

Service

As of the term "service", in the world of manufacture, it is usually referring to an offering provided to the customer [2]. For examples, services provided by a manufacturer to a B2B customer like training and consultancy, or to a B2C customer like installation and warranty. Although in most cases, these services involve the handling of physical products, the service itself rendered to the customers does not necessarily result in the transfer of the ownership of the tangible assets to the customer. The services, in general, are add-on economic activities that help the manufacturer to ensure that the product being sold, either in it own or in a bundle, is able to operate in good condition and deliver its purported functionality. Thus, in this paper, as shown in Table 1, we refer service to as an "economic activity that does not result in ownership of a tangible asset" [2].

Value in Use

'Value in use' is a concept addressed in Service-Dominant Logic Marketing and is seen as 'value co-created with the customer' [24]. This is offered as a new marketing paradigm that moves away from the 'old' Goods-Dominant Logic where value was considered to be embedded in the product. A customer attaches value to a product or service in proportion to its perceived ability to help solve his problems or meet his needs [25]. In this paper, we define Value in Use as "the value of the utility of an integrated combination of products and services delivered by PSS to a customer". Table 1 summaries the definitions discussed and the definitions of the key concepts related to PSS and Servitization that will be used in the discussion in the subsequent sections of this paper.

3.2 Moving Towards Servitization

Servitization was first presented by Vandermerwe and Rada [26] in 1988 in their article entitled "Servitization of business: adding value by adding services". Vandermerwe and Rada suggests to use Servitization as a competitive tool to setting up barriers to competitors, creating dependency, differentiating the market offering and diffusing new innovations. In the recent years, many researchers see Servitization as the movement "on a product-service continuum ranging from products with services as an "add-on", to services with tangible goods as an "add-on" [4, 8, 18]. Some researchers refer Servitization as "Servicification" [10] or "Servicising" [11].

Term	Definition	
Product Service System (PSS)	*PSS is an integrated combination of products and services that delivers value in use [1]*	
	Product Oriented PSS	*Promoting/selling the product in a traditional manner while including additional services as part of the offering*
	Use Oriented PSS	*Selling the use or availability of a product which is not owned by the customer such as leasing or sharing*
	Result Oriented PSS	*Selling a result or capability instead of a product, such as selling power by the hour*
Products	*Product is a tangible commodity manufactured to be sold, and is capable of falling on your toe and of fulfilling a user's needs -Goedkoop et al. 1999 [23]*	
Services	*Service is an economic activity that does not result in ownership of a tangible asset [4]*	
Value in Use	*The value of the utility of an integrated combination of products and services delivered by PSS to a customer*	
Servitization	*Servitization is the innovation of an organisations capabilities and processes to better create mutual value through a shift from selling product to selling PSS. [4]*	

Table 1: General Definitions Related to Servitization

Type of Service Typologies/Models

Table 2. shows a list of service typologies available in the literature. Mathieu classifies the service into two leading groups: Service supporting the product (SSP) and services supporting the customer's action (SSC)[28]. SSP referring to service supporting the supplier's product to ensure the proper functioning of the product and to facilitate the client's access to the product. In SSC, manufacturers explore how services can be used to support particular client initiatives and advance the mission of customer organization [28]. Another interesting concept is Service Factory in which manufacturing personnel and the factory itself share a service mission that extends beyond the basics of reliable, flexible and cost-effective production [29-32]. Factory can play a role of *Showroom, Dispatcher, Laboratory and Consultant* on top on other possible services in distribution and after sales. Likewise, Gebauer and Friedli suggest different service provider' roles, namely, *After Sales Service Providers, Customer Support Providers, Outsourcing Partners and Development Partner* for the manufacturers [18]. In the field of industrial services, Boyt and Harvey distinguish three service categories: *elementary, intermediate,* and *intricate* [13].

As discussed above, many different service typologies and models have been proposed. In this paper, nonetheless, we would like to focus the discussion in examining the role of PSS within Servitization.

Author	***Service Typology***
Silvestro et al. (1992) [27] Schmenner (2009) [8]	*1. Professional Service* *2. Service Shop* *3. Mass Service*
Boyt and Harvey (1997) [13]	*1. Elementary Services* *2. Intermediate Services* *3. Intricate Services*
Mathieu (2001) [28]	*1. Service Supporting Customer (SSC)* *2. Service Supporting Product (SSP)* *Product Service* *Service Product*
Chase (1991) [29] Chase & Garvin (1989) [30]	*1. The distribution Channel* *2. After Sales Service Operations* *3. Service Factory:* • *Factory as a showroom* • *Factory as a dispatcher* • *Factory as a laboratory* • *Factory as a consultant*
Ren & Gregory (2007) [33]	*1. Integrated solutions* *2. Maintenance and repair services* *3. Performance-based service contracts* *4. Operating and managed services* *5. Business consulting services* *6. Quick delivery services* *7. Technical specification services* *8. Design and engineering*
Gebauer & Friedli (2008) [18]	*1. After Sales Service Providers* *2. Customer Support Providers* *3. Outsourcing Partners* *4. Development Partner*
Neely (2008) [5]	*1.Integration Oriented PSS* *2.Product Oriented PSS* *3.Service Oriented PSS* *4.Use Oriented PSS* *5.Result Oriented PSS*

Table 2: Possible Service Models for Servitized Manufacturing

3.3 The Role of PSS in Servitization

Although PSS and Servitization started out as two different research concepts by different research communities, Baines et al. in 2007 has managed to provide a bridge to the two concepts [4]. As shown in Table 1, Baines et al. define *Servitization as the innovation of an organisations capabilities and processes to better create mutual value through a shift from selling product to selling PSS.* Concept of PSS was originated from the Scandinavian in the late 90's and one of the earliest definitions of PSS was given by Goedkoop et al. in 1999 as "a marketable set of products and services jointly fulfilling a user's needs" [23]. The original PSS concept has its roots in industrial ecology with the aim of reducing the consumption of materials and improving sustainability [23, 34, 35]. Linking up with servitized manufacturing concept, the focus of PSS has been shifted from sustainability to deliver value in use and PSS is more often regarded more as a competitive strategy than a tool to reduce environmental impact [1, 3, 4, 8]. Many PSS classifications exist in the literature. For example, Tukker classifies PSS into 8 different types [35]. As shown in Table 2, Neely outlines 5 different options of PSS under Servitization, namely *Integration Oriented PSS, Product Oriented PSS, Service Oriented PSS, Use Oriented PSS and Result Oriented PS* [5]. However, the most commonly used classification consists of basic three models [1], namely, Product oriented PSS, Use Oriented PSS and Result Oriented PSS.

Basically, Product Oriented PSS promotes and sells the product in a traditional manner while includes additional services as part of the offering whereas Use Oriented PSS sells the use or availability of a product which is not owned by the customer such as leasing or sharing. Result Oriented PSS sells the result or capability instead of a product. Typical examples of Result Oriented PSS are "Selling the copying" by Canon and Xerox, "Selling the power-of-the-hour" by Rolls Royce's engine service, "Selling the driving" by car sharing service provider and "Selling the washing" by community laundrette centre.

Baines et al. state that "with a PSS, asset ownership is not necessarily transferred to the customer" [3]. This is generally referring to both the Use Oriented and Result Oriented PSS. While the manufacturers provide goods to the customer, and receive payment with every unit of service or solution they provided, the ownership of the products, can still remain with the manufacturer.

4 ESTABLISHING THE FRAMEWORK OF A PSS COMPETITIVE STRATEGY

4.1 Defining the value preposition of a PSS Competitive Strategy

A PSS competitive strategy, theoretically, should offer a manufacturer the competitiveness to compete in the market. *Competitiveness is the ability to get customers to choose your products or services over competing alternatives on a sustainable basis* [36]. Competitive strategy is a concept that is perhaps most closely associated with Michael E. Porter [37], who expresses it as, *"essentially, developing a competitive strategy is developing a broad formula for how a business is going to compete, what its goal should be, and what policies will be needed to carry out those goals"*

Porter proposes three generic strategy choices, namely, differentiation, cost leadership and focus. As a competitive strategy, the value proposition of a PSS is inarguably to create differentiation for a company. Since the goal of a PSS competitive strategy is to offer integrated combination of product and service solution, another competitive strategic concept that can be used to describe PSS strategy is the "Best Packaged Offering" concept proposed by Baines [38]. Baines proposes competitive strategy concept based on *Best Packaged Offering (Offering the best total solutions to the customers), Best Price Offering (Offering the best total cost to the customers)* and *Best Product Offering (Offering the best product to the customers).* In the context of manufacturing strategy, the other widely used competitive strategy concept is the value preposition model proposed by Treacy and Wiersema [39]. Treacy and Wiersema relate competitive strategy to customer intimacy, operational excellence and product leadership. As the purpose of a PSS competitive strategy is to satisfy customer's needs, its competitiveness depends on whether the strategy can attain "customer intimacy" during implementation.

As a result, based on the above discussion, we would like to propose the following competitive elements for a PSS competitive strategy:

1. **Best Packaged Solution** - Firstly, a PSS competitive strategy offers Best Packaged Solution focusing in delivering the total solutions in a combined package of product and service to the customer
2. **Customer Intimacy** - Secondly, it emphasises on delivering value in use, which focusing in establishing long term customer relationship, provide best customer experience and develop customer intimacy
3. **Differentiation** - Thirdly, it creates a distinct Differentiation and value preposition through the offering of best packaged solution and customer intimacy

A PSS strategy will be a competitive one if a manufacturer able to deliver its competitive elements effectively. The next section we shall discuss on how the competitive elements of a PSS strategy can be evaluated by using traditional manufacturing performance criteria modified to include the new service order winning criteria.

Competitiveness	*Competitiveness is the ability to get customers to choose your products or services over competing alternatives on a sustainable basis - Schlie(1995) [36]*	
Strategy	*The determination of basic long term goals and objectives of an enterprise, and the adoption of courses of actions and the allocation of resources necessary for carrying out these goals. – Chandler(1962) [40]*	
Competitive Strategy	*A broad formula for how a business is going to compete, what its goal should be, and what policies will be needed to carry out those goals Porter(1980) [37]*	
Competitive Strategic Choice (Elements)	**Porter (1980) [37]**	*Cost Leadership, Differentiation, Focus*
	Baines (2009) [38]	*Best Packaged Offering, Best Price Offering, Best Product Offering*
	Treacy & Wiersema	*Customer Intimacy, Operational Excellence,*

Table 3: Summary of Concepts Related to Competitive Strategy

4.2 Evaluating PSS Competitive Strategy Using Manufacturing Performance Criteria

Performance Criteria in Measuring the PSS Competitive Strategy

Skinner points out that a firm's competitive strategy drives its manufacturing strategy leading to operations decisions which has resulted in the desired performance [41, 42]. Platts and Gregory say that manufacturing strategy is formed to achieve business goals and these goals are predominantly defined in terms of competitive priorities, for example, quality, cost and time etc [43]. Chase presents a set of guidelines for measuring service value chain performance while concluding with several propositions linking internal and external customers' satisfaction with factory services (i.e. information, problem solving, sales and support) and traditional indicators of factory performance criteria like cost, quality, flexibility and delivery [29-31].

According to Olouuniwo, who has cited Schmenner (1986), the dimensions to measure service quality are Tangibles Quality - product performance, Responsiveness - Speed in getting back to customer, Recovery - Speed in correcting wrong action, Knowledge - Product + Service Knowhow, Accessibility, Flexibility and Reliability [44]. Thus, a set of traditional product manufacturing performance criteria with the expansion to cover service has been proposed to measure the competitive elements of a PSS competitive strategy. Taking Quality as an example, instead of just measuring the quality of a product, it is now expanded to cover the measurement of quality conformance and reliability of both the product and service performance; Likewise, Delivery has also expanded to cover service delivery, i.e. *Responsiveness* (the willingness or readiness of employees or professionals to provide service) and *Recovery* (speed in correcting wrong action).

Measuring inputs and outputs of the tangible physical products are relatively easy compared to the measurement of intangible output of the service offering. Measurement of the effectiveness of service, or value in use relies on customer satisfaction, feedback and loyalty, which is rather subjective in most cases. Service quality is perceived and experienced, and relies heavily on the quality of the service delivery personnel [44]. In services, customer will pay only whatever they think the service is worth. Although some quantitative measurement could be straight forward, (e.g. number of service units delivered, customer retention, size of customer base, number of training sessions conducted) the quality of value delivered and customer intimacy level can only be measured by using subjective criteria like customer satisfaction and customer experience[45, 46].

Policies in Delivering PSS Competitive Strategy

Although customer intimacy can be generated through the provision of best packaged solution, it does not automatically resulting in differentiation. Manufacturers need to be able to formulate policies to attain the competitiveness of a PSS competitive strategy. Lee in 2007 has proposed a decision model for manufacturer to link best practices to competitive strategies [47]. As the role of the product is supporting the delivery of services in a PSS, first and foremost, a strategic fit check between the service intend to be offered and the life cycle stages (*Introduction, Growth, Mature* and *Decline*) of the product is fundamental [47]. Second, internal alignment of the PSS competitive strategy with its manufacturing core competency and capability to determine the technology fit, both structurally and infra-structurally (i.e. service driven, customer involvement, product customisation and change management) is essential[4, 8, 47]. Last but not least, how well an organisation can be transformed to support the Servitization plays a vital role in sustaining competitiveness [2, 4, 8]. The ability of a manufacturer to be able to transform itself to support Servitization strategy can be termed “Servitizability”.

Servitizability	*The ability of a manufacturer to effectively transform its operations to support the Servitization strategy, both structurally and infra-structurally*

Figure 1 shows the performance measurement system of a PSS competitive strategy and Table 4 summarises performance criteria that are required to measure the competitive elements of the PSS competitive strategy.

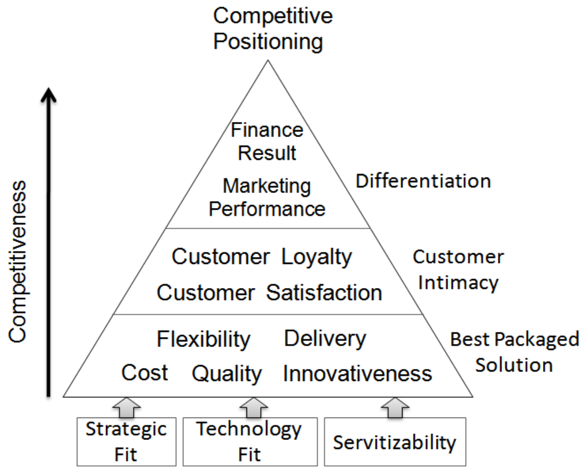

Figure 1. Performance Measurement System of a PSS Competitive Strategy

Competitive Elements	Competitive Dimensions (Performance Criteria)
Best Packaged Solution	*1. Cost (Product life cycle, Service)* *2. Quality (Conformance to specification, Reliability)* *3. Delivery (Responsiveness, Service Recovery, Product Availability)* *4. Flexibility (Accessibility, Level of Product Customisation, Variety of Services -SSP, SSC)* *5. Innovativeness (New Feature of Product and Service,)*
Customer Intimacy	*1. Customer Satisfaction (Acceptance, Willingness to pay)* *2. Customer Loyalty/ Base (no. of returned customer)*
Differentia-tion	*1. Competitive Positioning in target market segments (competitive advantage)* *2. Financial Performance* (Cash flow, Turnover, Profit and Return of Investment) *3. Marketing Performance (Market share, Market penetration, Brand Reputation)* *4. Operation Performance (Strategic Fit, Technology Fit, Servitizability)*

Table 4: Proposed Performance Criteria of a PSS Competitive Strategy

5 ASSESSMENT OF THE AWARENESS OF CONCEPT OF SERVITIZATION AND PSS IN SINGAPORE

5.1 Data Collection Method

In order to understand the awareness of the concept of PSS and Servitization in the Singapore manufacturing industry, we have conducted a simple exploratory study to gather necessary information. The main mission of the study is to gauge the awareness and acceptance level of such the servitized concept before the development of the structure for the PSSE methodology. The study also seeks to understand whether a methodology for helping manufacturing companies in adopting the PSS or service led business model is desirable by the Singapore companies and the preferred delivery mechanism of such a methodology. The exploratory case study was conducted by using semi-structured interview. A total no. of 10 product manufacturers was selected from the existing client base of Singapore Institute of Manufacturing Technology. The products manufactured by the selected companies represent an evenly distribution along the 4 stages of product life cycle, namely, Introduction, Growth, Mature and Decline. A set of questionnaires has been developed to assist in this study which consists of fundamental questions like "Have you heard of the Servitization and PSS concept?", "Do you think that you can gain competitiveness by providing more services on top of the products that you have manufactured?", "What are the services currently provided by your company?" and "How would you like the evaluation methodology to be delivered?" etc. Section 5.2 discusses briefly on the summary of some of the key findings.

5.2 Brief Summary of the Key Findings

First, product and Service mix offering was unanimously regarded as a potential competitive strategy. Most of the companies interviewed have also long been providing some forms of after sales supporting services like warranty, repair and training etc. to their B2B or B2C customers. Although mostly familiar with the concept of adding services to gain competitiveness, companies in Singapore generally do not heard of the concept of PSS and Servitization. Nevertheless, they did agree that it would be good to develop a methodology to assist the companies to assess whether the adoption of a new product service business model is a competitive one. Majority preferred the methodology to be delivered via facilitator guided workshop which they can seek advices and discuss their concerns with the experts/facilitators. They generally preferred platform to allow participation of key management from the various departments, and to certain extent, the intended customers. Table 5 provides the summary of the key findings.

Finding 1	*Product and Service mix offering is generally regarded as a potential competitive strategy to the Singapore manufacturing company – 100%*
Finding 2	*Companies in Singapore generally do not aware of the concept of PSS and Servitization – 80%*
Finding 3	*Companies in Singapore generally agreed that it would be helpful to develop a methodology that is able to assist company in assessing whether the adoption of a new PSS is a good competitive strategy- 100%*
Finding 4	*Identification of critical success factors, performance killers and other elements affecting the implementation of new service offering is crucial in helping the company to make the right decision of adopting a new PSS strategy - 100%*
Finding 5	*A clear and structured methodology to be delivered via facilitated workshop is generally preferred - 70%*
Finding 6	*Online evaluation tool generally regarded as "not professional enough" and not reliable enough to use it for making important decision as to whether to adopt a new PSS strategy – 60%*

Table 5: Summary of the Some of the Key Findings of the Exploratory Case Studies

6 DEVELOPMENT OF THE PSSE METHDOLOGY

A set of requirements for guiding the development of the PSSE methodology has been developed based on knowledge gained from literature of manufacturing strategy [43, 48-50] concerning the desirable characteristics of a good and practical methodology, and knowledge gained from industry concerning the context and delivery mechanism preferred by the industry through the case studies conducted. Methodologies from the areas of PSS and manufacturing strategy have been selected based on the requirements set to act as the conceptual base to develop the structure of the PSSE methodology [20, 21, 48-50]. The developed PSSE methodology is a seven-staged structural methodology as shown in Table 6.

INPUT ➔	PROCESS ➔	OUTPUT 🕮
Desire to Review Current Strategy ➔	**Stage 1: Scope Issue** – to study and analyse the current product based competitive strategy ➔	*Reason of moving towards Servitization* 🕮
Reason of moving towards Servitization ➔	**Stage 2: Identify Servitization Landscape-** to identify Servitization landscape ➔	*Servitization Landscape* 🕮
Servitization Landscape ➔	**Stage 3: Design PSS Activities** - to design PSS activities ➔	*PSS activities* 🕮
PSS activities ➔	**Stage 4: Review PSS Competitive Strategy** – to review current competitive strategy and assess new PSS strategy and the competitive gap ➔	*PSS Competitive Strategy* 🕮
PSS Competitive Strategy ➔	**Stage 5: Assess PSS Competitive Elements** -to valuate the competitiveness of the PSS elements ➔	*Score of PSS Competitiveness* 🕮
PSS Competitive Strategy➔	**Stage 6: Assess Servitizability of Companies** - To assess the Servitizability of companies ➔	*Score of Servitizability of Company* 🕮
Score of PSS Competitiveness and Servitizability ➔	**Stage 7: Generate PSS Competitive Strategy Scorecard** - To consolidate result and propose future action plan if necessary ➔	*Final Competitive Strategy Score Card and Future Plan* 🕮

Table 6: Overview of the Structure of PSSE Methodology

7 SUMMARY AND FUTURE WORK

This paper presents the background literature review of PSS and Servitization and describes the concept of PSS competitive strategy. Although the outline of the structure of the PSSE methodology have been briefly discussed, the tools and techniques used in each of the stages of the methodology are not covered in this paper. The PSSE methodology is currently under validation with companies in Singapore to test its Feasibility, Usability and

Usefulness. The companies selected for the validation phase are those who have been participated in the earlier round of exploratory case studies described in Section 5. As of the writing of this paper, the validation process is still in progress hence the result is not presented in this paper. The next phase of the research programme is to refine the methodology based on the feedback and results collected from the industry. Final methodology will be developed and validated again with more companies in Singapore. Detailed description of the final PSSE methodology and results will be presented in future publications.

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9 REFERENCES

[1] Baines, T., Lightfoot, H., Evans, S., Neely, A., Greenough, R., Peppard, J., Roy, R., Shehab, E., Braganza, A., Tiwari, A., Alcock, J., Angus, J., Basti, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, J. and Wilson, H., 2007, State of the Art in Product-Service Systems, Journal of Engineering Manufacture, Part B:1543-51

[2] Wise, R. and Baumgartner, P., 1999, Go Downstream: The New Profit Imperative in Manufacturing", Harvard Business Review, Sep-Oct:133-41

[3] Baines, T., Lightfoot, H., Peppard, J., Johnson, M., Tiwari, A. and Shehab, E., 2008, Towards an operation strategy for product-centric Servitization, International Journal of Operations & Production Management, 29:494-519

[4] Baines, T., Lightfoot, H., Benedettini, O. and Kay, J., 2009, The Servitization of Manufacturing – A Review of Literature and Reflection of Future Challenges, Journal of Manufacturing Technology Management, 20: 547-567

[5] Neely, A., 2008, The Servitization of Manufacturing: An Analysis of Global Trends, The 14th European Operation Management Association Conference, Ankara, Turkey

[6] Cook, M., Bhamra, T. and Lemon, M., 2006, The transfer and Application of Product Service Systems from Academia to UK Manufacturing Firms, Journal of Operations and Production Management, 14:1455-65

[7] Schmenner, R., 2009, Manufacturing, Service, and Their Integration: Some History and Theory, International of Operations and P3roduction Management, 29:431-443

[8] Oliva, R. and Kallenberg, R., 2003, Managing the Transition from Products to Services, International Journal of Service Industry Management, 14:1-10

[9] Spring, M. and Araujo, L., 2009, Service, Services and Products: Rethinking Operations Strategy, International Journal of Operations and Production Management, 29: 444-467

[10] Sakao, T. and Shimomura, Y., 2007, Service Engineering: A Noble Engineering Discipline for Producers to increase Value Combining Service and Product", Journal of Cleaner Production, 15:590-604

[11] White, A., Stoughton, M. and Feng, L., 1999, Servicising: The quiet transition to Extend Product Responsibility, U.S. Environmental Protection Agency

[12] Bullinger, H., Fähnrich, K. and Meiren, T., 2003, Service Engineering - Methodical Development of New Service Products, International Journal of Production Economics, 85: 275-287

[13] Boyt, T. and Harvey, M. ,1997, Classification of Industrial Services, A Model with Strategic Implementation, Industrial Marketing Management, 29 :291- 300

[14] Auramo, J. and Ala-Risku, T. 2005, Challenges for going downstream, International Journal of Logistics: Research and Applications, 8:333

[15] Pawer, K., Beltagui, A. and Riedel, J., 2009, The PSO Triangle: Designing Product, Service and Organisation to Create Value, International Journal of Operations & Production Management, 29:468-493

[16] Brax, S., 2005, A Manufacturer Becoming Service Provider – Challenges and A Paradox, Managing Service Quality, 15: 142-155

[17] Sakao, T., Sandstrom, G. and Matzen, D., 2009, Framing Research for Service Orientation of Manufacturers through PSS Approach, Journal of Manufacturing Technology Management, 20:754-778

[18] Gebauer, H. and Friedli, T., 2005, Behavioural implications of the transition process from products to services, Industrial Marketing Management

[19] Wilkinson, A., Dainty, A. and Neely, A.,2008, Changing times and changing timescales: the servitization of manufacturing, International Journal of Operations and Production Management,

[20] van Halen, C., Vezzoli, C. and Wimmer, R., 2005, Methodology for Product Service System, Innovation, Koninklijke Van Gorcum, Assen

[21] Kobayashi, H. and Kumazawa, T., 2006, A Procedural Methodology for Transition to Reuse Business, Proceedings of LCE 2006

[22] ERC., 2002, The Pursuit of Competitive Advantage: Value Manufacturing in Singapore, Report of Sub-Committee on Manufacturing, Economic Review Committee, October 18, 2002

[23] Goedkoop, M., van Haler, C., te Riele, H. and Rommers, P., 1999, Product Service-Systems, Ecological and Economic Basics, Report for Dutch Ministries of Environment (VROM) and Economic Affairs (EZ)

[24] Vargo, S., and Lusch, R., 2004, Evolving to an New Dominant Logic for Marketing, Journal of Marketing, 68:1-17

[25] Levitt, T., 1980, Market Success Through Differentiation – of Anything, Harvard Business Review, Jan-Feb 1980:83-91

[26] Vandermerwe, S. and Rada, J., 1988, Servitization of Business: Adding value by Adding Services, European Management Journal, 6:314-324

[27] Silvestro, R., Fitzgerald, L., Johnston, R. and Voss, C., 1992, Towards a Classification of Service Processes, International Journal of Service Industry Management, 3:62-75

[28] Methieu, v., 2001, Product Services, from a Service Supporting the Product to a Service Supporting the Client, Journal of Business & Industrial Marketing, 16:39-58

[29] Chase, R., 1991, The Service Factory: A Future Vision, International Journal of Service Industry Management, 60-70

[30] Chase, R., & Garvin, 1989, The Service Factory, Harvard Business Review 67/4 :61-69

[31] Youngdahl, W., 1996, An Investigation of Service Based Manufacturing Performance Relationships, International Journal of Operations and Production Management, 16/8:29-43

[32] Voss C., 2003, Applying Service Concepts in Manufacturing, International Journal of Operations and Production Management

[33] Ren, G., Gregory, M., 2007, Servitization in Manufacturing Companies: Forming an Academic Field with Meaning, Stocktaking and Coherent Inquiries, POMS College of Service Operations and EurOMA Conference

[34] Mont, O., 2000, Product Service-Systems, Final Report for IIIEE, Lund University, Lund

[35] Tukker, A., 2004, Eight Types of Product Service System; Eight Ways to Sustainability? Experiences from SUSPRONET, Business Strategy and the Environment, 13: 246-60

[36] Schlie, T. W., 1995, Advanced Manufacturing and New directions for Competitive Strategy, Journal of Business Research, 33 :103-114.

[37] Porter, M. E., 1980, Competitive Strategy, The Free Press, New York.

[38] Baines, T., 2009, Competitive Strategy, Lecture Note, Cranfield University

[39] Treacy, M. and Wiersema, F., 1993, Customer Intimacy and Other Value Discipline, Harvard Business Review, Jan-Feb:84-93

[40] Chandler, A., 1962, Strategy and Structure: Chapters in the History of Industrial Enterprise, MIT Press, Cambridge, MA

[41] Skinner, W.,1969, Manufacturing – The Missing Link in Corporate Strategy", Harvard Business Review, 47:136-46.

[42] Gyampah, W. A. and Acquaah, M., 2008, Manufacturing Strategy, Competitive Strategy and Firm Performance: An Empirical Study in a Developing Economy Environment, *Int. J. Production Economics 111*, pp. 575–592

[43] Platts, K. and Gregory, M., 1990, Manufacturing Audit in the Process of Strategy Formulation", International Journal of Production & Operations Management, 10:35-42

[44] Olorunniwo, S., Hsu, M., and Udo, G., 2008, Service Quality, Customer Satisfaction, and Behavioral Intentions in the Service Factory, Journal of Services Marketing, 20:59-71

[45] Kumar, R. and Markset, T., 2007, Development of Performance-based Service Strategies for the Oil and Gas Industry: A Case Study, Journal of Business and Industrial Marketing, 22:272-280

[46] Panizzolo, R., 2008, A Methodology to Measure the Value of Services Provided to Customers in Manufacturing Firms, Measuring Business Excellence, 12:3-15

[47] Lee, W., 2007, A Decision Model for Manufacturing Best Practice Adoption: Linking Practices to Competitive Strategies, EngD Thesis, Cranfield University

[48] Baines, T., Kay, G., Adesola, S. and Higson, M., 2005, Strategic Positioning: An Integrated Decision Process for Manufacturers, International Journal of Operations and Production Management, 25:180-201

[49] Lim, R., 2007, Development of a Supply Chain Positioning Methodology for SMEs in Singapore, EngD Thesis, Cranfield University

[50] Chandraprakaikul, W., 2008, Methodology for Strategic Positioning within Global Supply Chain, EngD Thesis, Cranfield University

Session 6B: Networks

Building Networks for Delivering Integrated Product-Service Offerings (IPSOs)

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Abstract

The paper describes the effect of forming business networks and collaborations for the purpose of developing an Integrated Product-Service Offering (IPSO) using the Product/Service Systems (PSS). The research method is an in-depth case study of a joint venture formed by four companies developing a new technology for chemical extraction from water sludge waste within the pulp and paper industry. Combining literature from PSS, network theories and collaborative product development, this paper puts forward the benefits for SMEs to collaborate in business networks and produce IPSOs when introducing a new technology in an emerging market. The case study shows that working towards the new market would not have been possible if each party acted individually or maintained their traditional buyer-supplier-operator roles, and that IPSOs can reduce the business risk.

Keywords

Product/Service Systems (PSS), Business-driven Networks, Collaborative Product Development (CPD)

1 INTRODUCTION

There is a great potential for Sweden and Swedish companies in the area of environmental technologies[4]. Especially, there is a large need for clean-tech solutions in developing countries where numerous ongoing infrastructure projects in industry and public sectors require technical solutions in order to encourage a sustainable society. The challenge is that full-scale demonstration plants are required to show proof-of-concept, preferably on-site in the developing country. Developing such total solutions that encompasses a whole production system – from suppliers, to producers, to customers and users – requires both financial strength and capabilities to manage business relations of many parties. Since many of the Swedish clean-tech companies are small, this is usually overwhelming challenges, and therefore export of Swedish environmental technology to developing countries where the need is vast is still quite weak [1], [2]. Nonetheless, previous research has shown that business networks can be an efficient way for SMEs to deliver complete offerings [3]. Moreover, technology-based SMEs need support for growth [4], [5].

2 OBJECTIVE

The objective of this paper is to analyse the creation and development of business-driven networks for the purpose of developing an integrated product-service offering (IPSO), in response to a need and opportunity spotted in an emerging market.

3 METHODOLOGY

In this study, the business network was chosen as the unit of analysis [6]. This finds support in, e.g. Mont [8], claiming for PSS that *"(t)he challenge with the new approach lies in developing system solutions, where bits and pieces fit together, integrated into a system of people satisfaction"* [7].

The case study was conducted as part of the LIAN[5] research project (2008-2010) focusing on the development of the innovation process in small environmental technology companies. The main goal of the project is to realise a systems solution through collaboration with other parties in business-driven networks. The research is performed as a joint-effort between KTH, LIU and a risk capitalist with interests in emerging markets.

A total of eight interviews were performed with respondents from five different companies and organisations. Due to the study being anonymous, the identities of the companies and respondents cannot be revealed. The roles of the companies, however, are detailed in the case description.

The case study is based on

1 a retrospective study where the innovation processes in terms of the technology development process and the business development process are the main foci, and
2 an ongoing study of the same case where the launching and testing of the full-scale pilot plant and implementation of their business model is being followed. Since both technical problems are currently being dealt with on site at the emerging market, and business issues are likewise currently undergoing negotiations, the respondents and the companies need to stay anonymous in this case description.

A semi-open interview guide was prepared based on topics central to the research project, i.e. on collaborative product development, PSS offerings, and business-driven networks. Questions were open-ended to allow

[4] Definition of Environmental Technology (or CleanTech used synonymously) according to EU Environmental Technology Action Plan (ETAP).

[5] LIAN in English translates as "Management of Innovation Processes for Business-driven Networks".

interviewees the opportunity and freedom to elaborate on key areas. The objectives of the interview sessions were to learn more about the individuals' and the companies' skills, capabilities, collaborations and contributions to the technology development and the business development processes.

Based on the interviews conducted by the authors, the paper describes the impact of forming collaborations and networks for the purpose of developing an integrated product-service offering (IPSO).

All interviews were transcribed and a case report is currently being written. Since the respondents are still in a phase of active work, the case report has not yet been shared with them, and therefore the data has not yet been validated. Even though the research work conducted is still a work-in-progress, some interesting preliminary conclusions can be drawn.

4 LITERATURE REVIEW

4.1 Product/Service Systems

Product/Service Systems (PSS) owes some origin to the emerging Service Economy in which both physical products and technology are means of providing functions. Instead of adding value through revamping or improving production processes, value is added by "servitising" products—in other words, integrating services with physical products. Some examples of such integrations include user training, technological improvements such as new software versions, aesthetic design, etc. (all intangibles) [8]. The main idea in PSS is that *function and utility* are key to customers' satisfaction, instead of the physical product itself. Thus, it can be considered that the concept of PSS depicts a shift from selling products to selling services.

The development of this concept addresses two important aspects of how the provider company's strategies should be designed—the business aspect, and the environmental aspect. Considering that today's customers demand more and more services, companies should realise that substantial revenue can be earned when a product life cycle is extended, not by selling more pieces, but by providing more services that are of value to the customer. Business developers can make use of environmental concepts (such as eco-design or EMS/environmental management systems) as corporate strategies, thus affecting business strategies and decisions in a more substantial manner [7]. From the business/economic point of view:

- The company should have a holistic perception of the whole production system (from product development, to customer use, and management of the used products) [7];
- Production of an offering focuses on value creation and utilisation of the offering, instead of producing a physical product; and
- Company activities that can contribute to this concept include service and repair, recycling, upgrading, re-manufacturing, and refurbishment [7].

From an environmental point of view, PSS has the potential to alter production and consumption patterns that might lead to more sustainable practices and societies [8]. It considers sustainability and the impact production has on the environment, by addressing efficient utilisation of resources. Specifically, PSS attempts to prolong the total life cycle of the product, with the least possible use (and/or re-use) of resources

Proponents of PSS argue that adding services to products can extend the product life cycle [9], and that companies can earn substantial revenue when the product life cycle is extended. However, there are hurdles to overcome with regards to adopting PSS:

- The readiness of companies to adopt the PSS concept, i.e. operating costs might increase as companies are now the owners of the products; and
- The readiness of consumers to accept the PSS concept, i.e. consumers might not be enthusiastic about ownerless consumption

Even at the strategic level, it is not clear what the extent of the service offer should be, or what factors to consider when deciding on a product-service mix [9].

It cannot be denied that it will require different societal infrastructure, human structures and organisational layouts in order for suppliers to realise the full potential of PSS in minimising environmental impacts of both production and consumption. In short, the complexity of the development process increases. One way of changing production, product usage and consumption patterns is to *create business solutions that present a different relationship to the consumer* than that offered by the traditional sale of products [7].

For example, to be able to deliver "new" services, companies need to continually develop their value chains and the competence of their staff, especially the ability to manage a new relationship with the customer [8]. This is because the added services requires of a company bureaucratic changes, structural changes and processes new to the producers [9]. The transition to Product/Service Systems also places new and demanding requirements on development and production of the product and service, along with new requirements for companies in the way they relate to and build relationships with their customers.

The PSS concept has the potential to offer a new way of understanding and influencing stakeholder relationships and viewing product networks, which may facilitate development of more efficient policies [8].

4.2 Network-building

From the study of business organisation, we can trace two related fields which hold two contradicting ideas: organisational theory and strategy management. Organisational theory studies state that the organisation is often embedded in its environment. Thus its actions and behaviours are greatly constrained by its environment. Strategy management theories, on the other hand, suggest that the opportunities exist for the organisation to control its own behaviour and assume that the organisation possesses the freedom to make its own choice [10].

Strategy management scholars make three assumptions of the organisation:

1 Organisations are affected by external factors;

2 Organisations have to use their internal capabilities to counter these external factors; thus

3 When environmental conditions change continuously, organisations need to adapt continuously to these changing conditions.

Networking and forming collaborations are just some of the sub-disciplines within strategy management.

The network model originated in the mid-1970s at the University of Uppsala. A network is defined as "...a set of high-trust relationships which either directly or indirectly link together everyone in a social group" [11]. The fundamental components of a network are the nodes and the connections. The nodes in a network are represented by actors or players. These actors (or players) can consist of individuals, organisations and institutions. The connections are usually the social ties and relations that connect the various actors in the network [12]. The network construct basically provides a picture of the inter-organisational relations that are maintained between various actors in its environment.

The network model puts forward three observations:

- Business organisations often operate in environments which include only a limited number of identifiable organisational actors;
- These actors are involved in continuous exchange relationships with the organisation; and
- In such cases each individual party exerts considerable influence on the organisation.

Pöyhönen and Smedlund [13] identified three types of networks, placing special emphasis on knowledge-creation with respect to the three:

- a *production network* assumes a hierarchical structure, where the leader of the network finds his place at the top of the network structure, and knowledge flows only one way, i.e. top-down (e.g. a bureaucracy);
- a *development network* is pictured as being rather flat and proposes all network actors to be empowered. Thus knowledge sharing can move in any direction, but always in a horizontal fashion (e.g. in task forces); and
- in an *innovation network*, information moves in a chaotic and sporadic fashion and connections are established between as many members as possible. For the innovation network, personal networking skills are given preference over individual power of the respective actors (e.g. new venture creation).

They conclude that in a knowledge-producing organisation, all three networks are utilised.

The relationships (linkages) between the actors are generally continuous over time, rather than being composed of discrete transactions. Routines strengthen the interdependencies between the two parties. Through these relationships, either party can gain access to the other's resources. To some degree, actors can therefore mobilise and use resources possessed or controlled by other actors in the network. Actors can use the existence of "complementarity" or competitiveness in their relationship in different ways, as they interact with one another. The establishment and development of an inter-organisational relationship requires a "mutual orientation" [10].

Leiserson states that actors having the same ideology have a higher possibility of forming a more successful network, as these actors possess similar attitudes and characteristics [14]. Within this opinion, communication is essential in order to allow network actors to identify partners who are most compatible and likely to contribute to the success of the network. However, Karathanos brings forward the idea of coalition as a "means-oriented alliance among (actors) who differ in goals" [14]. This opinion is appreciated especially when most research indicates that partner selection is always based on a pre-supposed "fit".

By the 1990's, the network approach has become the basis for new organisational forms [15]. In today's economy, networking has become the rule, rather than the exception, and reflects the appropriate way of communicating and organising resources for today's companies. It demonstrates how individual actors create and manage alliances among themselves as strategic responses to counter competitive forces and innovative uncertainties [13]. This is especially applicable to small and medium-sized organisations that lack resources and skills critical for them to develop and expand.

5 CASE STUDY

5.1 The Integrated Product and Service Offering (IPSO)

The IPSO in this case is based on:

- The Build-Own-Operate (BOO) concept, where the joint venture (JV) company takes responsibility for the design, builds and operates the water treatment plant at the customer's facility.
- The new technology process extracts chemicals from the water sludge waste. The water sludge waste (which is actually the facility's waste product) is free for the JV company.
- The chemicals extracted become raw material and is re-sold to the customer facility for use in their production process. The cost is regulated by the contract to be a certain percentage of the market price of the chemical. The facility is obligated to purchase the chemical from the JV company.
- The main motivation for the facility to be interested in the IPSO includes disposal of the sludge and the reduced costs for handling sludge waste. Other factors include environmental laws, costs for storing of the water sludge waste and lower raw material costs.

5.2 The Inventor

The Inventor is the initiator and inventor of the technology used in the chemical extraction process in this case. Currently, the Inventor holds two patents for this technology. The patents were taken over by Company 2 in exchange for financial backing in order to further develop the technology. At the same time the patent was acquired by Company 2, the Inventor was also employed as an independent technology consultant for Company 2.

5.3 The participating companies

The following summarizes some information regarding the companies and their motivations for participating in the joint venture:

Company 1

Company 1 is an engineering company and the appointed supplier to the JV company. Their main business is providing consultancy services within the energy industry. Their role in the JV company is to develop and deliver the technology, thus Company 1 is known as controlling the "heart" of the applied technology. Company 1 holds a critical role in the development project, and works extensively with Company 2 to develop and test the technology during its development phase

Company 1 owns the least amount of shares in the JV company.

Company 2

Company 2 is in essence, a chemical supplier. They own the technology used for the chemical extraction process. They acquired the technology from the Inventor (of the technology, and who was the one who originally filed the patent on the technology) in exchange for financial assistance. Following the acquisition of the technology, the Inventor was also hired as an external consultant in Company 2 in order to continue working on the technology.

Company 2 later became the major shareholder in the established JV company, and thus assumes most of the project leader role.

Company 3

Company 3 is physically located in the emerging market, in which the newly established JV company aims to offer its newly developed IPSO. It was Company 3 that originally spotted the opportunity and potential in bringing the extraction technology to the emerging market. Company 3's main role in the collaborative development project and later the JV company is their presence and knowledge of the emerging market. More precisely, Company 3 acts as the agent between the JV company and the clients, as they are the ones with the direct connection to the clients.

Ironically, Companies 1, 2 and 3 previously found their connections through key actors, who at different points of their lives were acquaintances and colleagues.

Company 4

Company 4 is a venture capitalist that joined the JV company at a later stage. At that stage, the technology development was nearly completed, and the other three companies were looking to build a full-scale plant. Keeping in mind the business side of the development, Companies 1, 2 and 3 agreed to seek assistance from Company 4. The main role of Company 4 here was threefold: (1) to assume some of the financial risks associated with new venture creation, as well as (2) to provide legal guidance in the establishment of the JV company and (3) to give support in entering the emerging market.

Local partner

There is also a local partner from the emerging market who has been actively involved in the business development process. The partner has local knowledge of the customers and their needs, knowledge of the local culture and how to perform business in that market.

5.4 Testing the technology

During the development of the technology, preliminary tests were conducted locally in Sweden. These tests plants were small and portable, which means they were transferable from one location to another. Most importantly, the tests produced encouraging results. The early-stage development tasks and tests were personally funded by the Inventor.

Once the patent was bought over by Company 2, a pilot facility was built and another test was conducted at a larger scale. This test was funded 50/50 by the Inventor and Company 2 and took place in the emerging market.

This was the JV company's first step towards entering the emerging market, i.e., a natural progression was to test the technology on site, at the customer's facility in the emerging market. This also resulted positively, and a plan was devised to build a full-scale plant and begin implementing the technology (in the emerging market).

Currently, the technology is at a stage where the technology is to be implemented for actual use in the process industry.

6 DISCUSSION AND ANALYSIS

The main purpose of this paper is to analyse and learn more about the two networks that developed in the process of developing the new technology and the IPSO, followed by the process of bringing the new technology to the emerging market. Some issues that were addressed include:

- partner selection and how the companies initiated the first contact;
- what kind of relationship existed in the beginning, and how has this relationship developed over the months; and
- what kind of communication were used in their dealings (was it open communication or closed communication); and
- what is the nature of these relationships now, in light of the challenges that the JV company is facing now.

For this case study, two types of networks were detected in the innovation process: a technology development network and a business development network.

6.1 Technology Development Process

The technology development process is illustrated in Figure 1. The formation of the JV company began several years before (even before the JV company existed), as long-time friends and acquaintances who share common history, backgrounds and interests try to assist each other with developing a new technology. These relations were informal, and assistance came in the form of ideas and discussions (between the Inventor and his former colleague who currently works in Company 1), references and recommendations (as in the Inventor recommending Company 1 to Company 2 as the supplier) and lending of equipment (again between the Inventor and the Individual in Company 1) and so on; but never financial assistance. Most of the work and much effort occurred at the personal level, and relations and ties were based on friendship and trust built over long years before.

The JV company first assumed formal ties and shape after the technology was nearly fully developed. Contracts were created and signed by the respective companies involved in the JV. The first formal agreement was between the Inventor and Company 2, where the Inventor sold the patent to Company 2 in exchange for financial assistance in order to carry on his work on the technology. At the same time, the Inventor began official employment as a consultant within Company 2 so as to continue his development work on the chemical extraction technology.

As a consequence of this, Company 1 was appointed the dedicated supplier (as they had the "heart") to build the pilot plant. Coincidentally, Company 3 was scouting for this precise technology for implementation in the emerging market, and based on references and old-time friendship, landed at Company 2. Together, the three companies came together to formalise their agreement in order to develop the technology and bring it into a new market.

In the beginning, personal relationships played more important roles. But once the relationships were formalised, inter-organisational networks were of more importance.

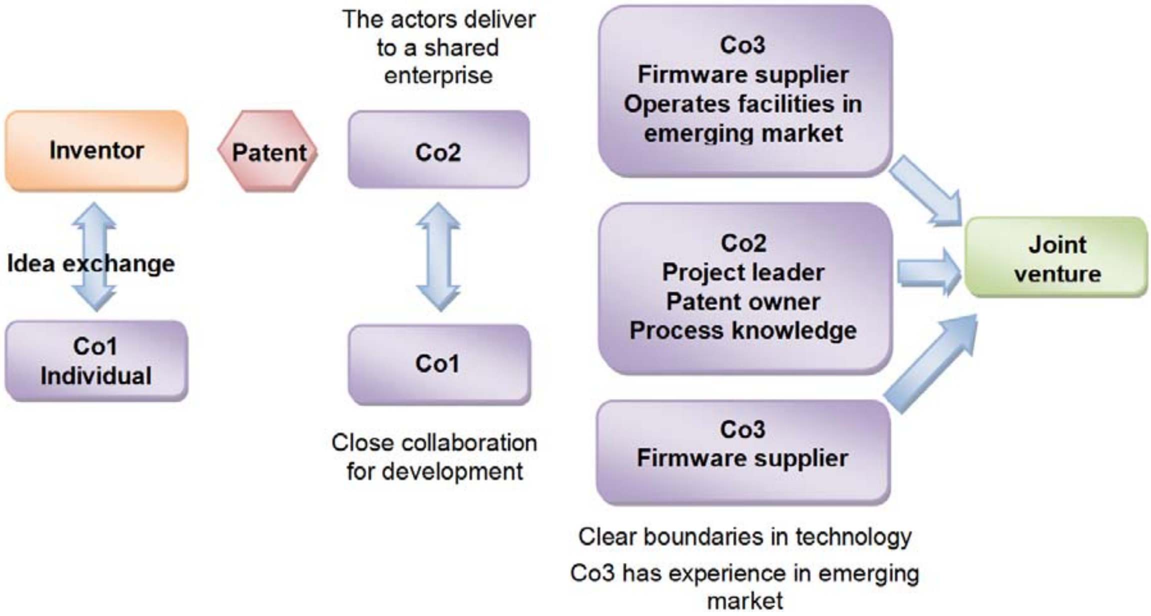

Figure 1: The Technology Development Process

It cannot be denied that the iterative work process between all the companies for developing the technology innovation went much smoother than expected. This is because all parties relied on long-time friendships and trust that they had built from past years. However, it should also be noted that the technology development is currently still an ongoing process, as the JV company has recently launched the first full-scaled pilot plant and is awaiting its results. As Leiserson and Karathanos states that common ideology plays a significant role—coalition formation is predicted to be more successful if members possess similar attitudes, even though respective parties differ in goals [14].

And that actors have the tendency to select and partner with other actors who are most compatible and likely to "grow" the network/company.

6.2 Business Development Process

The business development process is illustrated in Figure 2. The first business transaction was initiated when Company 2 purchased the patent from the Inventor. With this, followed a succession of business agreements and economic transactions that occurred between the companies in their efforts to develop the technology.

After acquiring the patent, the next step for Company 2 was to appoint a dedicated supplier (i.e. Company 1) to develop and build the facility in which the technology will be tested. What is interesting is that, Company 1 was contracted because of their assistance to the Inventor while he was developing the technology (prior to the sale of the patent to Company 2).

Coincidentally, Company 3 came into the picture when they were in search for this precise technology to be used within the process industry in the emerging market. Company 3's main intention was to purchase the patent from Company 2, and become owner of the technology. However, Company 2 did not agree to sell the patent; and a loose partnership was formed, in which the three companies agreed to work together in order to bring the technology to the emerging market.

Once the technology development process was approaching the market launch phase, the three companies realised that they needed to formalise their existence, before entering the emerging market. For this, they approached Company 4, whose specialty was in new venture creation in emerging markets.

Company 4's main contribution was to provide legal advice and financial capital to the JV company. With the new addition, the formation of the JV company was formalised.

In the business development process a local partner was also active. Due to legal reasons the local partner could not (at this moment) be included in the JV. The local partner has an important role as he has local knowledge, both in terms of customer connections, as well as knowing required business procedures.

Due to legal reasons, a corresponding JV company was also established in the emerging market. However, this JV company is fully owned by the JV company which was formed in Sweden.

The way the business development process evolved was very different from the technology development process. Each step taken was discussed by all the companies and decisions were made based on a need that was beneficial to the partnerships. This is concurred by Håkansson and Snehota when they observed that the establishment and development of inter-organisational relationships requires "mutual orientation" [10]. Each addition to the JV-company was an asset and also a way for the JV company to create and to build alliances in order to counter competition and uncertainties [13]. Though many initial discussions began with informal relationships, these relations were formalised rather quickly. This reflects the quality of the relationships that have taken long years to build and develop [13], and played an important role in expediting the formation of the JV-company.

6.3 Network-building within PSS

Within the JV initiative, certain features of the PSS concept can clearly be observed.

The main objective of the JV company is to develop an integrated product-service offering (IPSO) using the PSS concept. In doing so, both parties (the JV company and the customer) address some obvious environmental issues, that is (1) to dispose of the water sludge waste, (2) in the most cost efficient method, (3) using techniques that are environmental-friendly. All these three features can be found within the water treatment technology which utilises the water sludge waste as its raw material in its water

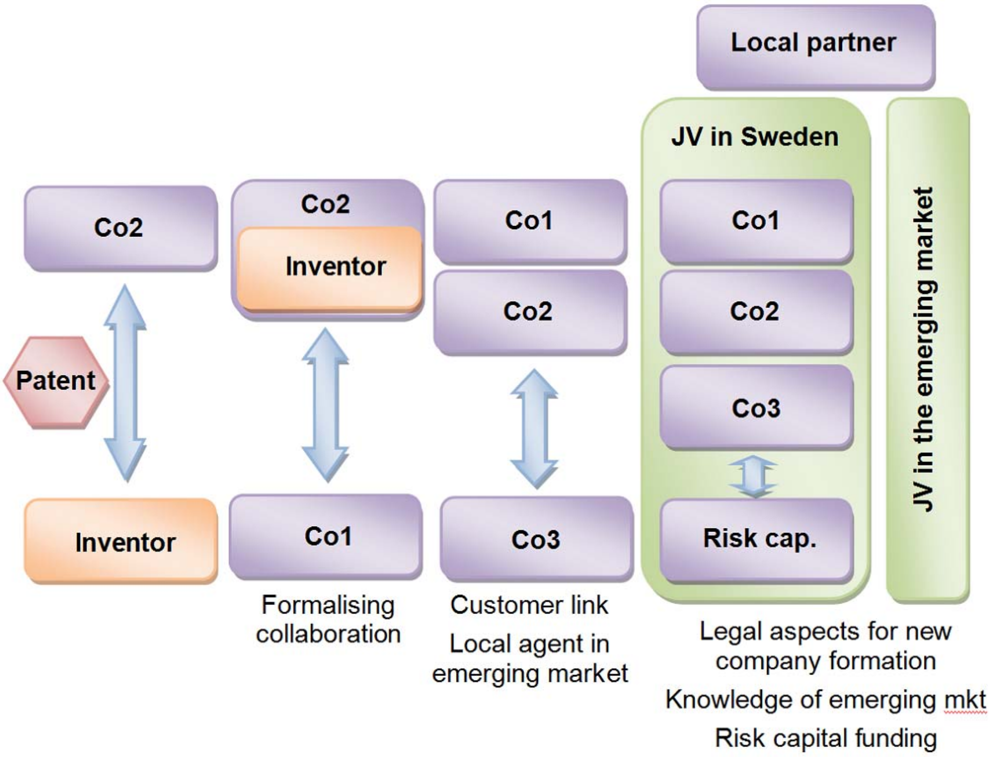

Figure 2: The Business Development Process

treatment process—the by-product of which is a mineral that will be sold back to the facility at lower-than-market price. This has obvious implications for the facility. Since the water treatment plant is built on the facility itself, the facility is now able to "nearly" eliminate the transportation cost that is incurred when disposing the water sludge waste. In addition, the plant now enables the facility to "generate" the needed mineral on-site, making the facility self-sufficient.

The pilot facility is to run for a test-duration of five years. At the end of this duration, the facility can choose whether to keep the water treatment plant running on its facilities, or discontinue the service obtained from the pilot plant and JV company. Should this option be chosen, the water treatment plant can easily be dismantled by the owners (the JV company) and transferred to another facility where it can again be re-constructed and operated in the same manner—thus taking care of the disposal costs of the water treatment plant.

It cannot be denied that the PSS concept compels us to view networks with a slightly different angle. This is because PSS has the potential to offer a new way of understanding and influencing relationships between actors.

The JV company was formed in order to exploit an opportunity of being first on the market using a completely new method in the industry. A decision was made to have an IPSO instead of selling the equipment and technology. By doing this, the JV company is able to shorten the time-to-market, as well as spread the risk amongst all partners involved. Furthermore, the process knowledge and technology knowledge would stay with the JV company. As described earlier a BOO approach has been taken.

The benefits for the customer include having to avoid dealing with the disposal of the water sludge, and the opportunity to purchase the needed chemical at a lower price than the market price. By doing this, the customer

- internalises some costs (especially depot costs for storing the water sludge waste);
- eliminates the cost of disposing of the water sludge waste; and
- reduces the delivery time and cost of purchasing aluminium by having the water treatment plant on site.

It should however be mentioned at this point that, the PSS concept does have some limitations. Firstly, the PSS concept is relatively new, and there is insufficient work carried out to capture and present successful PSS applications. Thus, there is no evaluation guide to examine whether a PSS is "successful" or not [21],[8]. Secondly, because companies do not have sophisticated theories and practices on maintenance and re-manufacturing model within the PSS, this poses many uncertainties and risks. Thirdly, a PSS evaluation tool is needed to guide customers in making decisions (what are their benefits, why should they decide for PSS, etc.)

7 CONCLUSION

It is clear that for small environmental technology companies developing and providing IPSO is a promising path for locating new business opportunities in new emerging markets. By approaching the customers with an IPSO and a total solution instead of offering part solutions or selling the technology many benefits can be achieved, among them:

- being able to expand businesses and penetrate new markets;
- get access to new customers by assuming more financial and technical risks;
- shortened time-to-market; while
- protecting the process and technology owner (as these valuable knowledge remains with the provider), i.e. the provider protects its know-how and technical core competence.

Competitive and sustainable PSS solutions can rarely be provided by a single company [21]. As seen in the case described, networking with partners complement each others' own knowledge. In the innovation process for developing and launching the IPSO the technology development process and the business development process have ran parallel to each other. In the two processes, different companies and different actors within the companies added their specific knowledge. An important indication of this is that, the companies need to learn how to promote their own skills, and at the same time, know where to find complementary knowledge. Besides this, the companies also need to learn how to act in and be part of a business-driven network.

When forming business-driven networks, the environmental context in which the respective actors exist [12] should also be taken into account. The network analysis was used to analyse the JV company as:

- it is seen as a form of co-ordinating asset-specific resources that were within the respective partners;
- the network/personal relations was/were used as a means to create and exploit opportunities, using close interactions; plus
- these relationships must be maintained in order to build social capital that is crucial for the success of future projects.

A knowledge-producing company utilises all three types of networks (a production network, a development network and an innovation network) [10] and the success of the JV company depends upon the partners' abilities to use the correct network construct depending on which stage of the development process.

The preliminary conclusions that can be drawn based on the development that has progressed within the full-scale pilot plant are:

- The concept of PSS facilitates innovation in multiple areas and various ways (i.e. in the technology and the business development);
- PSS has the potential to produce financial benefits; and
- By understanding integration of product and services AND being part of this network enabled the companies to identify new market opportunities and stay competitive at a global level. As a result, the JV company was able to produce a new technology in their field that could not have materialised, if done by only one party.

It is evident that PSS places importance on customer involvement as more focus is placed on the transition to service. In this research project, in the beginning of the technology development process, the customer needs were expressed directly through the involvement of Company 3, which was also the company who spotted the opportunity for bringing the technology to the emerging market. During the testing phase which is currently ongoing, the customer is very much involved in the development process, interacting on a daily basis for troubleshooting and problem solving purposes.

For future works, this project will focus on the results obtained from the full-scale pilot plant that has recently been launched.

8 ACKNOWLEDGMENTS

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9 REFERENCES

[1] ITPS, 2007a, *Svenskt näringsliv i en globaliserad värld - Effekter av internationaliseringen på produktivitet och sysselsättning.* Rapport A2007:004 av Hansson P., Karpaty P., Lindvert M., Lundberg L., Poldahl A., Yun L. för Institutet för Tillväxtpolitiska Studier (ITPS).

[2] Dagens Industri, 2007, published Aug 25, 2007.

[3] Öhrwall Rönnbäck, A., 2002, Interorganisational IT Support for Collaborative Product Development, dissertation IMIE no 59, EKI no 54, Linköpings universitet.

[4] VINNOVA, 2007, Innovativa små och medelstora företag – Sveriges framtid. Strategi från VINNOVA för ökad innovionskraft, VINNOVA Policy, Rapport VP 2007:01 av Jan Edling, Kenth Hermansson, Rolf Nilsson och Jenni Nordborg.

[5] Lindholm Dahlstrand, Å., 1997, Growth and inventiveness in technology-based spin-off firms, Research Policy, 26: 331-344.

[6] Yin, R. K, 1994, Case Study Research: Design and Methods (2nd ed.), Sage Publications, London, UK.

[7] Ölundh, G., 2003, Environmental and Development Perspectives of Functional Sales, Licentiate Thesis, Royal Institute of Technology, KTH, Sweden.

[8] Mont, O. K., 2002, Clarifying the concept of product-service system, Journal of Cleaner Production, 10: 237-245.

[9] Oliva, R., Kallenberg, R., 2003, Managing the Transition from Products to Services, International Journal of Science Industry Management, 14(2): 160-172.

[10] Håkansson, H., Snehota, I., 1989, No Business is an Island: The Network Concept of Business Strategy, Scandinavian Journal Management, 5(3): 187-200.

[11] McDonald, F., Vertova, G., 2001, Geographical Concentration and Competitiveness in the European Union. European Business Review, 13(3): 157-165.

[12] O'Donnell, A. et al., 2001, The Network Construct in Entrepreneurship Research : A Review and Critique, Management Decision 39(9): 749-760.

[13] Pöyhönen, A., Smedlund, A., 2004, Assessing Intellectual Capital Creation in Regional Clusters, Journal of Intellectual Capital, 5(3): 351-365.

[14] Karathanos, P. H., 1994, Communication Network Analysis and Dysfunctional Organisational Coalition, Management Decision, 32(9): 15-19.

[15] Nohria, N., & Eccles, R. G. (1992), (Eds.) "Networks and Organisations" (Boston, Mass.: Harvard Business School Press). (In) Child, J. and Faulkner, D. (1998), "Strategies of Cooperation: Managing Alliances, Networks and Joint Ventures", (Oxford: Oxford University Press).

[16] Maglio, P. P., Spohrer, J., 2008, Fundamentals of Service Science, Journal of the Academic Marketing Science, 36:18-20.

[17] Vargo, S. L., Lusch, R. F., 2008, Service-dominant Logic: Continuing the Evolution, Journal of Academic Marketing Science, 36:1-10.

[18] Lindahl, M., Sundin E., Öhrwall Rönnbäck A., Ölundh Sandström G. (2009), *Integrated Product Service Engineering (IPSE) project – Final report*. 2009, Department of Management and Engineering, Linköping University: Linköping. VINNOVA.

[19] UNEP, 2002, Product Service Systems and Sustainability. Opportunities for Sustainable Solutions. UNEP-DTIE:Paris.

[20] Sundin, E. et al., 2009, Conference: IPS2 - CIRP Industrial Product-Service Systems Conference 2009, Cranfield, United Kingdom, April 1, 2009 - April 2, 2009.

[21] Baines, T. S. et al., 2007, State-of-art in Product-Service System, J. Engineering Manufacture, 221(B): 1543-1552.

IPS² in China – A Systematic Approach for Market Entry

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Abstract

When establishing a service business in China, especially western small and medium-sized enterprises face several challenges. Therefore, an approach has been developed within a research project, which aims to support western industrial service suppliers in realizing their market entry in China successfully by offering methods and tools for the most challenging aspects of the process of internationalization on a web-based knowledge platform. The paper will focus on a self-assessment tool for companies' competencies in the process of internationalization and a tool which supports in choosing the adequate organizational form for a market entry in China.

Keywords

Internationalization, Self-Assessment, Organizational form, Industrial Service, China, Industrial Product-Service System

1 INTRODUCTION

Until recently, China had failed to recognize the important role service can play in economic development. As a result, the service industry has remained relatively underdeveloped compared to other fields of industry.

In 2008 the portion of the service sector of China's gross domestic product accounted for 39% [1]. Compared to Germany, with a proportion of the service sector of nearly 70%, the portion of the service sector to China's GDP is still low [2].

This huge potential of the Chinese service market together with the various reforms and the opening-up policy of the Chinese government offers enormous market opportunities and therefore attracts many multinational companies including German providers of Industrial Product-Service Systems (IPS²). [3, 4]

Although German manufacturing companies have obtained a lot of experience in entering the Chinese market, this remains a relatively new topic for industrial service providers. They face different problems when establishing a business in the Chinese service markets. Product piracy, employee qualifications, formalities and laws, cultural differences, service quality, fitting target market's requirements as well as choosing the optimal legal form for market entry are only a few examples of often named challenges, especially small and medium-sized enterprises seem to suffer from [5]. They can mean substantial risks and may lead to a loss in profitability.

Therefore, a procedure model that allows, especially small and medium-sized providers of Industrial Product-Service Systems, a successful entry into the Chinese service market was developed within a joint research project of research institutes and industrial partners.

This procedure model offers information, methods and tools for the most challenging aspects of the process of internationalization. Meeting the demands of SME, the approach with all developed methods, instruments and case studies is provided on a web-based knowledge platform, which will be presented in this paper.

The focus of this paper lays on two essential elements of this procedure model. The first one is a self-assessment tool for companies' competencies and status of preparation for the process of internationalization. The second tool supports service companies in choosing the adequate form of organization when entering the Chinese service market.

2 THE CHINESE SERVICE MARKET

2.1 Opportunities and Outlook

Since a fairly long time industrial enterprises are attracted by China's enormous economic growth. Despite the effects of the current financial and economic crisis, which China hasn't escaped unscathed either, China's gross domestic product (GDP) increased in the first six months of 2009 by 7,1% year-on-year [6].

Because of the continuously increasing volume of goods production, manufacturing companies more and more seize the chance of supporting their product's life cycle by a wide range of industrial services [7], which leads to Industrial Product-Service Systems. Driven by this trend, the service sector is emerging as the new key engine of Chinese economy [8], as services will provide a solution to China's serious employment challenges, sustain economic growth and raise living standards.

This development is also partially reasoned in the stimulation of economy through higher per-capita incomes and especially by the drastic liberalization of China's service sector [4]. The implementation of China's WTO commitments as to the amenability of their service sector slowly but steadily pays its tribute to economic growth. The cutback of service-related restrictions enables Chinese and foreign companies to benefit from formerly limited levels of the value-chain. However even the complete implementation of these WTO commitments is not capable of unleashing all economic potentials of China's service sector, with the consequence of limited international service trades and less foreign investments [8]. Regarding the service sector, The European Union Chamber of Commerce in China (EUCCC) emphasizes the necessity of an additional comprehensive reform in their „European Business in China Position Paper 2009/2010" [6].

China has already acknowledged the importance of services, which follows from its 10th (2001–2005) and its

11th Five-Year Plan (2006–2010). According to the government's plans further opening up and supporting of the service sector are going to contribute essentially to the expansion of its presence in the national economy. [9, 10]

Against the background of this development it can prospectively be assumed that the implementation of industrial services will become more and more important to assure satisfying product sales. This forecast is also verified by the empirical survey "Industrial services in China" conducted by Meier et al. [11]. This survey indicates that German service providers can reckon a duplication of the Chinese service market demand within ten years (Figure 1).

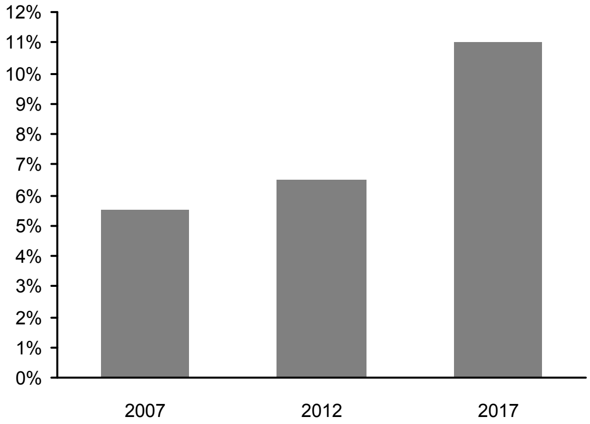

Figure 1: Future demand: Service share of overall turnover. [11]

Furthermore the study shows that service providing companies are going to furnish a wider range of market development strategies. While currently Industrial Product-Service Systems are limited to function-oriented basic services like spare parts, documentations, instructions, guarantee/warranty or repairing, future Industrial Product-Service Systems will be far more customized (e.g. availability-or result-orientation) (Figure 2) [7].

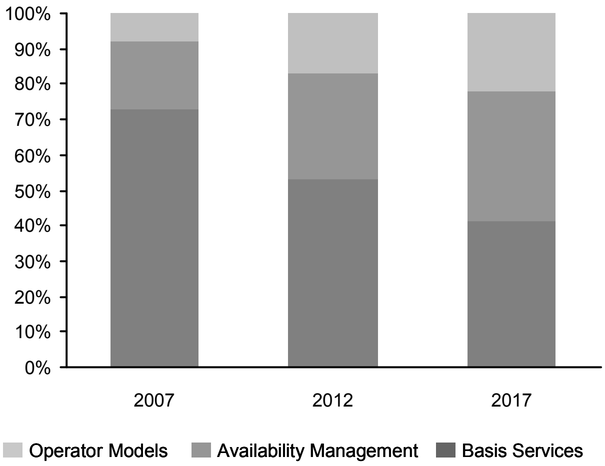

Figure 2: Future demand: Market development strategies. [11]

Availability-oriented services guarantee for the runtime of a certain product, while result-oriented services (e.g. operator models) take responsibility for the whole production process as well as for the allocation of production resources and its need in workforce. The customer only has to pay for the output of the machine.

In conclusion, China's service sector is seen as the next target for international business efforts as the opening of the sector and its increasing demand outlook offers enormous market opportunities independently from the company's strategy for internationalization (market-seeking or following customer).

In the survey "Service within the mechanical engineering industry", conducted by the Fraunhofer Institute for Production Technology, 70% of the respondents estimate China to be the market with the highest potential for growth of the industrial service sector in the Asian market [5]. In addition, a survey, conducted by the European Union Chamber of Commerce in China and Roland Berger Strategy Consultants shows that 83% of the respondents (companies, which are already present in China) are optimistic about the growth of the service sector in China over the next years [12].

2.2 Risks and Challenges

Anyhow the opportunities provided by the Chinese service market, harbor high challenges and risks. An empirical survey named "Growth through services" by Gebauer and Meier shows that the majority of industrial companies struggle to perform services in China sustainably profitable. Only 14% of the consulted companies confirm to cash in on their China investment, while 68% negate it [13]. This is underlined by the survey of the European Union Chamber of Commerce in China, which states that only 26% of the companies with a presence in China for less than 2 years are profitable in their China business [14].

According to these facts, the study by Meier et al. analyzed constraints of industrial service providing processes (Figure 3), considering the German suppliers' as well as the Chinese customers' point of view. Thus the biggest discrepancies derive from cultural clashes and thus communication problems, neglected face-to-face contact and the unavailability of qualified Chinese workforce[11].

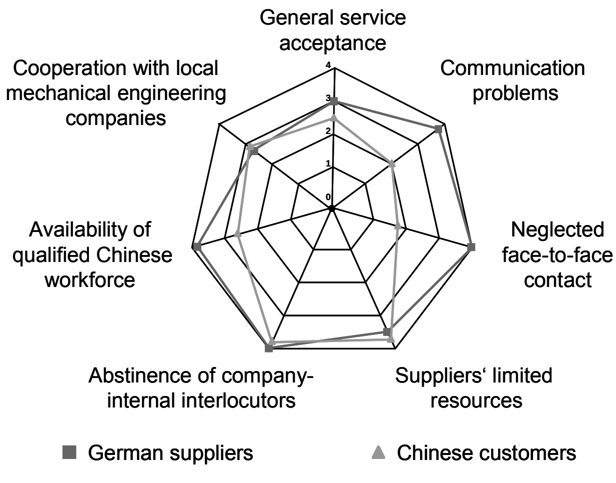

Figure 3: Service performance: Comparison of critical factors for success. [11]

Beyond that, the study compares the requirements for a successful service delivery on the supply side and demand side. As Figure 4 shows, the requirement profile of both involved parties' matches very well in every considered aspect, which leads to the conclusion that both sides share a similar attitude. Additionally to requests like attractive price conditions, short reaction time/response time or high service quality, face-to-face contact and local presents/customer support by the industrial service providing company are critical factors for success for good business relations [11].

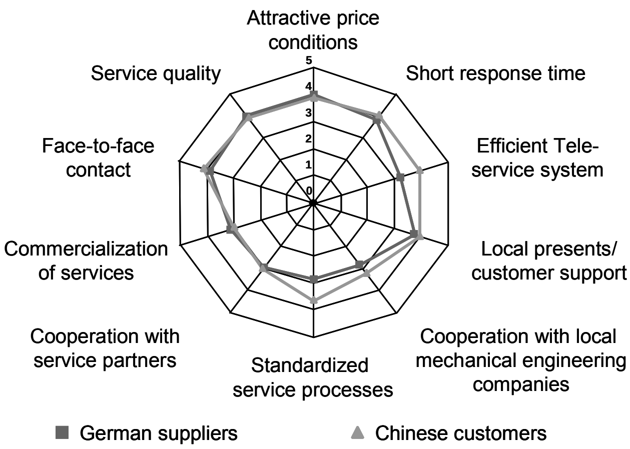

Figure 4: Critical factors of success for the service providing process. [11]

In this regard, the way of entering and especially dealing with the target market, such as the best possible cooperation between the German and Chinese business partner, play a decisive role. Particularly the form of organization for a market entry in China affects the whole business venture. The strategy of the market access depends on many internal and external parameters and has to be worked out company-specific [15].

The most common legal forms for a market entry of IPS² providers in China are:

- Export
- Representative office
- Licensing & Franchising
- Strategic alliance
- Joint Venture
- Wholly Foreign-Owned Enterprise (WFOE)

Even if decisions on market access strategies aren't necessarily irreversible, misconceptions often lead to uneconomical loss of resources and time due to long-term commitments [16]. While big established companies are able to face these difficulties, especially small and medium-sized service providing enterprises are overstrained by these challenges since their options are far more limited. For this reason support is strongly required.

Due to the fact that literature research showed no results for a support in the describes aspects, an approach has been developed within a joint research project of research institutes and industrial partners, which aims to support western integrated solution suppliers as well as pure industrial service providers in planning and successfully realizing a service market entry in China. The main focus of the approach is on the initial project phase, trying to avoid early failures and to ensure an efficient decision making at the project start.

Before accomplishing the entry into the Chinese service market a detailed analysis about the market and the process of internationalization with its requirements has to be initiated and compared with the company's already built-up competencies and the status of preparation for the process of internationalization. Thus, the developed procedure model envisions to apply a provided self-assessment tool for identifying deficiencies and potentials for improvement with regard to the readiness for an internationalization.

In order to handle the problem of choosing the adequate form of organization for a successful market entry in China the procedure model provides a proper tool, which offers suggestions for the optimal legal form for a market entry by considering all relevant aspects and conditions for this decision.

3 THE CHINA STAR – KNOWLEDGE PLATFORM

The procedure model or rather reference model, which was developed within the research project is structured in three phases.

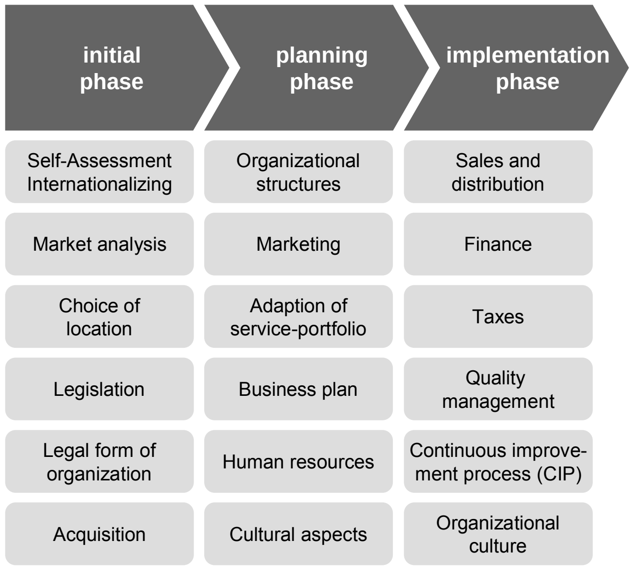

Figure 5: Three-phase procedure model.

Beginning with the initial phase the procedure model envisages that the phases are run through one after the other. Within each phase the modules for the different fields of action are arranged in a reasonable way, but the order can be adapted to the specific situation and individual needs of a company and its aspired China business. Furthermore single modules can also be left out. Depending on a company's plans in China, certain topics are not covered by the procedure model and have to be reprocessed by the company itself.

The developed procedure model can be used as a blueprint for companies' individual process of IPS² internationalization to China. It addresses all levels and business fields of enterprises. Regarded as a reference model it is a generic conceptual model that provides common or rather recommended practices for small and medium-sized enterprises who want to export their service portfolio to China and is motivated by the 'Design by Reuse' paradigm. It captures reusable efficient state-of-the-art practices, methods and tools and has the main objective in supporting the design of company individual models by providing a generic solution. It accelerates and simplifies the process of internationalization by providing a repository of potentially relevant information, business processes, methods and structures. Thus it allows for reducing the costs of developing individual procedure models and facilitates the management of the enterprise. [17]

Elements of the first phase are initial activities for preparing a possible China engagement and provide a basis for subsequent activities. For example, the analysis of the target market, an evaluation of market chances and risks, as well as the contacting of potential clients and business partners belong to this phase. Furthermore the identification of potential locations for a subsidiary fit in this first phase. A step which is intensively influenced by the choice of the legal form of organization. The objective of the phase is to establish a solid information basis for further decision making with regard to a China engagement. As a tool for determining the status quo of the companies' competencies and preparation progress in the process of internationalization, the self-assessment as the first step of the whole reference model can be applied. In addition a tool is provided for supporting the decision for the adequate form of organization in the Chinese market. The next chapters will focus on a detailed description of these tools.

The detailed planning of the internationalization process is accomplished within the second phase of the procedure model. For example, the organizational structures, concepts for marketing, services tailored to the target market requirements are developed and, together with the results of the first phase, lead to a business plan for the China engagement. Moreover the aspects like recruiting and qualifying Chinese personal as well as preparing German managers for their mission as expatriate are essential elements of the field "Human Resources", which is represented by a separate module in this phase. The module "Cultural aspects" covers different cultural characteristics, which are of interest for the whole internationalization process and the future business activities in China.

With regard to the intercultural cooperation and the establishment of a organizational culture, the objective of the third phase is to ensure a successful start of the new service business in China. It compasses also aspects like sales and distribution, finance and taxes, quality management and continuous improvements, which are important for a running business.

Meeting the demands of small and medium-sized enterprises, the whole reference process with all information and further sources for information, relevant contacts, developed methods, tools and case studies is provided on a web-based knowledge platform (www.service-in-china.de) and is therefore accessible for the public. Thereby the characteristic of this platform is similar to the Wikipedia-principle, which means it supports changes and supplementations of selected authors using the browser only. The content-management-system behind was programmed from scratch to allow for the needed functionalities.

3.1 Self-Assessment tool for the process of internationalization

The procedure model envisages that the self-assessment tool is applied as the very first step of the process of internationalization. Thus, a company can evaluate its status-quo with regard to the competencies needed for internationalization. At the same time it is possible to check the current status of preparation in the different fields of action, which are based on the modules of the procedure model (Figure 5). This should allow for a systematic consideration and execution of the modules.

The self-assessment tool should minimize the risk that the company's step to internationalize its Industrial Product-Service System by exporting it to China will fail or relapse due to a misjudgment of the necessary efforts which have to be accomplished by the exporting company. Thus the self-assessment tool can be seen as a kind of checklist which points out the important aspects and factors of success for the internationalization project that companies should be made aware of.

For the development of the self-assessment tool the following requirements had been defined:

- The status-quo of companies with the intention to internationalize their service business with regard to their competencies and progress of preparation should be assessable at the beginning.
- A repeated utilization of the self-assessment tool should allow for a continuous monitoring of the built-up competencies and the progress of preparation in the different fields of action.
- The duration for an application of the tool should be as short as possible.
- All relevant aspects of the internationalization process should be considered.
- The feedback of the status-quo and possible advisory actions should be in immediate timely relation to the completion of the self-assessment.

In order to meet the first and second requirement, the first step of the self-assessment tool allows for choosing the field of actions of the internationalization process which should be evaluated. Therefore, it is possible to select all fields of action when using the tool for the first time with the intention of determining the status-quo at the beginning of the process of internationalization. When using the self-assessment tool regularly for monitoring the process of internationalization with regard to the status of preparation in the different fields of action and the built-up competencies, it is possible to select only the fields of action, which are relevant at this special point in time. This means that already completed fields of action do not need to be run through again and fields of action, which are not of interest to the company or lie ahead in time can be deselected and run through in a later appliance of the self-assessment tool.

Two aspects account for fulfilling the third requirement. First, the possibility to select the fields of action, which should be considered for the appliance of the self-assessment tool (Already described in the previous paragraph.). Second, all fields of action can be assessed by answering 4-6 questions concentrating only on the most relevant aspects while all insignificant aspects are omitted.

All fields of action of the self-assessment tool correspond to the modules of the procedure model. Thus, it can be assumed that all relevant aspects for the process of internationalization have been considered in the self-assessment tool. Furthermore, plenty of studies and literature as well as the experience of the industrial partners of the research project had been analyzed and taken into consideration within the development of the self-assessment tool.

Since the self-assessment is a web-based tool, the feedback is given directly after answering all questions. As mentioned above, 4-6 questions must be answered in every field of action. Therefore, each question provides four possible answers. This 4-point scale should prohibit values in the middle of the answer continuum, which is a noticeable effect when using a uneven number of possible answers.

Each possible answer of every question represents a specific degree of maturity with regard to the topic of the related question. For the later calculation of the results the degree of maturity is represented in percentages in the database. The answering continuum thus ranges from 0% to 100% for each question. Additionally, each question is weighted within its related field of action. By multiplying the weighting of the question with the degree of maturity for the given answer and adding these results, a final result for each field of action can be given. The values in the database for these final results also range from 0% to 100%. These values are the basis for the feedback for each field of action, which is given in form of three possible levels of maturity. Oriented on the traffic light scheme the levels of maturity are:

- RED: 0-60%
- YELLOW: 61-80%
- GREEN: 81-100%

The feedback for each field of action comprises a short text describing the status-quo, giving advisories for further actions and pointing out possible risks. This text depends on the achieved level of maturity, which means that there exist three prepared texts for each field of action.

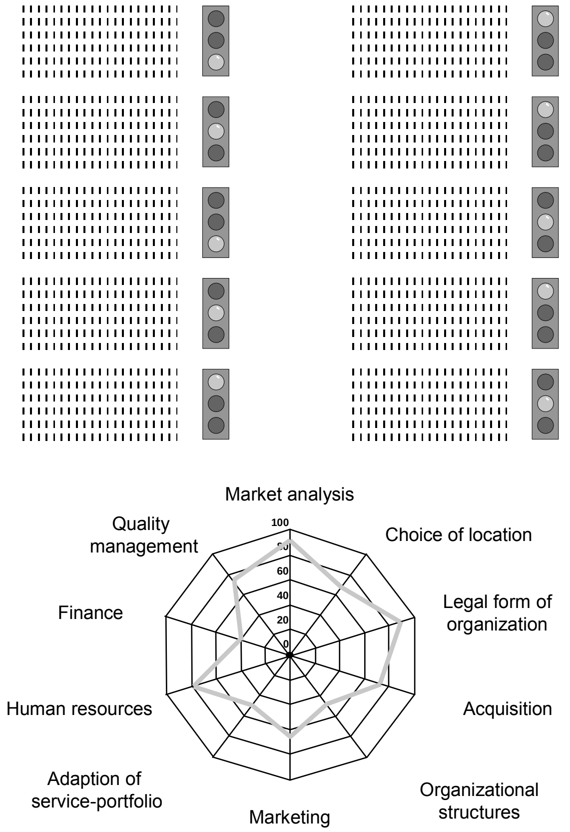

Figure 6: Result of the self-assessment.

Moreover, the level of maturity will be visualized by an icon illustrating a traffic light with the corresponding light illuminated. In addition to the feedback for each field of action a radar chart, in which each axis represents one field of action, summarizes the single results.

3.2 Market-entry tool for identifying the optimal organizational form for a market entry in China

Very early in the process of IPS² internationalization the decision about the legal form of organization – a company wants to start its China business with – must be taken.

Until the year of 1986 Joint Ventures and Representative Offices had been the only form of organization for foreign companies in China. Today there are many more possibilities for starting and building-up a business in China.

The most important legal forms of organization in China considered within the research project are:

- **Export**
  Temporally presence of natural persons in China; IT-based services
- **Representative office**
  Permanent representation of a company in China; secretary and supporting activities (contacting, marketing, market research, etc.); direct business prohibited (signing contracts, building up production)
- **Licensing**
  Contract-based provision of patents, brands, intellectual property rights or know-how to a Chinese company
- **Franchising**
  Contract-based provision of an extensive and well-proven concept for procurement, sales, organization and marketing to a Chinese company
- **Strategic alliance**
  Co-operation of at least two companies in an exactly defined domain without setting-up a new company
- **Joint Venture**
  New company founded by at least to companies; they yield capital, know-how and personnel
- **Wholly Foreign-Owned Enterprise (WFOE)**
  Legally independent subsidiary without a participation of a Chinese company and limited liability

Each of the organizational forms described above has advantages and disadvantages that need to be considered and is subject to legal restrictions that have to be met. Hence, especially for novices it is difficult to choose the adequate legal form of organization for a successful start of the China business.

Even if the chosen form of organization is not irreversible, wrong decisions often lead to considerable losses of resources and time. Therefore it is important to choose the optimal form of organization right at the beginning of the China engagement. After a possibly small and careful start of the China business the organizational form should be changed when the business is stabilized and profitable or demands for another legal form because restrictions of the current legal form constitute a handicap for a successful business.

In order to support companies within the scope of the procedure model in choosing the adequate legal form of organization for their entry into the Chinese market a tool was developed within the research project, which provides a recommendation for the appropriate form of organization after answering 25 questions.

This catalog of questions covers the decisive aspects, ancillary conditions and preferences of a company that affect the choice of the organizational form.

Subsequently, following aspects are considered:

- Readiness to assume financial risk
- Control of business activities
- Provision of human resources
- Type of service
- Experience in the process of internationalization
- Experience in international business
- Skills of personnel with regard to language/culture
- Appraisement of the home and the Chinese market
- Basic data of the company

These aspects and the according questions have been chosen on the basis of an intensive analysis of studies and literature as well as the through the experience of the industrial partners of the research project.

The predominant part of the questions provides four possible answers that are written in prose. Additionally, a few closed questions provide the possible answers yes/no.

Related to each possible answer values for each form of organization are stored in a database. The higher a value the more the organizational form matches the related answer. The lower a value the less the organizational form matches the related answer. Negative values mean that the related organizational form would have a converse effect to the meaning of the associated answer. In addition, the questions are weighted according to their impact for the choice of the legal form of organization.

The final result is generated by first multiplying the weighting of each question with the values of the related answer. In the next step the obtained results for each form of organization are added and then normalized.

Finally, a pie chart with a percentage value for each form of organization is generated. The higher the percentage value the more the related organizational form is the adequate one for the indented China business (Figure 7).

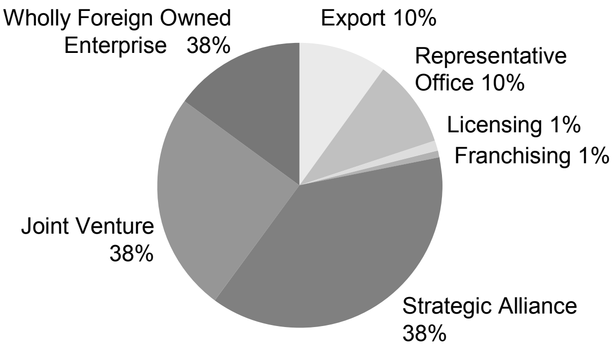

Figure 7: Recommendation of organizational forms.

Of course, the result is only a supporting recommendation, which can not substitute an intensive consideration of all aspects. With answering the question catalog of 25 questions it is not possible to include all company specific aspects that affect the choice of an organizational form.

4 SUMMARY

This paper describes the present situation of German service providing companies and their internationalization efforts with special focus on the target market China. The attractiveness of the Chinese service market, due to its immense growth potential, is counter-balanced by several problems and risks especially small and medium-sized IPS² providers have to face when trying to establish a business in China.

Subsequently, two selected tools of a procedure model, which were developed within a joint research project of research institutes and industrial partners, are presented. This procedure model aims to support both western Industrial Product-Service System suppliers as well as pure industrial service providers in planning and realizing a successful service market entry in China.

Being the very first step of the developed procedure model, a self-assessment tool enables companies to evaluate their competencies and status of preparation for the process of service internationalization. Thus it allows for building up the necessary skills and expertise systematically and for correcting a possibly wrong perception of the own capabilities for the process of internationalization.

Choosing the optimal legal form of organization when entering the Chinese service market represents a challenge for the most small and medium-sized enterprises. A tool which considers the conditions and constraints of the company and the service products that are to be exported, delivers a recommendation for an adequate form of organization after answering questions about the influencing aspects.

The presented tools have been successfully verified by the industrial partners of the research project, but continuous improvement and detailing is still subject to further research.

5 ACKNOWLEDGMENTS

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6 REFERENCES

[1] National Bureau of Statistics of China, 2009, Statistical Yearbook 2008, Beijing

[2] German Government; Federal Statistical Office: Statistical Yearbook 2008 for the Federal Republic of Germany, Wiesbaden, 2009

[3] Chadee, D. D., 2002, Foreign ownership structure of service equity joint ventures in China, International Journal of Service Industry Management, Vol.13, No. 2, pp.181-201

[4] Australian Government, Department of Foreign Affairs and Trade, 2005, Unlocking China’s Services Sector, Adcorp Canberra

[5] Fraunhofer Institute for Production Technology, 2006, Survey: Service within the mechanical engineering industry, Aachen

[6] European Union Chamber of Commerce in China, Roland Berger Strategy Consultants: European Business in China, Position Paper 2009/20010

[7] Gebauer, H., Pütz, F., Seite, F., 2008, Ausbau des Servicegeschäfts in China, Industrie Management Vol. 24, No. 1, pp.19-22

[8] Britton, E., Rossi, V., 2007, The Future of China’s Service Sector, The China Business Review, Vol. 34, No.3, pp.42-47

[9] Pan, L., 2006, The 10th Five-Year Plan (2001-2005), Official Web Portal, Government of China

[10] Yan, Y., 2006, Facts and figures: China's main targets for 2006-2010, Official Web Portal, Government of China

[11] Meier, H., Kroll, M., Gu, R., 2007, Industrielle Dienstleistungen in China - Erschließung neuer Marktpotenziale, Zeitschrift für wirtschaftlichen Fabrikbetrieb, Vol.102, No. 5, pp.268-272

[12] European Union Chamber of Commerce in China, Roland Berger Strategy Consultants: European Chamber Business Confidence Survey 2009

[13] Gebauer, H., Meier, K., 2005, Wachstum durch Dienstleistungen: Heutiges und zukünftiges Dienstleistungsangebot, SWISSMEM 1.2005-D, Zurich

[14] European Union Chamber of Commerce in China, Roland Berger Strategy Consultants: European Chamber Business Confidence Survey 2008

[15] Kutschker, M., Schmid, S., 2008, Internationales Management, Oldenbourg, Munich

[16] Haas, H.-D., Neumair S.-M., 2006, Internationale Wirtschaft: Rahmenbedingungen, Akteure, räumliche Prozesse, Oldenbourg, Munich

[17] Rosemann, M.: Application Reference Models and Building Blocks for Management and Control (ERP Systems). In: Handbook of Enterprise Architecture, eds.: P. Bernus, L. Nemes, G. Schmidt. Springer-Verlag, Berlin, Germany, pp. 595-615.

Information support of equipment operations – the case of a hydropower plant

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Abstract

In the contribution a new product-service system business model for production equipment is discussed. It is based on a value network, which enables lasting partnership and collaboration among a customer, OEM, suppliers and service providers, and is focused on production performance and equipment utilization by providing products and related services. It is expected that due to synergetic effects of collaboration better equipment utilization could be achieved and thus additional value generated and shared among partners. The business model integrates an information service system, which supports all stakeholders with data and information related to equipment operations. The system is illustrated in the case of a small hydropower plant. It clearly exhibits economical, technical, social and ecological benefits of integrating products and services.

Keywords

Product-service system, Industrial equipment, Remote monitoring

1 INTRODUCTION

Production equipment is an important element of a production system which is needed for performing a production process. The equipment installed in discrete manufacturing, process industry or energy production is today complex high tech machinery. Not only design, development and manufacturing but also operating and the maintenance of such equipment require high level specialized knowledge and skills, which are, especially at the beginning of exploitation, usually not gained adequately by its user. The operational performance, such as the output, costs, quality, equipment utilization, availability is far from optimal, as a consequence. The root of the problem lies in the existing relation between the customers and suppliers of production equipment which are predominantly based on a traditional buy/sell relationship. This relationship is concentrated on acquisition and delivery of equipment and as such does not offer acceptable support to end users. Besides, other stakeholders and parties which may be affected or are concerned with the operations of the equipment are not considered at all in the relationship.

The customer and supplier relationship has to be transformed into a new one, with the focus on equipment utilization by providing products and related services for the entire equipment life cycle. The idea of a product-service system has been introduced. It is defined as a marketable set of products and services capable of jointly fulfilling user's needs [1]. An industrial product-service system is an integrated product and service offering that delivers values in industrial applications [2]. The way of thinking leads to new business models including new financing concepts from buying or leasing to “pay-on-production” [3]. A paradigm shift from separated consideration of product and services is observed [4].

In the work a new product-service system business model is being researched. It is based on a lasting partnership and collaboration among a customer, an original equipment manufacturer, suppliers and service providers. The model is focused on the equipment utilization by providing products and related services. It is expected that due to the synergetic effects, better equipment utilization could be achieved and thus additional value could be generated and fairly shared among partners.

The business model incorporates an on-line information service system, which provides information services related to equipment operations. The system has to make the equipment’s behavior visible to all stakeholders in real time. On this basis, needs for services can be detected and provided adequately at the right time.

In the research, small hydropower plants (SHP) are being considered as a pilot implementation area of the information service system. The prototype solution implemented on a SHP in Slovenia illustrates the approach.

2 TOWARD A PRODUCT-SERVICE SYSTEM BUSINESS MODEL

A business model defines underlying principles of how a company creates, captures and delivers value. The business models of this kind are company internal and self-centered while companies try to minimize costs of captured values and maximize price of delivering values in order to maximize profit. But capturing and delivery of value is always a game between two players, a customer and a supplier. The customer/supplier relationship has gradually developed in a commonly accepted business model regulated by national and international directives for free trade.

The purpose of the customer/supplier business model is to enable common trading among two parties. It regulates the buy/sell interactions. The model covers two trading phases, the pre-sales phase and the sales phase. In the first one, there exists a relatively loose interaction among parties, such as requesting/biding. A conflict of interests may appear in this phase due to self-centric business models of the participating companies. The conflict can be resolved by negotiations which may or may not lead to an agreement. In case of the agreement confirmed by both sides by an order/order-confirmation or a contract, the sales phase starts. The agreement is fulfilled by delivery of goods or services, invoicing and payment. During the sales phase, the common liabilities of the parties are well regulated by trade rules and laws. The liability of the customer ends with the payment and the liability of a supplier ends with expiration of a guarantee. Figure 1 shows the basic parties and interrelations of the classic business model.

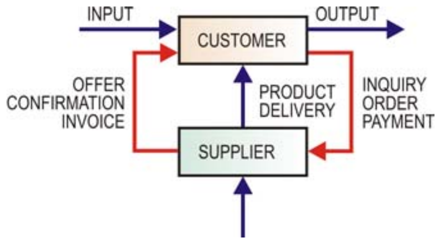

Figure 1: Customer/supplier business model.

The described model is commonly used in trading. It connects a supplier and a customer into a value chain where the first one delivers value which is captured by the second one. It results in a zero-sum game.

As such it is adequate for many businesses but the question here is if it is appropriate also for trading product-service systems where synergetic effects are searched for.

In order to point out specifics of the product-service systems in case of production equipment let us consider the issue from the customer view and from the supplier perspective. The customer is primary focused on products which he delivers just-in-time to his customer. Therefore, he requires not just a equipment supplier but a partner who would develop, manufacture, install, put the equipment into operations and, later on, who would offer support in operations in terms of process optimization, maintenance, spare part delivery, system improvement, upgrading, reconfiguration, etc. [5].

The suppliers' perspectives are discussed in [6]. The authors analyzed business models in project-based firms. There exist different solutions which suppliers of capital investment goods are offering to their customers - from simple equipment deliveries to full-scale turn-key deliveries. This exhibits flexibility of suppliers in adapting to customers requirements. The authors categorized the existing models into five types and discovered that the so called life-cycle-led solution utilizes synergies.

The way that leads to a win-win game is co-creation of value by interacting systems [7]. Therefore, the industrial product-service system business model should rely on collaboration among the main actors, i.e. a customer, an original equipment manufacturer (OEM) and its suppliers as well as service providers, in which the involved parties share the same goals. It should provide a joint offering of product and services covering the entire life-cycle of the production system enabling high performance of operations.

Based on these cognitions a product-service system business model is being conceptualized. It originates from the conceptual framework for collaborative design and operations of manufacturing work systems developed in [5]. The framework provides elements for collaboration of different parties in a network and introduces two distinct units (1) the virtual coordination unit (VCU) for coordination of collaboration among different experts from different cultural environments and (2) the virtual competence center (VCC) as a portal for communication, teamwork, and provision of information, knowledge and services. The product-service system business model proposed here extends the framework for collaborative design and operations toward product-service systems.

Figure 2 shows the structure, elements and actors of the product-service system business model and interrelations among them. It has a form of a value network. The network is established not only for a single business transaction but forms a lasting relationship. This is a significant advantage in comparison to the classic customer/supplier business model, which links companies in a value chain only for a single transaction.

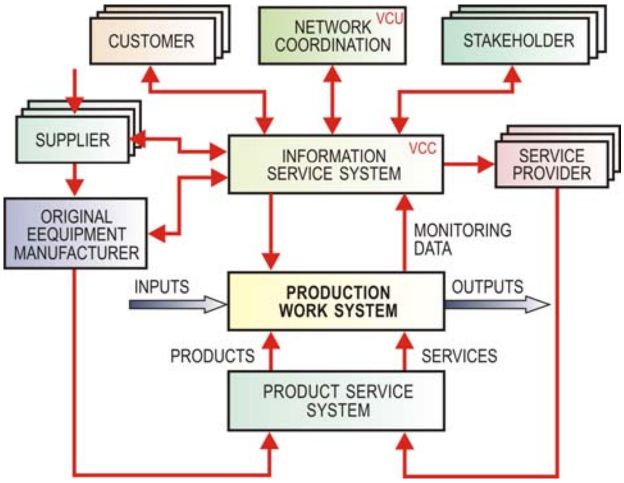

Figure 2: Value network of the product-service system business model.

Of course, the involved actors have to position themselves in the value network and have to adapt their business models to the new common goal of the network, which is enhanced performance of the target work system of the customer.

The expected benefits of the proposed model are lasting partnership and increased trust among the actors, value co-creation through collaboration with common objectives, coordinated and responsive problem solving, sharing of information, knowledge and risks, decreased transactional costs, etc. All this indicates the win-win game.

Now let us have a closer look on the value network model (Figure 2). In the center of the model is the production work system of the customer (user). This is the target element not only for the user, but also for the OEM and service providers, which jointly offer the product service system. Through the OEM also its suppliers are interconnected in the value network. They all share the common goal – to maximize value creation of the target work system. But each of them has its own position, role and responsibility in the network. Also the user customers are involved in the value network while they benefit from the improved production system performance. And there may be also other stakeholders which are related to or are interested in the production system operations from various aspects.

This research is focused on providing services during production system operations. During operations the common goal is optimal system performance resulting in high output generation, high operation reliability, high productivity and efficient utilization of resources, minimal operational costs, minimized environmental impact, etc. All actors of the value network require adequate and accurate information about the system states in order to be able to identify a need and to perform their role in the value network by providing an adequate service when required.

Implementation of services into complex industrial systems is possible only with the use of new communication and information technologies [8]. They enable cost effective and reliable monitoring and control of production equipment.

Therefore, the key issue of the research is how to provide on-line information on system operation and how to adjust information content to needs and responsibilities of each actor in the value network. Adequate service infrastructure has to be conceptualized and developed which will enable collecting of relevant data in the work system, management of these data and provision of relevant data in form of information services.

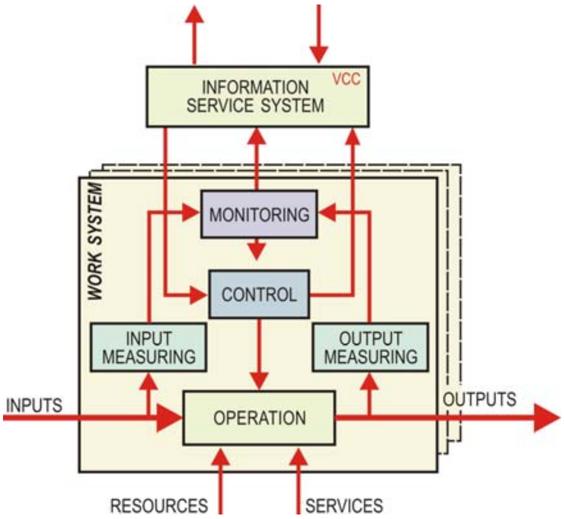

Figure 3: Service infrastructure of the value network.

An element of the proposed infrastructure is the information service system (ISS) as a part of the VCC portal introduced in [5], which provides information services related to system operations. The ISS in integrated in the value network (Figure 2).

Another part of the service infrastructure forms a system for monitoring production operations. Monitoring is performed by measuring different physical quantities band by collecting different signals in the production system, data acquisition and data management. Monitoring provides data on production processes, equipment states, and operations related events, quality state, state of the environment, etc. These data are inputs for the information service system. ISS provides information services which interpret monitoring data and are tailored to needs, responsibilities and access rights of actors and stakeholders. The infrastructure of the product-service value network is shown in Figure 3.

3 PRODUCT-SERVICE SYSTEM FOR SMALL HYDROPOWER PLANTS

Small hydropower plants (SHP) are a challenging industrial sector for the implementation of the product-service system concepts. They have similar structure as industrial power plants but they are less complex and therefore easier to handle and more feasible for implementing and testing of innovative solutions. On the other hand they represent a prospective market searching for solutions which may improve their performance. There are many opportunities and challenges for new developments in the sector.

For illustration, there are approximately 500 SHPs which operate in Slovenia, most of them ranging from 25 to 100 kW of output power. They provide about 12 % of electricity produced from renewable sources [9]. The majority of them were built in the 90-ties by private landowners. Building renewable energy plants was at that time encouraged by the government's policy with subventions and bounties. Many of them are of rather simple design.

There are many actors and stakeholders in the sector which are not well connected. They would all benefit if they would be connected in the value networks. The main actors and stakeholders are electricity producing companies, plant operators, plant owners, electricity distributors (customers), manufacturers of equipment, maintenance providers, engineering companies, business associations, fishing associations, associations of ecological movements, governmental institutions, etc.

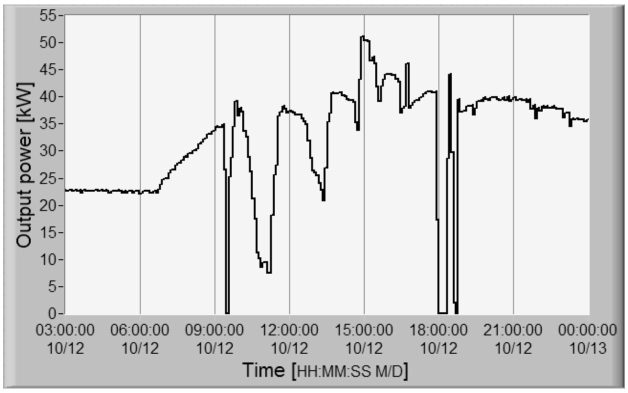

Figure 4: Power generation diagram.

Of course, the actors and stakeholders have different roles, interests and responsibilities in relation to operations of a power plant. It is a fact that they all have only limited or even no access to information from power plants which they need to fulfill their responsibilities and perform their work. Hence, they often have to collect information by themselves and they make their decisions on incomplete and inaccurate information. Each of them is searching for a solution which would deliver him relevant information when and where needed. For example, a plant operator is interested in operational performance monitoring, such as shown in Figure 4. He would prefer access to on-line monitoring from anywhere at any time to be able to see what is going on and to identify possible malfunctions. He would also prefer remote control for performing control actions on a distance and receiving of alarm messages in case of malfunctions. An owner would prefer periodic insight into economic figures, productivity, equipment utilization, etc. A maintenance provider would favor data on equipment behavior. A fishing association would prefer permanent monitoring of water level in a form as shown in Figure 5 and communication of warnings in case that the water level drops under the biological limit level.

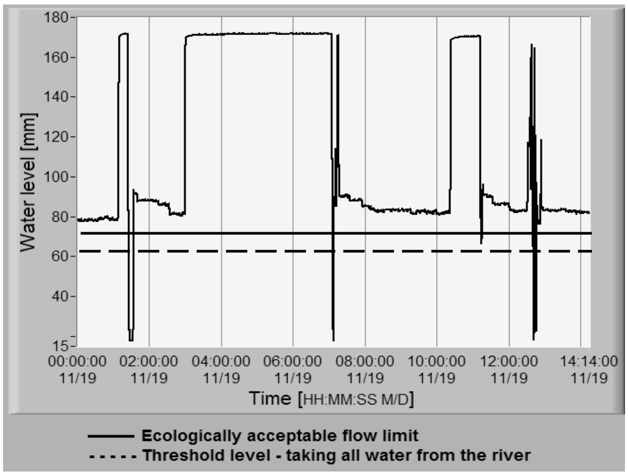

Figure 5: Water level diagram.

These observations clearly indicate what an adequate information service system based on the concept proposed in Chapter 2 providing tailored pieces of information in form of services would be a sound solution for most of actors and stakeholders.

In order to identify more precisely needs and requirements for developing an appropriate ISS for supporting SHP operations an empirical survey was conducted. The survey was focused on private SHPs in Slovenia and 86 SHP operators and/or owners participated in it.

The main focus of the survey was related to SHP management, monitoring, control and maintenance. Some of the figures are given in next. More results are given in [8].

Most of the SHPs (61%) are observed and controlled manually. Other operators use different systems for monitoring, alarming and control. In the case of stable conditions, operators visit SHP once or twice per day in average. A few operators visit SHP even more than three times a day and some only once in a week.

The major cause of SHPs breakdowns is sudden cut off from the electric grid. In average it happens about 5-15 times in a year. Most of operators (80%) confront problems of clogging a turbine and/or an intake grate with leaves and branches.

SHPs are out of operation several times in a year due to high or low water, and maintenance on the electricity grid or other systems.

Operators consider output electric power as the most valuable information for monitoring operation performance. The second most important parameter is the water level in a river. On this basis the operator sets the guide vane ring angle and consequently energy production.

Operators recognize SMS alarming of critical operational states as the most important functionality of the information service system. Automatic control of guide vanes position according to the actual water level is the second most important functionality. Live video stream from a power house and from a dam are the least preferred functionalities.

Another important issue which motivates this research is related to control of SHPs. As already mentioned, the most of SHPs are of rather simple design. This implies that the level of automation is low and most of SHPs are controlled manually. But this does not imply permanent presence of a human in a power plant while there are safety systems which react independently in abnormal situations.

In case of a normal situation (e.g. stable water flow) the manual control is performed like this. An operator occasionally visits a plant, typically located in remote, hardly accessible areas, and visually inspects various states and parameters, such as dam water level, output electric power, bearings temperature, vibrations. Based on the identified state, he sets a reference value for control manually. He manipulates guide vanes opening according to head, energy production and assurance of ecologically acceptable water flow in a river bed. Then, the plant runs according to this setting until he inspects it again. During this interval the situation on the plant may change. For example, it can happen that the power plant is cut out from the electricity grid. It happens in case of a sudden hazardous event, when the safety system must disconnect the generator from the grid and stop the turbine. Hazardous events may happen due to short-circuit in the power grid as a result of ice or snow on electrical wires, strong wind or fallen trees on electrical wires, etc. In such cases the plant may be out of operation for hours or days till the operator's manual intervention.

It is evident that such control is not adequate. Especially information about generator cut off, and about excess or shortage of water on a dam are critical. Magnitude of water flow, which can be used in a power-plant depends on actual water flow, water temperature, season, etc., and is governed by ecological considerations and jurisdiction. The mentioned problems and challenges motivated the decision about developing an information service system for remote monitoring, alarming and control of a SHP. The objective was to improve operational performance of SHP operations. The system is realized as a modular information service system for remote and mobile monitoring and control and is implemented on a SHP in Slovenia. The pilot implementation is described in next.

4 SHP INFORMATION SERVICE SYSTEM FOR REMOTE AND MOBILE USERS

The basic objective of the SHP information service system is to provide the following remote and mobile services to operators and other stakeholders concerned in safe and efficient SHP operations: (1) operation monitoring, (2) activation and deactivation of the plant, (3) guide vanes manipulation, and (4) alarming about abnormal and critical situations.

The developed system is implemented as a functional prototype of the information service system in SHP "Volaka" [10], which uses a Francis type turbine with nominal output power of 70 kW. The information service system consists of the following units:

- Data acquisition system with sensors and signal processing for collecting data about key operational parameters;
- Control loops for plant activation/deactivation and manipulation of the guide vane opening;
- On-site control and monitoring system based on a pc with control software, database and internet server;
- Web application for remote and mobile users;
- Short message service (SMS) module for alarms; and
- Mobile communication network.

The mobile communication is selected because a broadband connection is usually not available on SHP sites and because it suits better mobile users and enables around-the-clock availability which is needed during 24/7 plant operations.

Figure 6 shows the semi-operational scheme of the information service system integrated in a small hydro power plant.

Several plant operational parameters, e.g. output power (Figure 4), dam water level (Figure 5), guide vanes position, temperatures of critical elements and generator frequency, are constantly measured and monitored. The acquired data are logged into the database and enable visualization of an actual situation and elaboration of periodical reports, invoices for customers, etc.

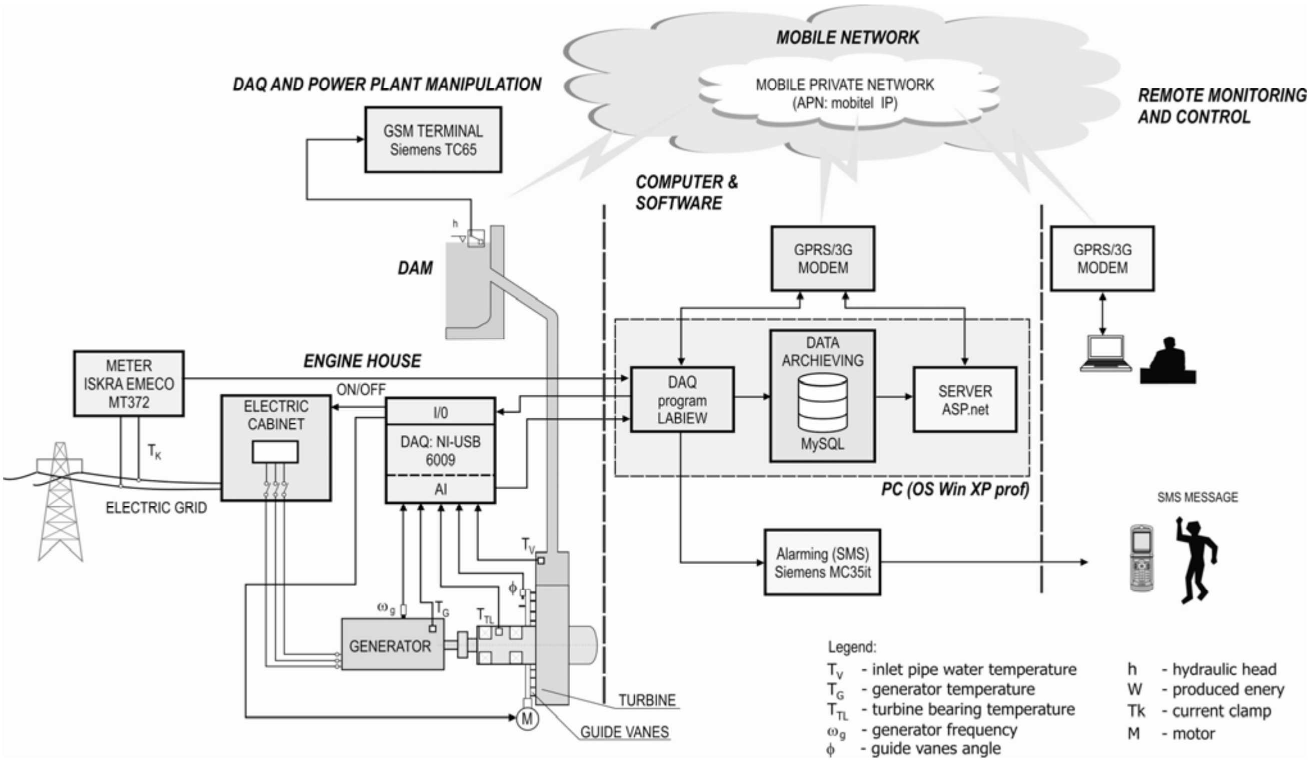

Figure 6: Semi-operational scheme of the information service system.

Measurement of output power and produced electric energy is the basic information on power-plant operation. The output power depends on the flow and dam water level. Power readings are acquired from a digital power meter periodically. Any deviation in operations (e.g. generator speed increase, power loss, water level fall) is reflected in this measurement and results in a corresponding control action and/or triggering of an alarm message to the operator.

Three functionalities are enabled for remote users: plant monitoring, remote control and access to the database. A remotely located operator connects with a laptop computer to the mobile network and logs onto a mobile private network within the public one. The mobile private network interconnects the SHP control and monitoring system with remote users. The crucial advantage of the mobile network lies in its ubiquitous signal. Business users are entitled to communicate business data with a safe private mobile IP network. Inside such a private network communication between any particular SIM card is possible anytime anywhere. An APN (access point number) and a password are assigned to the user, and each SIM card obtains its own IP address. The communication is safe and speed acceptable.

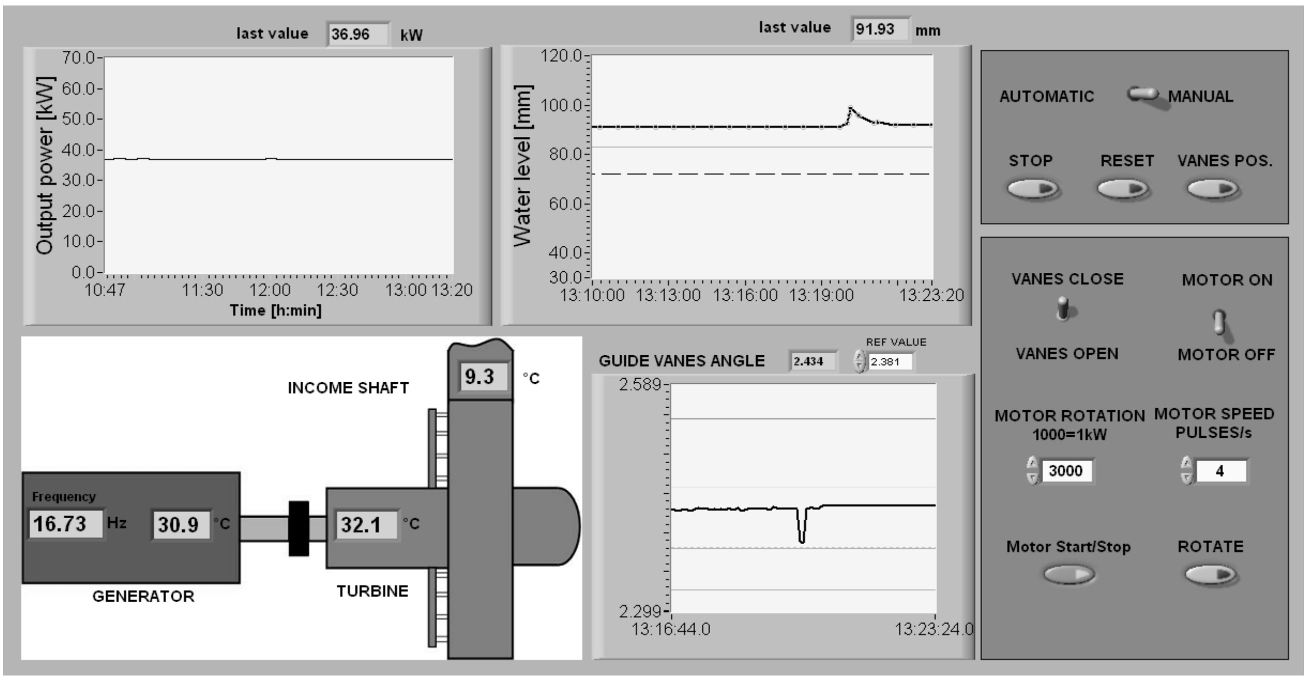

Figure 7: Web application for monitoring SHP operations.

Once connected, the operator can access to the SHP via a web application. This application enables him to view the monitoring data and to trigger the appropriate control actions when necessary. Figure 7 shows a typical screenshot of the application.

The described remote service system has been in operation for several months. During this time the following advantages have been identified:

- Energy production is increased for about 5 % in average.
- Sensing of selected operations parameters improves the insight in the SHP, which makes its operation and maintenance more straightforward.
- Remote monitoring and control facilitates operator's work.
- Increased equipment utilization.
- Flexible system design enables easy adoption of the system.
- Alarm messaging is automatic and prompt.
- Database offers numerous reporting possibilities and automation of various functions.
- Better control of water flow due to prompt water level observation and remote control of guide vanes.
- Moderate communication costs and adequate security.
- Reliable operations of the monitoring system.

5 CONCLUSION

In the contribution an approach toward a new product-service system business model for production equipment is discussed. The kernel of the model represents the value network, which enables partnership and collaboration among a customer, OEM, suppliers and service providers, and is focused on production performance and equipment utilization by providing products and related services

It is expected that due to synergetic effects of collaboration, better equipment utilization could be achieved and thus additional value created and fairly shared among partners.

The business model integrates an information service system, which supports all actors and other stakeholders with information services related to production system operations and tailored to the individual needs and responsibilities. The adequate infrastructural elements are introduced and integrated in the value network.

The pilot information service system ‘Volaka’ is developed and implemented on a small hydropower plant. It enables remote and mobile access to the on-line monitoring system of the power plant, alarming of operators in case of malfunctions and triggering of control actions.

For the communication backbone the mobile network is selected due to the ubiquitous signal reach. This is a significant advantage in case of SHPs, which production sites are usually in remote and hardly accessible locations.

The pilot system clearly exhibits economical, technical, social and ecological benefits of integrating products and services.

The knowledge gained in this research will be used and further developed in the newly proposed EUREKA project E! 5343 “Collaborative platform for operations support of work systems – case of hydro power plants”. The project consortium is composed of six partners from three European countries: two OEM providers of equipment for hydropower plants, one service provider with competence in measurement of dynamic quantities and diagnostics, one software provider for supporting collaboration, one operations and maintenance provider and agent of a customer and an academic institution. The major aims of the project are to research the issue of relationship between customers and suppliers of production equipment and to develop a new business model of this customer/supplier partnership and adequate services related to support of equipment operations and maintenance. That would significantly improve the equipment utilization and contribute to competitiveness of customers, OEMs and service providers.

6 ACKNOWLEDGMENTS

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7 REFERENCES

[1] Goedkoop M., van Halen C., te Riele H., Rommens P., 1999, Product Service Systems, Ecological & Economical Basics, Pre Consultants, The Netherlands.

[2] Meier H., 2009, Industrial Product-Service Systems IPS2, IPS² Spring School, Cranfield, February 2009.

[3] Meier H., Massberg W., 2004, Life Cycle-Based Service Design for Innovative Business Models, CIRP Annals - Manufacturing Technology 53/1: 393-396.

[4] Meier H., Roy R., Seliger G., 2010, Industrial Product Service Systems – IPS2, CIRP Annals - Manufacturing Technology, 59/2, to be published.

[5] Sluga A., Butala P., Peklenik J., 2005, A Conceptual Framework for Collaborative Design and Operations of Manufacturing Systems, CIRP Annals - Manufacturing Technology, 54/1:437-440.

[6] Kujala S., Artto K., Aalonen P., Turkulainen V., 2009, Business model in project-based firms – Towards a typology of solution-specific business models. Int. J Project Management, in press.

[7] Ueda K., Takenaka T., Vanza J., Monostori L., 2009, Value creation and decision making in sustainable society, CIRP Annals - Manufacturing Technology, 58/2: 681-700.

[8] Selak L., Sluga A., 2009, Mobile control of a small hydropower plant (in Slovene), Ventil, 15/3: 240-245.

[9] Slovenian small hydro power association, Available from: http://www.zdmhe.si/, Accessed: 2009-09-24.

[10] Selak L., Sluga A.. Butala, P., 2009, Mobile Monitoring of Small Hydropower Plants. In: Katalinic B. (Ed.); Annals of DAAAM for 2009 & Proceedings of the 20th International DAAAM Symposium, Vienna, Austria:1795-1797.

Potential of the Competence-Cell-based approach for services in co-operative networks

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Abstract

The importance of services and product service systems is constantly rising. Internationalization makes it especially for small companies increasingly difficult to meet the service requirements of their customers. Co-operation by combining various competences of all involved partners into a service-network is an option for a flexible solution for this problem. This paper answers some of the conceptual questions with regard to the configuration and operation of service Competence Cells. The presented approach, based on the Competence-Cell-based networking approach, is to date primarily used in manufacturing settings. The paper investigates the advantages of this approach and how its potential can be used for service networks.

Keywords

product service systems, service networks, Competence-Cell-based networks

1 INTRODUCTION

The economical impact of small and medium-sized enterprises (SME) is evident on a broad basis. With their high proportion of gross value added, these enterprises will also in the future constitute the backbone of economies, acting as employers and innovators. In Austria more than 60% of the jobs are created by SME. [1] In the European Union the share of the SME in total value added is about 58% in the non-financial sector. [2]

Apart from their specific core competencies, small enterprises command only limited resources. Therefore, they can only partially execute sequences of process chains. In order to acquire the ability to supply complex and innovative products and services or product service systems (PSS) in a holistic and customer oriented manner, they have to either integrate deficient competencies or recruit these by co-operation.

Services and PSS are constantly gaining importance for the manufacturing industry. On average, service products achieve higher returns than the tangible product "machine" or "plant" and thus make a substantial contribution to ensure a company's long-term success and competitiveness. [3]

The rising demand for integrated offerings and comprehensive solutions to multi-faceted problems as well as stringent requirements concerning quality and availability of services, are increasingly challenging for SME, especially with respect to international markets. For many SME, the only way of providing services and PSS on international markets is by employing co-operative networks.

Present day co-operational organization is set on hierarchical structures in and between enterprises. These co-operational relations are frequently dominated by major enterprises with respect to technical, organizational and economic aspects therefore creating dependencies, especially for SME. The benefit of relative stability corresponds to the disadvantage of unilateral dominance. While these dependencies act restricting on enterprises which are regionally established, they work as considerable market entrance barrier for start-ups, small and smallest enterprises.

As a result, existing competencies are not thoroughly accessed. Additionally, small enterprises are obstructed in the founding and their development and it is necessary to aim future efforts towards the organization of non-hierarchical production and organizational structures. This is supported by studies which consider autonomous, elementary business units [4], co-operating in temporary networks [5, 6] also called 'nanocorps' [7], as a form of enterprise organization of the future. Recent research projects [8, 9] follow the idea of collaboration of smallest business units. Due to this development in manufacturing organization, which in recent years has been lastingly influenced by the phenomena of elementarization and networking, a specific vision aimed at small and medium-sized industry has been developed. [10]

Autonomous, elementary units of production, co-operating in temporary networks, are considered as an efficient organizational form of enterprises for the 21st century. A scientific approach for this concept is provided by networks based on customer-oriented, directly linked, smallest autonomous business units – called Competence Cells. The concept researched at the Collaborative Research Centre 457 (CRC 457) 'Non-hierarchical Regional Production Networks' at Chemnitz University of Technology has pointed out perspectives for present-day small and medium sized enterprises and among them particularly micro firms to face ever-changing economic conditions. [11]

This article is intended to evaluate the applicability of the Competence-Cell-based approach for the configuration of service networks, especially for networks of SME.

2 STATE OF THE ART

2.1 Services and product service systems

Services are distinguished from physical products through the following properties:

- intangibility,
- simultaneous production and consumption
- non-storable and heterogeneous results.

Although there is not a broadly accepted definition for service, there is a variety of attempts for a comprehensive definition for service [12]. In literature various approaches for finding a definition are described [12, 13]: definition by enumeration (e.g. in [14, 15]), negative definition [16] and definition by constitutive attributes [17].

Contemporary research in the field of service and PSS (the combination of physical products with services [18, 19]) is multi-faceted and covers the area from developing new services to their marketing as well as new business models and encompasses the whole life cycle. Especially product service systems are object of current research [20-22], which deals amongst other issues with the internal and network related demands, the organizational requirements to the providing company, its entrepreneurial strategy and the integrated development and delivery of product service systems.

Service Networks

The necessity of co-operation in networks in order to provide services, especially for SME, is the subject of various research projects. The definition of the participating partners and their respective roles and relationships are described in [23] and [24].

Operator or contracting models are co-operative arrangements between producers and users of capital goods and are a special form of a service or product service system. This co-operative arrangement between primarily two partners with its opportunities and risks has been already discussed by Harms & Famulla and Meier & Zuther [25, 26]. However, the notion of network building is covered insufficiently.

The necessary close collaboration between manufacturers and providers of services resp. product service systems and their customers leads to increased requirements concerning the structures of the service networks in comparison to the manufacturing networks [27]. New scientific contributions, such as the one of Zhang et al. [28], deal with the differences between classical engineering networks and service networks and the transition from one into the other.

A detailed configuration of service networks under consideration of the competences of the single partners is neither subject of any broader research activities in general, nor is the Competence-Cell-based approach in particular.

2.2 Networks and networking

The scientific approach of Competence Cells cooperating in non-hierarchical networks and its systematic robust implementation has been exclusively researched at Chemnitz University of Technology in the research projects “Non-hierarchical Regional Production Networks” (Collaborative Research Centre 457) [29] and “Competence-Cell-based Production Networks” (Project Cluster 196) [30].

The research on Competence-Cell-based production networks is rather unique. Usually, strategic, hierarchical corporate networks are the object of research. In the European scientific landscape, there has been an increasing concentration on “Virtual Organisations” (starting with [31]) and “Collaborative Business Networks” (e.g. [32]) for several years now. In most cases, similar basic assumptions are made compared to the vision of non-hierarchical networks, which confirms the approach. All of the research projects share the ambition to find new organizational forms. But the characteristics of the analysed Competence-Cell-based networking approach are not considered explicitly.

The vision of the Competence-Cell-based networking approach (Figure 1) is the following:

Elementary business units – called Competence Cells – are co-operating in Non-hierarchical Regional Production Networks in a customer-oriented manner and thus are capable of facing global competition.

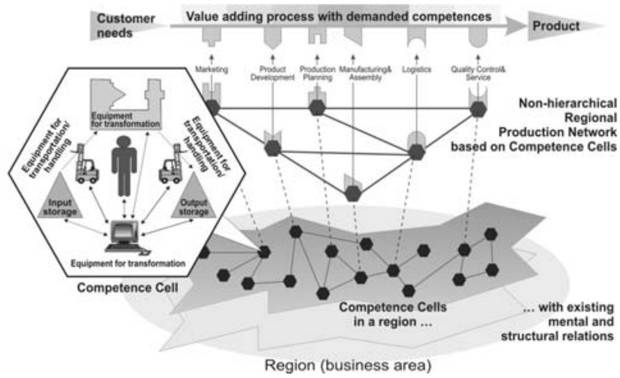

Figure 1: Conception of Non-hierarchical Regional Production Networks (see [11])

In order to substantiate the vision of Competence-Cell-based networking a model for the Competence Cell (Figure 2) and a procedure model for the networking (Figure 3) as well as an operationalized concept of organization (Figure 4) were developed.

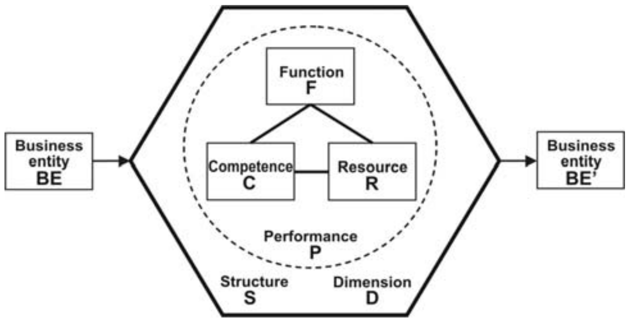

Figure 2: Conception of the Competence Cell (see [11])

A Competence Cell (see Figure 2) is considered as the smallest autonomous indivisible business unit of value adding, being able to exist independently. The model of the Competence Cell consists of

1 the human with his competencies, arranged according to professional, methodical, social and personnel competencies [33],
2 available resources as well as
3 the fulfilled task or executed function; with this function a business entity can be transformed and a certain yield can be achieved.

The aspects of dimension and structure were supplemented to obtain a complete technical description.

The procedure model (Figure 3) comprises three levels and seven phases. From loose infrastructural and mental relations present in a regional network (Level I) there initially emerges an institutionalized competence network, based on Competence Cells (Level II, phase Competence Network Composition). Institutionalization takes place via the co-ordination of behaviour (e.g. agreements on offer generation, agreements on cost allocation) and via the pooling of capacity (e.g. common servers and data bases). These facilitate an efficient acting towards the customer and avoid internal discrepancies. Institutionalization thereby creates the basis on which autonomous Competence Cells join to find to a collective creation of value. In order to hold fixed expenses down, the institutionalization is to be limited to the necessary amount. The actual creation of value takes place in a production network (Level III, phase Production Network composition), i.e. a temporary linking of selected Competence Cells, initiated by a customer's request. In order to select and cross-link Competence Cells and to operate the network, co-ordinated ways of behaviour and pre-installed structures are available in the Competence Network.

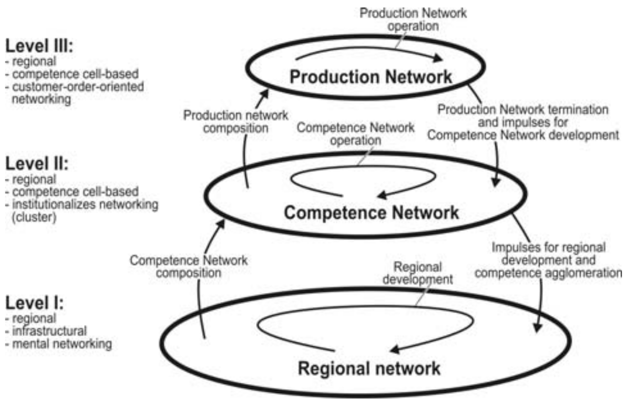

Figure 3: Procedure model of competence cell-based networking (see [11])

For running the innovative type of co-operation "Non-hierarchical Regional Production Networks" an operationalized concept of organization is needed. Such a concept was developed with the "holistic integration method" (HIM). HIM marks a comprehensive instruction as a kind of organizational manual for the Competence Cells. It is based on the levels and phases of the procedure model. The general architecture of HIM consists of the levels "Portal", "Process Engine" and "Methods&Tools", see figure 4.

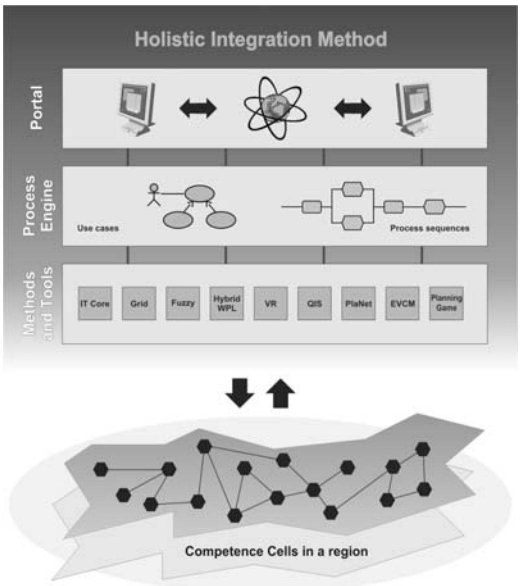

Figure 4: Holistic integration method (see [11])

The Competence Cells as users access the functions of HIM through a web-based portal. The portal is linked to the Process Engine. On the highest level of the Process Engine typical co-operative use cases respectively procedures inside the levels and phases of the procedure model are defined. On the lowest level the different methods are described in an application-driven form and, if applicable, linked to supporting software tools.

3 CONCEPT

3.1 Objectives

So far the Competence-Cell-based approach has mainly been studied for the field of production. For this purpose Competence Cells have prototypically been formed and their networking has been analysed.

The objective is now to enhance this approach and to test its transferability and adaptability on production-related services in networks. As a result, potentials of this approach for services in networks are to be identified and also prepared to become operative (see Figure 5).

The aimed enlargement of this field of research is not only of practical importance. Also an enormous gain of scientific insight concerning Competence-Cell-based networks can be assumed. The competitiveness of European small and medium sized enterprises, which maintain service networks due to their involvement in international business and in order to provide services, has to be strengthened regarding production and service. However, the configuration and management effort will be particularly high in these SME networks.

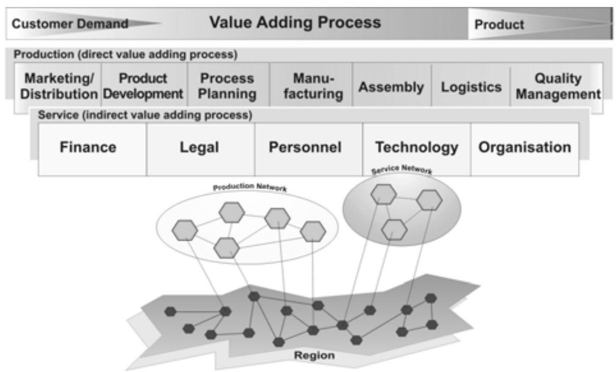

Figure 5: Production and service networks (e.g. [34])

The following assumption supports the objective of transferring the presented approach: The Competence-Cell-based approach is predestinated for an application in service networks (see definition of Competence Cells: autonomous, elementary business units acting in self-controlling, non-hierarchical networks). In contrast to manufacturing, services by tendency require a lower input of resources (immateriality), which facilitates the configuration of smallest business units. Compared to manufacturing, services rather demand high flexibility (customer as external factor, heterogeneity, non-storability – uno actu principle), which encourages the application of Competence-Cell-based networks.

In addition to testing the transferability and to assessing the potentials, there is the need to develop models, methods and tools on the basis of the Competence-Cell-based approach for a systematic generation and operation of customer value-driven service networks. For this purpose, appropriate basics have to be compiled in the first place.

Objectives of the Competence-Cell-based approach:

A first objective is to create the preconditions for the transferability and adaptability of production-related services in networks. The theoretical basics of both, Competence-Cell-based networking and services in networks have to be reviewed and adapted. Furthermore, the phenomenon has to be substantiated by identification of essential characteristics (including their specification) and their systematization in a descriptive framework. An assessment of characteristical forms of Competence-Cell-based service networks can be achieved by an evaluation framework, which still has to be developed.

A second objective is to identify and to review empirical basics, again with respect to both Competence-Cell-based networks and services in networks. As a deduction from the empirical basis a research framework is defined, which will be the template for the following detailed explorative proceeding.

As a conjoint result of the two above mentioned objectives the evident area of research is defined. A basic set of conclusive case studies is available.

A third objective is now to integrate typical profiles of Competence-Cell-based service networks in a framework on the basis of a descriptive (morphologic characteristics) and an evaluation (potential and ratio system) framework.

Ideally, the results can be examined in explorative case studies by analyzing typical applications of this approach for services in networks.

All these efforts result in a rough framework which includes a requirement and design profile, questions, hypothesizes and working principles.

The implementation of a pilot solution represents another objective of the Competence-Cell-based approach. By means of scenarios within the pilot, frameworks regarding description, evaluation and configuration are to be substantiated and specified in detail. The hypothesis, that the Competence-Cell-based approach is particularly meeting requirements in the service sector must be verified or, respectively, falsified. A benefit analysis has to take into account on the one hand the descriptiveness as well as the assessment and configuration potential of Competence-Cell-based service networks and on the other hand the instantiated Competence Cells and their cross-linking for certain services and business processes.

As a result the descriptive, assessment and configuration frameworks are elaborated. Benefit cost analysis is then available for Competence Cells and network configurations are established for selected services and business processes. The operation of the phenomenon Competence-Cell-based service networks will be understood.

A further objective consists in evaluating the pilot solution and developing a generalization concept. The evaluation has to show how stable the transferability will be. Besides that, its limits need to be defined.

Finally potentials of application of the Competence-Cell-based approach on services in the network will be proven and further research issues will be derived.

3.2 Approach

Deduced from the mentioned objectives above, the proceeding, consisting of five work packages, is as follows:

<u>Step 1:</u> Development of theoretical basics in order to transfer the Competence-Cell-based networking approach to production-related services, aiming to make available existing approaches from both areas, i.e. Competence Cells and service/service networks.

The research domain “Competence Cells” provides concepts regarding description, evaluation and configuration for production (see Collaborative Research Centre 457 [29] and Project Cluster 196 [30]). These concepts are to be scrutinized and transferred to the service sector. Thus the concept as a general modeling paradigm and the Competence-Cell-based approach as a specific descriptive concept will have to be researched and, respectively, adjusted. Also strategies of decomposition and composition of Competence Cells and their cross-linking need verification and, respectively, modification.

The research domain “service” asks for a characteristic of services including appropriate characteristic values, which will have to be identified and classified (e.g. immateriality, customer integration, networkability of services). This will result in a descriptive and evaluation framework being refined and evaluated through continuous feedback discussions in the following work packages. The focus lies on production-related (industrial) services. However, the descriptive framework will have a design that allows comparison to other branches. Generalization of the outcomes is possible. Methodical components could be for example the morphological box or performance measurement systems.

Bringing these aspects together, general organizational concepts (amongst others specific production and logistics concepts, such as supplier parks) and networks (amongst others intra-organizational, worldwide F&E networks or, respectively, production networks, existing service networks) will be analyzed regarding their ability for developing and producing services. Consequently the reasonable object domain of research, e.g. branches and branch mix, will be defined.

<u>Step 2:</u> Definition of the evident area of research and deduction of the profile requirements within the relevant area of application. The descriptive and evaluation framework, worked out in Step 1, represents the basis and will at first be advanced and then be substantiated by means of empirical studies and surveys.

The objective of this work step is to limit the defined solution space of the evaluation framework to practice-relevant characteristics. Furthermore, controlling features regarding competence approach and services will be defined within the solution space. For this, relevant areas of application need to be identified within the basically evident area of research, such as branches (amongst others automotive industry including supplier and logistics industry, architecture, consultancy, small scale manufacturing, engineering services, maintenance; also branch mix) or spatial dimensions/cultures (regional networks) and inter-regional networks. Then, further topics have to be worked upon within the relevant areas of application, such as the statistical distribution of occurring sizes of enterprise, number and duration of established co-operation for the competence approach as well as the existing service portfolio, specificity of services or networkability in the service sector. In addition, general conditions (also with regard to the configuration), such as competitiveness, overall economic environment, flexibility or social aspects for the producing of services have to be identified and their specific characteristics have to be worked out.

A research on other selected services networks from different business sectors, not belonging to the industrial sector, will suit the development and deduction of analogies.

Finally, these field inquiries will lead to conclusions on how appropriate the areas of application, with regard to the Competence-Cell-based networking approach, are. Thus, the evident area of research is focused on. Through this, a basic set of relevant case studies can be provided. The empirically confirmed research framework will serve as model for following detailed research. Theoretical basics as well as the empirical research will help to define the profile requirements for explorative case studies.

<u>Step 3:</u> Specifying the concept by forming prominent profiles from the descriptive and evaluation framework via the morphologic box and then describing and abstracting these in a configuration framework. The profiles consist of

theoretically possible and, with regard to the data analysis, reasonable combinations of features, which can be mutually dependent or exclusive. The adjustment of the configuration framework to practice relevant types will result in a basic set of solutions, which can be evaluated by criteria defined in the evaluation framework. As a result a set of preferential solutions can be presented.

Transferring the results from the sector of industrial services to other business sectors and analyzing existing services in those business sectors will allow for comparability of outcomes and a further refinement of the defined descriptive and configuration framework.

From the above mentioned set of preferential solutions a pilot solution, which is available from industrial practice, will be chosen. This is achieved on the one side by considering the outcome of the evaluation framework and on the other side by appropriate qualitative evaluation methods, e.g. the provided database for a subsequent benchmark and an access to the providing service network. The choice of a pilot solution and its advantages will be backed up by interviews with experts from the network. In result, a pilot solution is selected in order to verify the adaptability and successful application of the Competence-Cell-based approach within the subsequent work packages.

Step 4: Conception and configuration of a pilot solution and application by means of the Competence-Cell-based approach on the basis of the preliminary work (Step 1-3). The pilot solution is a selected, especially qualified by explorative case studies, service network in a production-related area, which will primarily consist of SME. The analysis of the pilot solution will be carried out by means of scenarios.

Descriptive, evaluation and configuration frameworks are applied to the pilot solution and then substantiated and specified in detail. Intensive benefit cost analysis is done for the pilot in order to answer the following question: When does networking based on the Competence-Cell-based approach have a favorable effect and under which circumstances is this approach disadvantageous?

According to the Competence-Cell-based approach the proceeding is structured as follows:

1. Data acquisition, processing and description

Firstly, the database for the pilot solution has to be provided. For this, a comprehensive data acquisition has to be exercised in an existing network, which has been chosen as demonstrator network. This data must be compressed and transferred into the appropriate description format. Alternatively, the demonstrator network can be created synthetically. Descriptions of relevant services, business processes, enterprises (range of products and services, technology, competence and resources) represent important data categories.

2. Decomposition

Within the decomposition the described benefits, technologies, competencies and resources are being separated into their elementary parts, i.e. basic benefits, basic functions, components of competencies and minimum resources (see Figure 6).

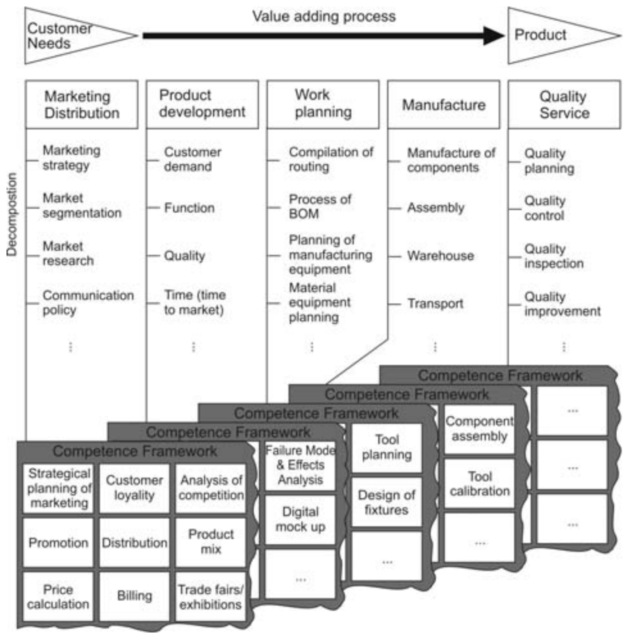

Figure 6: Decomposition of business processes into Competence Components (e.g. [34])

3. Composition

In the end the fundamental components form adequate Competence Cells as organizational units (see (Figure 7).

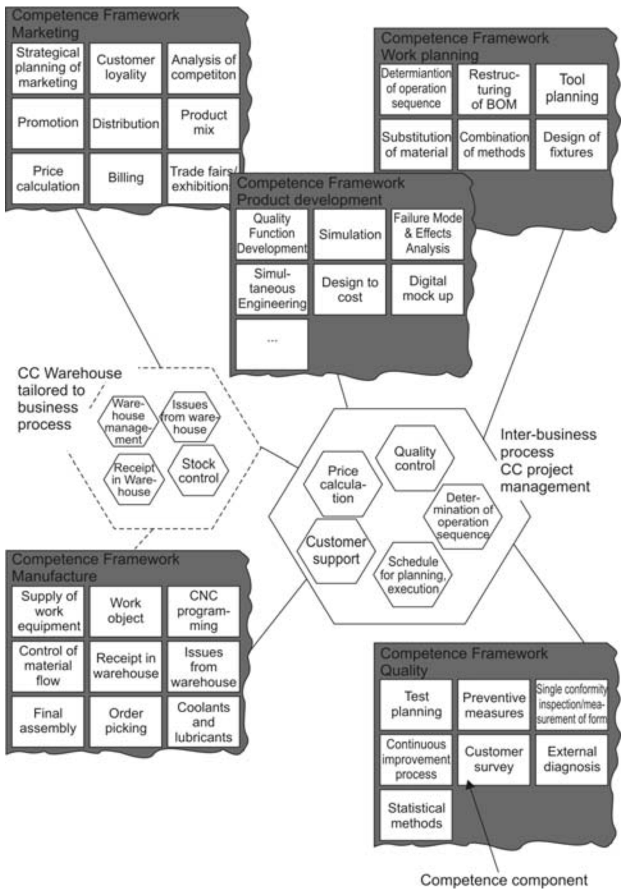

Figure 7: Composition of Competence Components to Competence cells (e.g. [34])

On the basis of precast (real/virtual) service portfolios and process chains and the created Competence Cells, scenarios of networking can be developed. These scenarios can then be researched on laboratory scale.

Step 5: Evaluation of the pilot solution in the form of an analysis of potentials by means of the pilot-based proven criteria of evaluation and evaluation of the adaptability of the methodology. In addition to the analysis of potentials, a benefit analysis is conducted. Hypotheses will then be verified or falsified and identified mechanisms will be explained. Potential, utility value and SWOT analysis are methods applied in this step. That broad analysis allows highlighting the limits of the application of the approach. Consequently, knowing the limits allows sound conclusions on the transferability of the Competence-Cell-based approach to the defined areas of application in service networks.

The research of an innovative, but for this research project atypical, services network from a non-production-related field is the basis for further conclusions about the adaptability and the possibility of generalization of the Competence-Cell-based approach in the field of service networks.

Finally, the further need for research will be documented in a research roadmap. Amongst others, it will contain areas of research that remain interesting for further research, such as certain branches. The further need for research will also address rising scientific issues and objectives as well as requirements on necessary models (e.g. descriptive, process and explanatory models), methods (educational and management methods) and tools (e.g. co-operation platform).

4 CONCLUSION AND OUTLOOK

The Competence-Cell-based approach for co-operation in non-hierarchical networks appears to be a very promising approach when it comes to innovation in service networks, especially for networks of SME. Therefore, the applicability of this for service networks has to be evaluated. The evaluation is based on both the advancement of the theoretical basis on Competence-Cell-based networks and service networks, as well as empirical studies on existing service network.

The objectives of the evaluation and the work program are presented and first hypotheses are discussed. However, the presented work program should assist in the transition to make the presented concepts applicable for pilot implementations.

5 REFERENCES

[1] Austrian Economic Chamber, Labour Statistics, 2008

[2] Schiemann, M., 2008, Unternehmen nach Größenklassen – Überblick über KMU in der EU; eurostat, Statistik kurz gefasst, 31/2008

[3] Matyas, K., Rosteck, A., Sihn, W., 2009, Empirical Study Concerning Industrial Services within the Austrian Machinery and Plant Engineering Industry, In: Rajkumar, R., Essam, S. (Hrsg.), Cranfield: 40-45.

[4] Laubacher, R. J., Malone, T. W., MIT Scenario Working Group, 1997, Two Scenarios for 21st Century Organizations – Shifting Networks of Small Firms or All-Encompassing 'Virtual Countries'?, MIT Initiative on Inventing the Organizations of the 21st Century, Working Paper 21C WP #001.

[5] DELPHI'98, 1998, Umfrage-Studie zur globalen Entwicklung von Wissenschaft und Technik, FhG-ISI im Auftrag des BMBF, Symbolog GmbH, Bad Homburg.

[6] Malone, T. W., Laubacher, R. J., 1998, The dawn of the e-lance economy, Harvard Business Review, Sept.-Oct. 1998, 145-152.

[7] Salmons, J., Babitsky, T., 2001, Shamrocks and Nanocorps – Business Model and Technology, Innovation to Bridge the Digital Divide, Net Impact Conference, Chapel Hill, North Carolina.

[8] ECOLEAD (European Collaborative Networked Organisations Leadership Initiative), http://www.ve-forum.org/default.asp?P=284, 14.06.2005.

[9] Reinhart, G., Weber, V., Broser, W., 2002, Kompetenz und Kooperation – Kompetenznetzwerke als Organisationsmodell für die Produktion der Zukunft, In: Milberg, J.; Schuh, G. (Hrsg.), Erfolg in Netzwerken, Springer, Berlin: 287-300.

[10] Enderlein, H. et al., 2002, Sonderforschungsbereich (SFB) 457: Hierarchielose regionale Produktionsnetze – Theorien, Modelle, Methoden und Instrumentarien, Arbeits- und Ergebnisbericht 2000, 2001, 2002, TU Chemnitz.

[11] Müller, E., Horbach, S., Ackermann, J., Schütze, J., Baum H., 2006, Production system planning in Competence-cell-based Networks, In: Middle, J. E. (ed.), International Journal of Production Research, Special Issue: Selected papers from the 18th ICPR – The networked enterprise: a challenge for a sustainable development, Vol. 44, Nos. 18-19, 15 September-1 October 2006, Taylor & Francis: 3989-4009.

[12] Meffert, H., Bruhn, M., 2003, Dienstleistungs-marketing – Grundlagen, Konzepte, Methoden, Gabler, Wiesbaden: 27ff.

[13] Corsten, H., Gössinger, R., 2005, Dienstleistungs-management, Oldenbourg, München.

[14] Langeard, E. et.al., 1981, Services marketing: new insights from customers and managers, Marketing Science Institut, Report No. 81-104, Cambridge, MA.

[15] Ascher, B., Whichard, O.G., 1987, Improving services trade data, In: The Emerging Service Economy, Pergamon Press, Oxford.

[16] Altenburger, O. A., 1980, Ansätze zu einer Produktions- und Kostentheorie der Dienst-leistungen, In: Betriebswirtschaftliche Schriften, Heft 101, Duncker&Humblot, Berlin.

[17] Bullinger, H.-J., Meiren, T., 2001, Service Engineering – Entwicklung und Gestaltung von Dienstleistungen, In Bruhn, M., Meffert, H. (Hrsg.), Handbuch Dienstleistungsmanagement. Von der strategischen Konzeption zur praktischen Umsetzung, Verlag, Wiesbaden: 149-175.

[18] Mont, O. K., 2002, Clarifying the concept of product service systems, In: Journal of cleaner production, 10/3: 237-245.

[19] Baines, T. S., Lightfood, H.W., Evans, S. et al., 2007, State of the art in product-service systems, In: Journal of Engineering Manufacture, 221 (B): 1543-1552.

[20] Meier, H., Kortmann, D., Golembiewski, M., 2006, Hybride Leistungsbündel in kooperativen Anbieter-Netzwerken. In: Industrie Management 22 (2006) 4: 25-28.

[21] Rese, M., Karger, M., Strotmann, W.-C., 2007, Welche hybriden Leistungsbündel für welche Kunden? In: wt Werkstattstechnik (online) 97 (2007) 7/8: 533-537.

[22] Schenk, M., Ryll, F., Schady, R., 2006, Anforderungen an den Produktentwicklungsprozess für hybride Produkte im Anlagenbau, In: Industrie Management 22 (2006) 1: 55-58.

[23] Schweitzer, E., Mannweiler, C., Aurich, J.C., 2009, Continuous Improvement of Industrila Product

Service Systems, In: Roy, R., Shehab, E. (Ed.), Industrial Product Service Systems, Proceedings, Cranfield: 16-23.

[24] Meier, H., Uhlmann, E., Krug, C.M. et.al., 2009, Dynamic IPS²-Networks and -Operations Based on Software Agents, In: Roy, R., Shehab, E. (Ed.): Industrial Product Service Systems, Proceedings, Cranfield: 305-310.

[25] Harms, V., Famulla, B., 2002, Betreiberservice – ein Serviceprodukt, In: Service Today, Heft 5: 13-18.

[26] Meier, H., Zuther, M., 2000, Innovative produktnahe Dienstleistungen in Kunden-Lieferanten-Netzwerken der Investitionsgüterindustrie. In: wt Werkstatts-technik 90 (2000) 9: 375-380.

[27] Meier, H., Völker, 0., 2008, Industrial Product Service Systems – Typology of Service Supply Chain for IPS² Providing, The 41st CIRP Conference on Manufacturing Systems, Tokyo, Japan: 485-488.

[28] Zhang, Y., Srai, J., Gregory, M., Iakovaki, A., 2009, Engineering Network Configuration: Transition from Products to Services, In: Roy, R., Shehab, E. (Ed.), Industrial Product Service Systems, Proceedings, Cranfield: 315-322.

[29] Müller, E. et al., 2007, Sonderforschungsbereich (SFB) 457: Hierarchielose regionale Produktionsnetze – Theorien, Modelle, Methoden und Instrumentarien, Abschlussbericht 2006, TU Chemnitz.

[30] Müller, E. et al., 2006, Paketantrag (PAK) 196 „Kompetenzzellenbasierte Produktionsnetze – Entwicklung einer Methodik zum Bilden und Betreiben von kompetenzzellenbasierten Produktionsnetzen, Neuantrag, TU Chemnitz.

[31] Mowshowitz, A., 1994, Virtual Organization: A Vision of Management in the Information Age, The information society 1994; 10(4): 267-288.

[32] Camarinha-Matos, L.M., Afsarmanesh, H., Ollus, M. (eds.), 2006, Networks-Centric Collaboration and Supporting Frameworks, IFIP TC5 WG 5.5 Seventh Working Conference on Virtual Enterprises. Helsinki, Finland, 25-27 September 2006, Springer.

[33] Erpenbeck, J., 1998, Kompetenzentwicklung als Forschungsaufgabe. QUEM Bulletin. 18–23, 2/3.

[34] Baumann, A., 2000, Kompetenzzellenbasierte regionale Produktionsnetze. Dissertation, Wissen-schaftliche Schriftenreihe des IBF, Heft 26, TU Chemnitz.

Assessing the potential of business model innovation for investment goods through Life Cycle Costing

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Abstract

In light of increasing competitive pressure, many manufacturers of investment goods are growing aware of the importance of business model innovation. Alternative business models that put more emphasis on the service content of the value proposition are gaining ground across many sectors. Manufacturers often face the challenge to identify the business model with the greatest earning potential. This paper demonstrates that Life Cycle Costing can be used to identify and quantify the potential for business model innovation. The relevance of this approach is illustrated with the findings of eighteen in-depth interviews with executives of Belgian industrial companies.

Keywords

Product Service Systems, Business Model, Life Cycle Costing

1 INTRODUCTION

European manufacturers can no longer rely exclusively on technological innovation to keep ahead of ever fiercer global competition. The importance of business model innovation is widely recognized by academia and practitioners alike. A 2005 survey by the Economist Intelligence Unit highlighted that more than half of 4,000 global executives believes business model innovation to be of higher importance for the competitive advantage of their company than innovation in products or services [1]. A survey among CEO's carried out by IBM in 2008 reported that two thirds of them are implementing extensive innovations in their business model [2]. Wilson De Pril, director-general of Agoria Flanders, Belgium's largest employers' organization and trade association, confirms the increasing importance of business model innovation for European industrial companies: "The lead that our companies have due to innovation in products and production processes is becoming smaller and smaller. That's why it is of the highest importance to implement complex forms of innovation that are difficult to copy. This can only be done by finding new ways of value creation, and this is where business model innovation comes into sight."

For manufacturers of investment goods (i.e. means of production) there is a trend towards business models that put more emphasis on the service content of the customer value proposition as opposed to a traditional, 'product-centric' business model. This leads to the development of Product-Service Systems (PSS), business models combining tangible products with intangible services to deliver value in use. In a PSS, the focus shifts from sales of the product towards sales of the use or result of the product. The most cited examples in this context are Xerox Corporation, which offers a price per copied page instead of selling copying machines and Rolls-Royce plc, which offers a "power-by-the-hour" contract under which airlines are charged a fixed fee per flying hour of an aircraft engine. Another example can be found in Belgium, where the company Arcomet has transformed itself from a small producer of construction cranes into the biggest independent construction crane rental company in the world. Over the last fifteen years the share of services in Arcomet's total turnover has increased from 20% to 95%. Between 2000 and 2007 its turnover more than doubled and its EBITDA almost tripled.

These examples are indicative of the huge earnings potential of business model innovation. Indeed, in the words of Johnson: 'business model innovations have reshaped entire industries and redistributed billions of dollars of value' [3]. But for most companies it is not evident to assess what the potential impact on profitability of an alternative business model is. Especially for companies that are traditionally organized around the delivery of products, the transition towards a PSS business model encompasses uncertain benefits and costs that are difficult to forecast.

Apart from the vagueness surrounding the term 'business model' itself, which is reflected in diverging definitions in the specialized literature, there is a clear lack of quantitative techniques to support business model innovation decisions. The goal of this article is to present the rough outline of a decision support method to assess the potential of a Product Service System for developers of investment goods, based on a Life Cycle Costing analysis of the technological infrastructure that delivers the customer value. An overview of the relevant literature on business models and PSS is presented in Section 2. Section 3 provides a short overview of Life Cycle Costing, followed by the main findings of eighteen in-depth interviews with executives of Belgian industrial companies. The relevance of LCC within the context of business modeling is illustrated with industrial examples. Finally an LCC-based method to identify the potential for business model innovation for investment good manufacturers is presented.

2 RELEVANT LITERATURE ON BUSINESS MODELS AND PSS

2.1 Introduction

The scientific literature on business modeling has mainly developed out of an interest in eBusiness models, related to the rise of the internet [4]. Therefore, most business model research has concentrated on business models for ICT services and systems. However, several constructs developed within the existing literature on eBusiness models are also useful for manufacturers of investment goods. In this Section those constructs and techniques will be presented. The focus will be on definitions of the term business model (Section 2.2), on the atomic elements of business models and the link with PSS (Section 2.3), on the design parameters of business models (Section 2.4) and on evaluation methods of business models (Section 2.5).

2.2 What is a 'business model'?

There is no universally accepted definition of a 'business model'. During the internet boom at the end of the 90s 'business model' became a buzzword that 'could be invoked to glorify all manner of half-baked plans' [5]. This explains the skepticism evident from Michael Porter's 2001 comment that 'the business model approach to management becomes an invitation for faulty thinking and self-delusion' [6]. Although Porter certainly had a point when condemning the lack of clarity surrounding the term 'business model', few researchers have followed his suggestion to dispose of it altogether. Business model research survived the 'dot com crash' and gained particular momentum over the past decade because – as Magretta notes – 'the experience of companies like Dell and Wal-Mart shows that [business models] are concepts of enormous practical value' [5].

Then what can be understood under the term 'business model'? It is not within the scope of this paper to discuss all the definitions that can be found in the literature (for an overview see [7] and [8]). Only a brief summary of the most important aspects that are necessary to understand the way the term 'business model' is used throughout this article is presented here:

1 Linder and Cantrell defined a business model as 'the organization's core logic for creating value' [9]. The notion of 'value creation' is probably the greatest common factor in all definitions. But other definitions emphasize the creation as well as the capture of value [10, 11]. The capture of value, referring to a conversion mechanism of a business idea into a sustainable profit, is essential in any successful business model [12]. Thus a business model is essentially '**a company's core logic for the creation and capture of value.'**

2 Many authors emphasize the **multidimensionality** of a business model, leading to more elaborate definitions, such as Osterwalder's [13]: 'A business model is a conceptual tool that contains a set of elements and their relationships and allows expressing a company's logic of earning money. It is a description of the value a company offers to one or several segments of customers and the architecture of the firm and its network of partners for creating, marketing and delivering this value and relationship capital, in order to generate profitable and sustainable revenue streams.' The view that a business model consists of several elements or levels appears in many definitions (e.g. [10], [14], [15]). A specific set of the constituting elements of a business model will be elaborated in Section 2.3.

3 As several authors observe, a business model **transcends the boundaries of one company**. Amit and Zott even make this multi-firm view the central idea in their definition of a business model: '[A business model] elucidates how an enterprise works with those external stakeholders with whom it engages in economic exchanges in order to create value for all involved parties' [16]. As Brandenburger and Stuart noted, value creation is an inherently cooperative process, while value capture is inherently competitive [17].

4 Among researchers there are differing views on the link between the business model of a company on the one hand and its strategy and business processes on the other hand. Only one approach is mentioned here, that views a business model as the translation of 'the strategy of a company into a blueprint of the company's logic of earning money' [18], thus viewing the business model level as an **intermediary level between the strategy and the business process level** in a company's management structure.

Summarizing, the **basic characteristics of a business model** are:

- It describes the way value is created and captured.
- It can be decomposed into several elements.
- It transcends the boundaries of one company.
- It forms an intermediary level between the strategic and the business process level within a company's management structure.

2.3 Elements of a business model and the link with PSS

Most recent business modeling research has focused on the decomposition of a business model into its 'atomic' elements [19]. Only one decomposition is mentioned here out of a multitude of approaches (for an overview see [19] and [20]). According to this approach, a business model consists of 4 basic elements:

1 The **customer value proposition:** the benefits delivered through products and/or services by the vendor to the customer in return for the customer's associated payment.

2 The **value network:** all actors that are involved in the creation and capture of value.

3 The **technological infrastructure:** the technical components, used for value creation, that generate costs.

4 The **revenue model:** the description of the formal relations within the value network, defining how revenues and costs are divided between the different actors.

Ballon and Arbanowski proposed a visualization of this decomposition into four elements (cfr. Figure 1), with an explicit indication of the way these elements are connected [10].

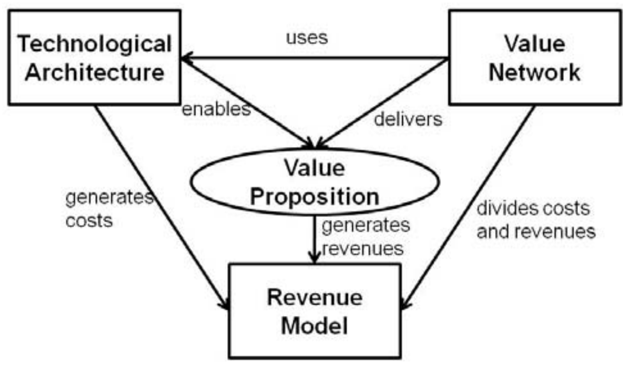

Figure 1: Basic elements of a business model [10].

These elements are not independent but provide four complexly intertwined levels on which a business model can be analyzed. Each level enables a complementary analysis of the business model.

Tukker clarified the link between 'product-service systems' and the terminology of business model research. He sees a 'product-service (PS)' as a particular value proposition, ‘that consists of a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs’ [21]. A ‘Product-Service System’ (PSS) on the other hand consists of the PS, the value network, the technological architecture and the revenue model [21], thus containing all the elements of a business model. According to these definitions, a **PS is a specific type of value proposition** and a **PSS is a specific type of business model.** Throughout the PSS-literature, the terms PS and PSS are not always used consistently. For example in the state of the art article of reference [22], a PSS is defined as ‘an integrated product and service offering that delivers value in use’, a definition that is more suitable for a PS. Throughout the remainder of this text, a PSS will be understood as a specific type of business model and the classification of a PSS in three basic types, product-oriented (type 1), use-oriented (type 2) and result-oriented (type 3) found throughout the PSS literature, will be adopted.

2.4 Design parameters of business models

A set of design parameters can be assigned to each of the atomic elements of a business model, that were introduced in the previous paragraph. In the business modeling literature several authors have proposed theoretical frameworks of business model design parameters (e.g. [4], [8]). The combination of these parameters aims to provide a complete and unambiguous characterization of the business model in question. The most comprehensive framework is provided by Ballon [4], but the fact that most of his parameters are rather high-level and specifically designed for ICT systems and services limits the applicability of his framework for investment goods.

Lay, Schroeter and Biege [23] have proposed a typology of ‘business concepts’ for manufacturing industries on the basis of a set of parameters found throughout the diverse literature relating to ‘new service-based business concepts’ (e.g. PSS, performance based contracting, full service contracts, etc.). Their parameters are arranged in a morphological box according to several options. The focus is on parameters concerning ownership and payment options. The fact that this framework is grounded in practice and specifically designed for manufacturing companies increases its applicability. But the set of provided parameters and options lacks comprehensiveness. Especially parameters related to the specification of the value network and the technological infrastructure are missing. This incompleteness can mainly be attributed to the fact that the term ‘business concept’ is vaguely introduced and seems less comprehensive than the term ‘business model.’

2.5 Evaluation methods of business models

Pateli and Giaglis identified the development of business model evaluation methods as a ‘less mature’ sub-domain of business model research, concerned with the assessment of the **feasibility** and **profitability** of business models [20].

The **feasibility** of a business model is, according to Bouwman, determined by the ‘fit’ between the different business model design parameters [8]. Ballon speaks of a ‘strategic alignment’ between design parameters in order to be able to speak of a feasible business model [4]. Feasibility assessment requires a qualitative approach.

Assessment of the **profitability** of a business model requires a quantitative approach. For an alternative business model, benefits vs. costs and risks need to be determined in order to calculate the expected profit potential.

Few relevant profitability evaluation methods exist. Gordijn introduced the e3-value method to assess the profitability of Ebusiness models [24]. Representation methods of value networks introduced in his e3-value ontology [25] will be applied for investment goods in Section 4.

3 LIFE CYCLE COSTING AND ITS USE FOR BUSINESS MODEL INNOVATION

3.1 Introduction

In this Section the applicability of LCC within the context of business model innovation for investment goods is illustrated. In Section 3.2 a brief state of the art of LCC is provided, based on a literature study. In Section 3.3 the link between LCC and business model innovation is discussed and illustrated with industrial examples. Eighteen in-depth interviews with executives of Belgian manufacturers of investment goods were performed during the summer of 2009. The main topic during the interviews was the experience these companies had with Life Cycle Costing and their vision on the link between the LCC of their products and the opportunities of an alternative business model such as a PSS. In Table 1 the companies that participated in the interviews are listed.

	Type of product	Interviewee job title	Company size
A	Compressors	Sales Manager	large
B	Production machines	R&D manager	large
C	Transport systems	Project Leader R&D	large
D	Elevators	Business Unit Manager	SME
E	Gear boxes	R&D manager	large
F	Production machines	Service Manager	large
G	Insulation panels	R&D manager	SME
H	Production machines	Service Manager	large
I	Printing equipment	R&D manager	large
J	Telecom equipment	R&D manager	large
K	Robotics	CEO	SME
L	Packaging machines	CEO	SME
M	Egg incubators	Service Manager	SME
N	Weaving machines	Project Leader R&D	large
O	Switch panels	R&D manager	SME
P	Fire safety systems	CEO	SME
Q	Traffic control systems	R&D manager	SME
R	Weaving machines	R&D manager	large

Table 1: Characteristics of the 18 companies that participated in the interviews.

In Section 3.4 a method to identify and quantify the cost reduction potential of an alternative business model is presented.

3.2 State of the art of Life Cycle Costing

Life Cycle Costing is a method to quantify resources a product consumes over its complete life cycle in monetary terms. The Product Life Cycle (PLC) includes four phases design, production, use and end-of-life (EOL) [26]. LCC was introduced in the 1960’s in the U.S. Department of Defense to support purchase decisions of weapon systems. Over the last decades LCC has been methodologically well developed and used extensively in the military and construction sector [27]. In other industries, several authors observe the limited uptake of LCC and similar methods such as Total Cost of Ownership (TCO) [28-30]. Korpi and Ala-Risku performed an extensive review of LCC case studies published in academic and practitioner literature [31]. They conclude that most reported applications were ‘far from ideal’, assessing costs only from a limited number of PLC phases and using a deterministic approach in half of the cases, although throughout the literature a stochastic analysis is deemed essential in order to cope with the inherent uncertainties and risks when forecasting costs [32, 33].

The main purposes of LCC analyses are [34]:

- **Affordability studies** aimed at the quantification of the impact of the LCC of a system on long term budgets.
- **Supplier selection and evaluation studies** aimed at supporting choices between competing offers.
- **Design studies** aimed at identifying and influencing design aspects of products that directly impact LCC.
- **Repair level analyses** aimed at quantifying maintenance demands and costs.
- **Sales argumentations** aimed at informing customers of the LCC of products.

The financial metric used in an LCC analysis is preferably the Net Present Value (NPV). NPV allows to calculate costs in their present worth, taking the time value of money into account. A crucial parameter in the NPV formula is the discount rate, which determines the balancing of costs that occur now and in the future. A popular choice for a discount rate is the company’s Weighted Average Cost of Capital (WACC); the rate that the company is expected to pay on average to its providers of capital.

Each cost component can be quantified by applying a cost estimation method. Such methods could be intuitive, analogical, parametric or analytic (see [35]). The analytic method that often succeeds best in capturing the causal relations between cost drivers and costs is Activity Based Costing.

Costs can be categorized in several ways:

1. A hierarchical categorization according to the life cycle phase. A Cost Breakdown Structure can be built up in a tree (see for example Figure 2). Each node is split into sub-nodes.

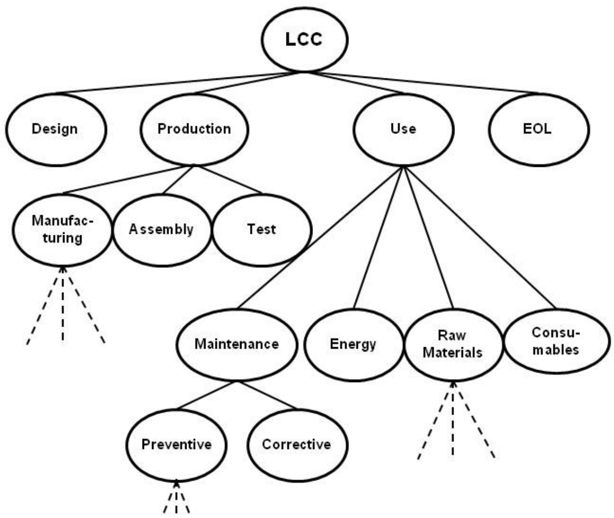

Figure 2: Cost breakdown in a tree structure.

2. A categorization according to the degree of quantification difficulty (cfr. [33]). Based on Emblemsvag’s classification scheme, the following categorization will be used:
   - **Usual costs**: these are costs that can be traced directly (e.g. direct labor, supplies, energy, materials).
   - **Hidden costs**: these are usually lumped in the overhead in traditional cost accounting systems and are more difficult to trace (e.g. reporting, inspection, planning).
   - **Liabilities**: these are costs that arise due to non-compliance and potential future liabilities (e.g. liabilities from customer injury, penalties and fines)
   - **Opportunity costs**: these ‘costs’ are not a cost in the sense of a consumption of resources but reflect the minimum of the lost revenue due to non-performance and the cost of the best available alternative (e.g. quality loss, missed output). See 3.3 for examples.

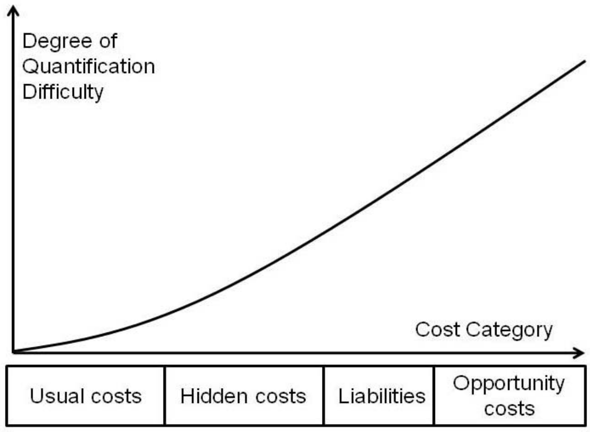

Figure 3: Cost categorization according to the difficulty of quantifying costs (based on [33]).

Both classifications can be combined in a simplified conceptual model, presented in Figure 4. Four concentric ellipses indicate the cost categories according to quantification difficulty. The quadrants in the scheme indicate the life cycle phases.

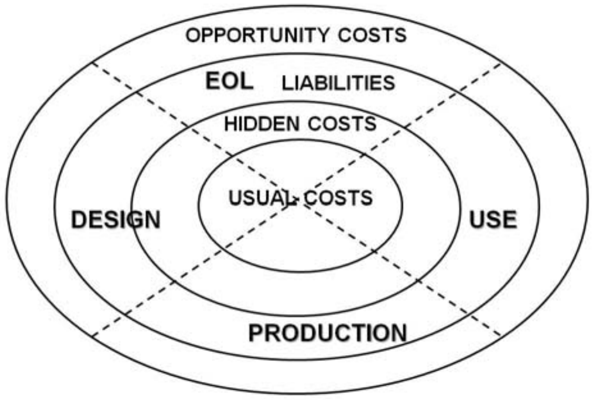

Figure 4: Combination of both categorizations in a simplified model.

3.3 LCC within the business model framework and industrial examples

In this Section the applicability of Life Cycle Costing within the framework provided by the ‘business model’ construct is discussed. Specifically for manufacturers of investment goods, LCC can be employed to identify the potential of an alternative business model such as a use- or result-oriented PSS, adding one more possible purpose of an LCC analysis to the list of Section 3.2.

The rationale behind applying LCC in this context is that often there is an 'untapped LCC reduction potential', that could be realized in a new business model. Within a business model, an LCC analysis is performed at the level of the technological infrastructure. The focal point of the analysis is the investment good, but the business model framework allows extending the horizon of analysis towards other technological systems that are interacting with the main system.

What the 'untapped LCC potential' means in practice will be clarified with examples of successful business model innovations.

- Xerox, probably the most cited example in this context, reports on its website that through reuse of remanufactured components, each year 'hundreds of millions of dollars' are saved. In its 'pay per copy' business model Xerox retains ownership of its products and thus has a guaranteed delivery of reusable components. The untapped LCC reduction in the End-Of-Life phase was only realized after the new business model had been adopted.
- Arcomet, the Belgian crane rental company, developed a type of construction cranes, with an on-site assembly and disassembly time of only 15 minutes. This untapped LCC potential in the use phase is captured by Arcomet itself, as it performs these operations in its rental business model.

These examples make clear that the potential of a use-oriented or result-oriented PSS can be made visible by quantifying the 'untapped LCC potential' of the technological infrastructure used to deliver value within the business model. Often the manufacturer's business model does not provide the right incentives to optimize the design of its products over their complete life cycle. Competitive pressure forces the manufacturers to make design choices that are not LCC-optimal.

During the interviews most respondents confirmed the existence of an 'untapped LCC potential.' Ten out of eighteen answered this potential is certain and substantial for their products.

Some interesting conclusions can be drawn from their comments on this question:

- Seven out of ten respondents indicate that a potential LCC reduction exists because market conditions pressure them to reduce the sales price of their product, rather than the complete LCC. Company O for example, an SME manufacturing switch panels for industrial customers, notes that most of its clients are not concerned with the energy usage of its products, although the energy cost over the lifetime of a switch panel (typically twenty years) is a multiple of the initial investment cost. As a result most of their products are not designed with the best available technology, but with cheaper, less energy efficient components.
- Several companies see a substantial LCC-reduction possibility in external systems interfaced to their product or system that can be realized by adapting the design of their product. Company D for example noticed a cost saving potential that could be realized if heat losses through the elevator shaft were taken into account during the design of an elevator. Company P noticed important LCC reductions possible in many external systems interfaced to their fire safety systems (cfr. Section 3.4).

In a next question, the company representatives were asked to specify what they assumed to be the predominant factor of the LCC for their customers. It was remarkable that six respondents indicated that the 'cost of non-performance' is always dominant. Four more indicated that for some customer segments it is dominant. The 'cost of non-performance' is actually not a cost in the true sense of the word. It is not a consumption of resources, but the missed revenues due to product malfunctioning accumulated over the lifetime of the product. High variability from customer to customer was mentioned by twelve respondents as an inherent attribute of this missed revenue. Some examples:

- If a weaving machine (companies N and R) is not preset correctly it produces 'second choice' fabrics, salable at lower market prices. Accumulated over the life time of a weaving machine this lost revenue is quite substantial.
- Company M manufactures egg incubators to poultry farms. The hatching process yield depends on complex interaction of parameters such as the temperature, the humidity, the air quality and the risk that eggs are damaged during transport. The cumulative value of eggs that are not hatched over the life time represents a substantial lost revenue.
- Two companies (A and J) noticed that their customers often insure themselves against the cost due to product malfunctioning by installing redundant capacity. This confirms that the opportunity cost is bounded from above by the cost to provide a backup.

The last question was whether the respondents saw an evolution towards a use- or result-oriented PSS for (some of) their products.

- Three companies (A, C and P) indicate that they already have a PSS type 2 or 3 operational for some customer segments. Company A delivers compressed air per m³ to some customers, company C offers a transport service per km and company P offers total protection solutions.
- Two companies are developing a PSS type 2 or 3 and will introduce it to the market within one year.
- Nine companies regard a PSS type 2 or 3 as a possibility for the near future (within five years).
- Three companies do not regard a PSS type 2 or 3 as a realistic business model for the near future. Two of these companies develop subsystems of an investment good.

This extensive case-based research clarifies that out of this sample of eighteen companies, the majority notices an evolution towards PSS type 2 or 3 business models and that majority sees an untapped LCC potential that could be realized in another a PSS type 2 or 3.

3.4 LCC based method to identify the potential of an alternative business model

The potential of an alternative business model can be identified by an LCC based method, passing through the following steps:

<u>Step 1:</u> Map the **technological infrastructure** of the current business model in terms of:

- all subsystems forming part of the investment good
- all external systems that are networked to the product either physically or electronically over the life cycle of the investment good

As an example, a fire safety system can be decomposed in subsystems as demonstrated in Figure 5. A non-comprehensive overview of external systems that are networked to the fire safety system are drawn in Figure 6.

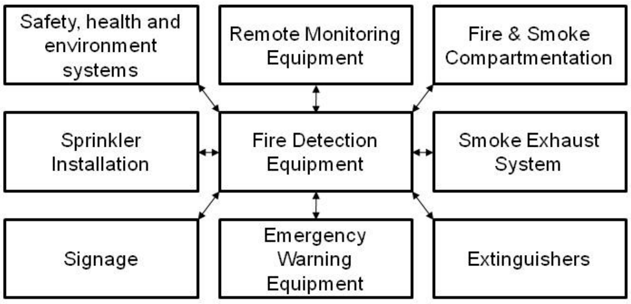

Figure 5: Technological infrastructure of a fire safety system.

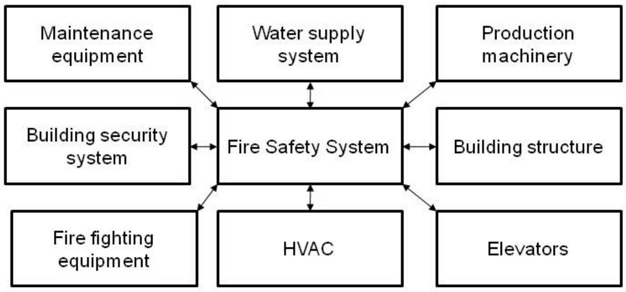

Figure 6: Some of the external systems interfaced to the fire safety system of a production facility.

<u>Step 2:</u> Map the **value network** of the business model, including all companies that create or capture value over the life cycle of the investment good.

In the eBusiness model literature several tools and methods exist for value network mapping. The approach demonstrated here is the e3-value™ ontology of Gordijn and Akkermans based on UML class diagrams [25]. In this representation, all actors are depicted, indicating the value objects (products, services or experiences) they exchange through value interfaces. A non-comprehensive value network for a fire safety system is provided in Figure 7 as an example.

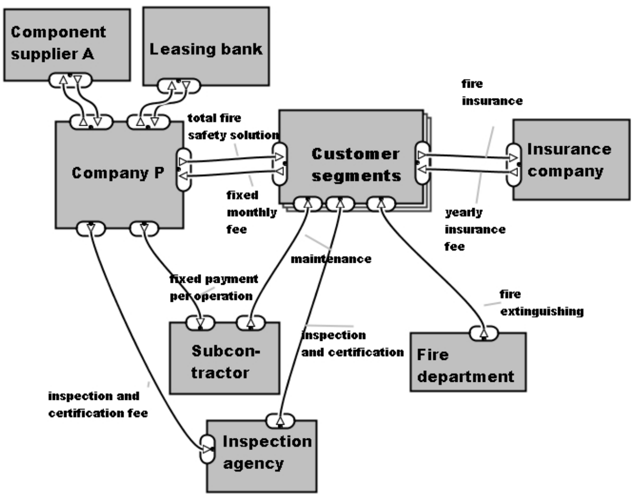

Figure 7: Simplified value network for a fire safety system business model, following the e3-value™ ontology [25].

<u>Step 3:</u> List the possible **LCC saving opportunities** over all actors of the value network in the technological infrastructure and its interacting systems. LCC reductions can be realized in three categories:

1. LCC reductions in subsystems realized through design modification of the investment good
2. LCC reductions in external systems realized through design modification of the investment good
3. LCC reductions in subsystems realized through design modification of external systems.

During this step all possible LCC reduction possibilities are listed. A first rough outline can be made by constructing the 'circles model' of Figure 4 for each actor of the value network. For a fire safety system, these are some examples of cost reductions in the three categories:

1. LCC reductions in subsystems realized through design modification of the fire safety system:
   - Sprinkler fitting costs (e.g. test and inspection) for the subcontractor that can be influenced through an adapted design of sprinkler nozzles.
   - Reduction of EOL costs by design for remanufacturability of sprinkler pipes
2. LCC reductions in external systems realized through design modification of the fire safety system:
   - Liabilities that arise when elevators are used during fire that can be prevented by controlling elevator access by the fire detection unit.
   - Lost production revenue for the customer due to false alarms, reducible by increasing the reliability of the fire safety system
3. LCC reductions in subsystems realized through design modification of external system:
   - LCC reductions possible in lifetime extension and reduced maintenance costs by controlling the water quality.
   - LCC reductions possible by using construction materials that require less cooling capacity of a sprinkler installation in case of fire.

<u>Step 4:</u> Identify **feasible business models** that capture the LCC saving opportunities of the previous step through changes in one or more design parameters of the business model.

Based on the LCC opportunities identified in the previous step, an inventory is made of business models that capture the cost saving potential. New business models can be constructed by changing one or more parameters within the four business model elements, for example:

- **Technological infrastructure**: extend the technological infrastructure with extra subsystems (e.g. integrate the building security system with the fire safety system)
- **Value network**: add or remove actors from the value network (e.g. extra subcontractor), implement a joint value creation (e.g. bundling of a fire safety system with a fire insurance)
- **Value proposition**: offer extra services (e.g. building structure design support for optimal fire safety), include other Critical To Value (CTV) attributes in the value proposition (e.g. reduce the ecological impact of operating the fire safety system)
- **Revenue model:** payment per availability, setting of contractual penalties (e.g. fixed fee for continuity of services)

In addition to these specific examples of design parameters per element, Table 2 presents a generic overview of design parameters of a business model. This framework is specifically designed for investment goods and partially inspired by the frameworks mentioned in Section 2.4.

Value proposition design parameters	
CTV attributes	Which attributes are critical to value to the customer and how are they reflected in the value proposition?
Customer involvement	How involved is the customer in the value creation process?
Product vs. service content	What is the relative importance of the product content vs. the service content in the value proposition?
Target customers	Which (segments of) customers are targeted by the business model?
Value network design parameters	
Actors involved	Which actors are involved in the value creation and capture? Does this change over the life cycle of the investment good?
Role of each actor	What is the role of each actor in the different life cycle phases of the investment good (design/ production/ use/ disposal)?
Customer access	Which actors of the value network have direct access to the customer or end user of the investment good?
Hierarchy	What are the hierarchical relationships among the actors of the value network?
Technological infrastructure design parameters	
Asset specificity	Which products and components are designed and used specifically in this business model?
Degree of modularity	How modular is the technical buildup of the investment good?
Product ownership	Which actor owns the investment good during the different product life cycle phases?
Interface with external systems	Which external systems are in which way interfaced to the product or system?
EOL recovery	Which material content is recovered during the End Of Life phase of the products through recycling, reuse or remanufacturing?
Revenue model design parameters	
Operational expenses	Which actor pays which operational expenses during the different life cycle phases?
Capital expenses	Which investments are carried by which actors during each phase of the life cycle?
Revenue model	How are the revenues divided among the actors of the value network? What is the transaction basis (e.g. payment per use, per result, per availability, per product)?
Risks	Which actor carries which risks during the different life cycle phases?

Table 2: Design parameters of a business model of an investment good

Inventorying possible new business models can be done by sweeping each parameter over its discrete or continuous set of possibilities. Only the feasible business models are retained. The evaluation of the feasibility of a business model will not be elaborated here; such a method would require a comprehensive, qualitative approach. In practice however, decision makers within the company for which the analysis is performed can eliminate most of the unfeasible business models easily, by using their knowledge of the market in which the company operates and by applying common sense.

Step 5: Compare the feasible business models quantitatively through an LCC analysis. Choose the **optimal business model** out of the remaining alternatives.

Only for the feasible business model alternatives the profitability is assessed quantitatively. This encompasses first a high level analysis: modeling and simulating each cost component in detail is often unnecessary. Of interest are only the cost components that have a substantial contribution to the total LCC and those which are most susceptible to optimization. An iterative process can be followed that reduces the set of business model alternatives while raising the resolution of the LCC analysis.

An essential part of this step is the analysis of the uncertainties and risks involved. Methods that can be employed in this analysis are Monte Carlo simulations and scenario techniques, to generate 'what-if' analyses that aid the decision making process.

Choosing the 'best' business model out of the remaining alternatives can be supported with a Multi Criteria Decision Aid (MCDA) method. MCDA is a theoretically sound approach for making complex decisions with multiple decision makers and multiple criteria under uncertainty [36]. Development of an appropriate MCDA model that can aid business model innovation decisions will form the subject of further research.

4 SUMMARY

In this paper the relevance of Life Cycle Costing within the business model framework was demonstrated. The outline of a systematic method to identify and quantify the LCC reduction potential of an investment good within a new business model was presented. This kind of analysis can make the potential of a use- or result-oriented PSS visible, and can indicate opportunities for joint value creation, e.g. with manufacturers of external systems. The main advantages of combining the constructs of eBusiness modeling research with Life Cycle Costing is that the complex but important decisions regarding business model innovation can be quantitatively supported. Representation techniques of business models and a set of design parameters were presented.

The industrial relevance of the presented method is illustrated with the findings of eighteen in-depth interviews with executives of Belgian industrial companies. The majority of the interviewees notice an evolution towards PSS type 2 or 3 business models and confirm the existence of an untapped LCC potential that can be realized through business model innovation.

5 ACKNOWLEDGMENTS

We extend our sincere thanks to all company representatives who participated in the interviews.

6 REFERENCES

[1] Economist Intelligence Unit, 2005, Business 2010: Embracing the Challenge of Change. E.I. Unit

[2] IBM, 2008, The Enterprise of the Future, IBM global CEO study 2008. IBM Corporation

[3] Johnson, M.W., Christensen, C.M. & Kagermann, H., 2008, Reinventing Your Business Model. Harvard Business Review, 86(12), 50-59.

[4] Ballon, P., 2007, Business modeling revisited: the configuration of control and value. Info - The journal of policy, regulation and strategy for telecommunications, Volume 9, Number 5, 2007 , pp. 6-19(14).

[5] Magretta, J., 2002, Why Business Models Matter. Harvard Business Review, 80(5), 86-92.

[6] Porter, M.E., 2001, Strategy and the Internet. Harvard Business Review, 79(3), 62-78.

[7] Ballon, P., 2009, Control and Value in Mobile Communications: A Political Economy of the Reconfiguration of Business Models in the European Mobile Industry. Ph.D. thesis, Vrije Universiteit Brussel.

[8] Bouwman, H. et al., 2008, Conceptualizing the STOF Model. In Mobile Service Innovation and Business Models. pp. 31-70.

[9] Linder, J. et Cantrell, S., 2000. So What Is a Business Model Anyway: Accenture Institute for High Performance Business.

[10] Ballon, P. & S. Arbanowski, 2005. Business Models in the Future Wireless World, in: Tafazolli, R. (ed.), Technologies for the Wireless Future: The Wireless World Research Forum Book of Visions 2004. Chichester: John Wiley & Sons Ltd, pp. 90-112.

[11] Amit, R. & Zott, C., 2001. Value creation in E-business. Strategic Management Journal, 22(6-7), 493-520.

[12] Shafer, S.M., Smith, H.J. & Linder, J.C., 2005. The power of business models. Business Horizons, 48(3), 199-207.

[13] Osterwalder, A., 2005, Clarifying business models: Origins, present, and future of the concept. Communications of the Association for Information Systems 16.1 (2005):1.

[14] Slywotzky, A.J., 1996, Value migration. , Harvard Business Review Press, Boston (MA).

[15] Timmers, P., 1998, Business models for electronic markets. Electron. Commer. Europe 8 April, pp. 1–6

[16] Zott, C. & Amit, R., 2007, Business Model Design and the Performance of Entrepreneurial Firms. Organization Science, 18(2), 181-199.

[17] Brandenburger, A. and Stuart, H. 1996, Value-based business strategy, Journal of Economics and Management Strategy, 5, pp. 5-24.

[18] Osterwalder A. 2004, The Business Model Ontology: A Proposition in a Design Science Approach. Ph.D. thesis, HEC Lausanne.

[19] Pateli, A. & Giaglis G., 2003, A Framework for Understanding and Analysing e-Business Models, Proceedings of the 16th Bled Electronic Commerce Conference eTransformation, Bled (Slovenia), 9-11.

[20] Pateli, A. & Giaglis G., 2004, A research framework for analysing eBusiness Models, European Journal of Information Systems, 13, 302-314.

[21] Tukker A. and Tischner U., Editors, 2006, New business for old Europe. Product services, sustainability and competitiveness, Greenleaf Publishing Ltd., Sheffield.

[22] Baines, T. et al., 2007, State-of-the-art in product-service systems. Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture, 221(10), 1543-1552.

[23] Lay, G., Schroeter, M. & Biege, S., 2009, Service-based business concepts: A typology for business-to-business markets. European Management Journal, 27(6), 442-455.

[24] Gordijn, J., 2001, Designing and evaluating e-Business models. IEEE intelligent systems, 16(4), 11.

[25] Gordijn, J., 2002, Value-based Requirements Engineering: exploring innovative e-commerce ideas, Ph.D. thesis, Vrije Universiteit Amsterdam.

[26] Asiedu, Y. and Gu, P., 1998, Product life cycle cost analysis: state of the art review. International Journal of Production Research, 36(4), 883 - 908.

[27] Woodward, D.G., 1997, Life cycle costing--Theory, information acquisition and application. International Journal of Project Management, 15(6), 335-344.

[28] Lindholm A. and Suomala, P., 2005, Present and Future of Life Cycle Costing: Reflections from Finnish companies., Finnish Journal of Business Economics, 2, 282-292

[29] Ellram, L. and Siferd S., 1993, Purchasing: The Cornerstone of the Total Cost of Ownership Concept, Journal of Business Logistics, (14:1), 163-185.

[30] Ferrin, B. & Plank, R., 2002, Total Cost of Ownership Models: An Exploratory Study. The Journal of Supply Chain Management, 38(3), 18-29.

[31] Korpi, E. & Ala-Risku, T., 2008, Life cycle costing: a review of published case studies. Managerial Auditing Journal, 23(3), 240-261.

[32] Roy, R., 2003, Cost Engineering: Why, What and How?, Decision Engineering Report Series, Cranfield University.

[33] Emblemsvåg, J., 2003. Life-cycle costing: Using Activity-Based Costing and Monte Carlo Methods to Manage Future Costs and Risks, John Wiley and Sons, Inc., Hoboken, New Jersey.

[34] Barringer, H. and Weber, D., 1996, Life cycle cost tutorial, Fifth International Conference on Process Plant Reliability, Houston, TX, October 2-4.

[35] Niazi, A. et al., 2006, Product Cost Estimation: Technique Classification and Methodology Review. Journal of Manufacturing Science and Engineering, 128(2), 563-575.

[36] Roy, B., 1996, Multicriteria Methodology for Decision Aiding, Kluwer Academic Publishers, Dordrecht.

Product-Service Systems across Industry Sectors: Future Research Needs and Challenges

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Abstract

This paper explores the current research in Product-Service Systems (PSS) across various industries such as industrials, basic materials, utilities, and financials, based on the Industry Classification Benchmark (ICB). PSS elements are identified within each industry in terms of tangible and intangible elements of products and services. Based on this identification, the differences in PSS delivery across industry sectors are defined based on two sources namely (i) actors, relationships, and networks, and (ii) delivery packages. Founded on the differences identified, the paper explains future research needs and challenges with focus on the scope of PSS, intra- and inter- sector flows and interactions between actors involved in PSS delivery and PSS design.

Keywords

Product-Service Systems, Value creation, Industry production, Benchmark, Networks

1 INTRODUCTION

Across industry sectors, production trends continue to emerge in which the importance of offering services for value creation is promoted. Product-Service Systems are arrangements for production (in industry) that emphasise the importance of integrating products and services [1].

A product-service system (PSS) is also a ‘business model’ for promoting the co-creation of value between customers and companies [2]. This business model offers a generic approach to production that delivers value propositions based on providing functionality, availability or results to customers. The generic approach can then be applied across a range of industry sectors for the delivery of products and services that meet customer needs.

As a result, the delivery of a PSS within an industry sector is dependent on the characteristics of products and services that determine how customer solutions are integrated to realise value propositions [3]. Furthermore, the delivery of a PSS involves exploring and identifying relevant partnerships, networks and relationships in industry and with clients to aid the flow of material, information, cash, products, services and so on [2]. Consequently, capturing the industry sectors where a PSS could be applied can be crucial in identifying possible configurations that are consistent with the PSS premise of minimising resource use and maximising value for customers and companies [4].

This paper begins with an overview of the PSS concept. Next, the characteristics of products and services are described. The Industry Classification Benchmark (ICB) will then be introduced. This industry classification offers a high-level structure of sectors and sub-sectors for production by companies. Its selection was based on two criteria: completeness of sectors and reliability in terms of global coverage. The current state of product-service systems in industry will then be highlighted using literature examples. The examples provided will be based on sectors captured by the ICB approach. An approach for PSS delivery will then be proposed to identify: (1) industry relationships and company networks within and between industry sectors, and (2) ‘delivery packages’ for the co-creation of value between customers and companies. Finally, considerations for PSS delivery highlighted by the approach will then be discussed and used to make recommendations for future PSS research.

2 PRODUCT-SERVICE SYSTEMS

The business model proposed by a PSS is based on function-orientation [5]. Function oriented design is a strategy that involves the decomposition of a system into interacting units [1].

In a PSS, function-orientation decomposes the system into products and services that are integrated based on processes of servitization and productization. Servitization is a process that involves integrating services to products while productization closely links and incorporates products to services [1, 4].

In traditional business configurations, production and services are viewed as independent, unrelated concepts. In a PSS, this may not be the case. As noted in [6], production considers product characteristics such as dimensions and mechanical phenomena but incorporating services requires considerations for new characteristics such as time and interaction.

According to Morelli [6], a PSS must also be modelled as a ‘social construct’ or an organisation so as to deliver competitive and innovative customer solutions. The organisation for a PSS involves identifying actors, roles and scenarios that define the flow of material, energy (or work) and information. Furthermore, Manzini and Vezzoli [7] highlighted how a PSS could aid companies in forming new relationships and partnerships with customers and between other businesses. Becker, Beverungen and Knackstedt [8] supported this view and argued that the drive to implement a PSS could cause companies to collaborate in delivering ‘‘product-service packages’. These packages are delivered according to pre-production, production, distribution, use and end-of-life phases or straight down the line according to service and product needs.

3 PRODUCT/SERVICE CHARACTERISTICS AND THE INDUSTRY CLASSIFICATION BENCHMARK (ICB)

3.1 Product Characteristics

A product refers to 'something sold by an enterprise to its customers' [9]. It is described as an artefact that is 'conceived, produced, transacted and used' due to the properties it possesses and the functions it performs [10]. Products are also defined by their attributes and levels [11]. Product attributes include the weight of an aircraft engine or the size of a medical device whereas product levels include flight speed and degrees of accuracy for a medical device.

Products can also be characterised as having functional and physical elements [9]. The functional elements refer to 'individual operations and transformations' which aids the functioning of the product on the whole e.g. "hold water" while the physical elements are the components, parts and subassemblies that are required for the product to perform its functions e.g. handle, base.

One school of thought believes that all products have intangible elements in them because the customer can not always experience every aspect of the product prior to purchasing it [12], however it can be argued that some products have a higher level of intangibility than others. Some products are highly dependent on technology especially information technology as an integral aspect of the product. This is seen in sectors like banking, consulting, IT solution providers etc.

3.2 Service Characteristics

From service and marketing literature, services are usually described as having four main characteristics: intangibility, heterogeneity, perishability and inseparability [13-15]. *Intangibility* means that services cannot be seen, heard, smelled or tasted. They could be difficult to ascertain mentally and they cannot be stored. *Heterogeneity* means that services may not always be standardized as there could be different aspects and elements to them. The performances of services vary so it might be difficult to assess them based on certain standards. *Perishability* implies services cannot be produced and stored to be used at another time. Failure to consume them once they are made available could result in a loss of the service capacity.

Inseparability of Production and Consumption means services are consumed at the same location where they are created. Usually, the customer has a closer interaction in the creation of the service e.g. a customer participates in the service offered by the hair dresser by selecting the desired hair style and staying to go through the process of achieving the desired style.

3.3 The Industry Classification Benchmark (ICB)

Background

FTSE Group and Dow Jones created a classification system called the Industry Classification Benchmark (ICB) in 2005 [16]. This classification system is based on over 60,000 companies and 65,000 securities worldwide from

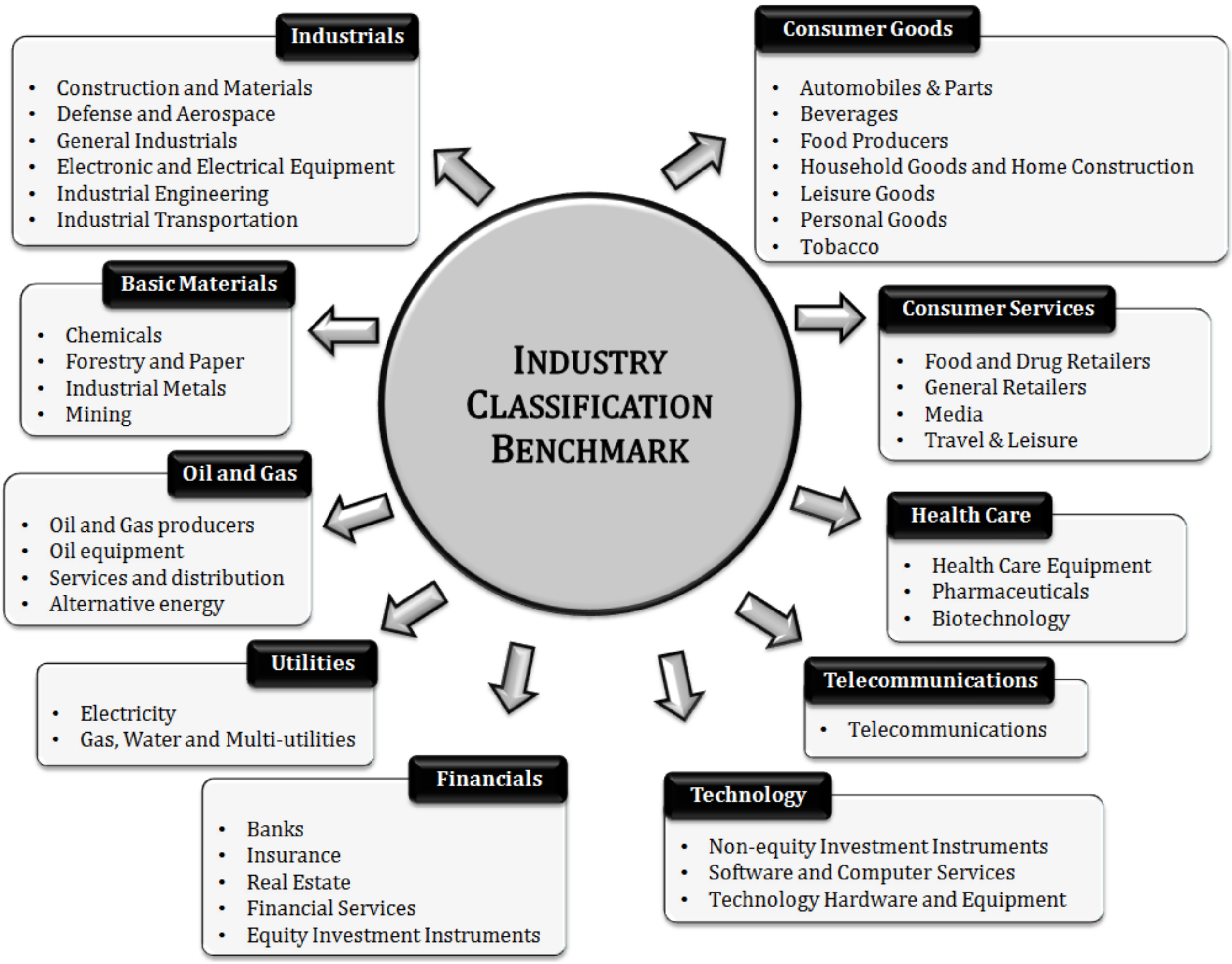

Figure 1: The Industry Classification Benchmark showing industries and sectors

Dow Jones and FTSE Universes.

The ICB contains four classification levels: Industries (10), super-sectors (19), sectors (41), subsectors (114). The coverage of the classification facilitates global sector analysis. Figure 1 shows the industries and sectors of the ICB.

A classification of industries enables practitioners to systematically arrange cases in terms of their similarity [17]. It constitutes a first and generic initiative to conduct scientific inquiry. By substituting structural knowledge for exhaustive information, the diversity of real-life phenomena is condensed into a smaller number of salient classes that can be benchmarked.

Smith et al. [18] identify the benefits of benchmarking as: showing an organization how to better meet customer needs, identifying an organisation's strengths and weaknesses, stimulating continuous operational improvement, and offering a cost-effective way of collecting innovative ideas.

Sectors and Subsectors

The ICB as shown in Figure 1 classifies industries into oil and gas, basic materials, industrials, consumer goods, health care, consumer services, telecommunications, utilities, financials, and technology.

The ICB is further classified into sectors for instance in the case of the oil and gas industry, sectors include oil and gas producers, oil equipment, services and distribution and alternative energy.

The ICB also enables companies to acquire information with regards to related products/services in each sector. For instance, for the consumer goods industry, some of the products/services include automobiles, auto parts, and tires.

Benefits

Three main benefits are associated with the use of the ICB [16].

The first benefit of the classification involves its use as an efficient and effective approach to collate data in a single source, which enables to undertake, cost and time efficient sector search. Secondly, it Improves sector analysis, as it provides a standardized base for analysis, stock selection, and performance measurement.

Thirdly, it offers accurate and timely maintenance of data that reflects global industrial landscape.

4 EXAMPLES OF PRODUCT-SERVICE SYSTEMS ACROSS INDUSTRY SECTORS

Using the ICB classification, the current state of PSS across industry sectors will now be captured by way of examples (See Table 2).

Malakata [19] described PSS provision for **financials**. Where banking sectors usually provided customers with financial products like loans, now additional online services were provided through the use of information communication technology. This helped to deliver PSS solutions comprising Internet banking and international cash transactions through electronic cards to customers.

Within the **health industry**, an example of PSS provision is seen in glucometers which provide patients with information about their blood glucose concentration and the solution provider would provide technical support if the glucometer was faulty. Ajai et al. [20] stated that this PSS was product oriented since the focus was on delivering a functional glucometer. The authors proposed a result-oriented PSS where the results from the glucometer can be sent to health professionals remotely, who could interpret the results and provide advice to the customer on how to improve their health condition through a wireless communications link based on the results obtained.

In terms of **consumer services**, a group of companies comprising a meal producing firm, a software company, the local social services and the local market traders, worked together to provide healthier food options to consumers (elderly and less favoured people and company employees) in a local Spanish town. This involved a change from the former system of delivering food to individual homes at specified times (which were an environmental issue) to a system of ordering food online which was quicker and offered a wider choice. The meals were delivered to a market and another specified location where the consumers could come and get the food and also buy some fresh fruit. This PSS solution resulted in a significant change in the logistics and a reduction of environmental impacts and costs. It also led to a higher level of satisfaction as it enhanced the consumers' social life and improved the state of their health [21].

Tasaki [22] proposed a quantitative method for accessing the level of material use in the **utilities** industry for current Electrical and Electronic Equipment (EEE) systems in Japan and for a hypothetical EEE type PSS. The value

INDUSTRY	PRODUCT		SERVICE	PRODUCT-SERVICE SYSTEM SOLUTION	REFERENCE
	TANGIBLE	INTANGIBLE			
Basic material	Commodity, speciality chemicals	-	Procurement, delivery, inspection, inventory, storage, labelling and disposal	Improved processes in acquiring value from the use of chemicals which derives cost saving	[27]
Consumer goods	Car	-	Leasing	Convenient transportation	[23]
Consumer services	Food	-	Taking and delivering orders	Improved feeding and health	[21]
Financials	-	Loans, mortgages	Online services	Business leverage	[19]
Health care	Glucometer	-	Upgrades/replacements	Improved health care	[20]
Industrials	Spares	Availability data	Maintenance	Availability of equipment	[24]
Oil and gas	Crude oil and natural gas	Financial incentive-supporting payment	Transportation, storage, marketing	Convenient oil and gas availability and delivery	[26]
Telecommunications	Set up boxes, routers	Operating systems, music catalogue	Electronic publications, home shopping,	New business configurations to meet customer needs	[25]
Technology					
Utilities	Electric cables, electric meters	-	Equipment leasing and reuse	Reduction in material use and waste generation	[22]

Table 1: Examples of product-service systems across industry sectors

proposition is based on reuse and leasing services for equipment such as electric cables and electric meters for extending equipment life and use.

Using the quantitative method Tasaki demonstrated how the PSS approach could reduce material use and waste generation for less environmental burden.

Rexfelt and Ornas [23] conducted a study to find out the opinion of individual consumer about a car-lease in PSS **consumer goods**. The result of the study revealed that consumers' choice of a PSS provision was guided by individual interest. In this case, most consumers were generally interested in a car-lease; however those without drivers' licenses were not interested in the car-lease.

As for **industrials**, the defence and aerospace industry sector is experiencing a major transformation from a product centric business motive in to one that focuses on the delivery of service [24]. This has typically been achieved through availability contracts, which consider the delivery of product through spares, and intangible product delivery is concerned with the data (e.g. performance, component availability) that is helpful in planning for the future of the given equipment. Furthermore, service relates to aspects such as health checks, training, on-call response and maintenance. As an outcome the customer is assured of attaining equipment availability over a long duration (e.g. 10-30 years).

Citing examples in the **telecommunications** and **technology** industries, Wirtz [25] discussed how the need to deliver integrated product and service offerings has triggered acquisitions and mergers in some major firms such as Microsoft, AT&T and Time Warner. From the context of PSS delivery, the reasons for these mergers and acquisition reflect themes identical to the PSS approach. For instance, in the case of the merger involving AOL and Time Warner, a new business model was created that allowed Time Warner to market its products with integrated services offered by AOL's online business. Wirtz also noted that as a result of these mergers and acquisitions, new business configurations are required to meet customer needs and demands brought on due to a change of ownership.

Tukker and Tischner [27] discussed the main areas of services that are related to chemicals within **basic materials**. Services include precise product selection, procurement, materials and maintenance management, process engineering, waste minimisation, environmental compliance assistance, health and safety training, laboratory services and identification of opportunities for continuous improvement. As a result of the integrated product and service delivery the customer benefits from improved processes in acquiring value from the use of chemicals which derives cost savings.

Neely [26], aims to capture the financial consequences of the servitization of manufacturing. The paper defines implications of findings with regards to a number of companies including PetroChina Company Limited, which operates in the Oils and Gas industry. A list of products and services that the company provides is explained. The main product output concerns crude oil and natural gas. On the other hand, intangible product which facilitates the product and service transaction is related to financial incentive that supports payment by the customer. Services cover aspects related to transportation, storage and marketing. This example within the **oil and gas** industry could be considered as a PSS, because it combines products and services to deliver value to the customer. The output is the availability of oil and gas at the convenience of the customer.

5 APRROACH FOR PRODUCT-SERVICE SYSTEMS DELIVERY

This section presents an approach for the delivery of a PSS. It is focused on two main dimensions so as to identify possible means and ends for delivery.

At the organisational level, industry relationships and company networks within and between industry sectors are proposed as possible means for PSS delivery.

At the solution level, product-service systems packages for the co-creation of value are proposed for configuring and integrating products and services.

5.1 Industry relationships and networks for delivery

There are several actors that collaborate in networks for the delivery of a PSS. As shown in Figure 2, PSS delivery involves one or more customers and some solution providers (companies).

The customer could be an individual consumer or a company. A customer and the solution providers could collaborate to jointly design and deliver the PSS which is known as value co-creation [28]. Also two customers could cooperate with each other to co-create value (with solution providers). The main solution provider is Company A who deals with the customer directly. It is

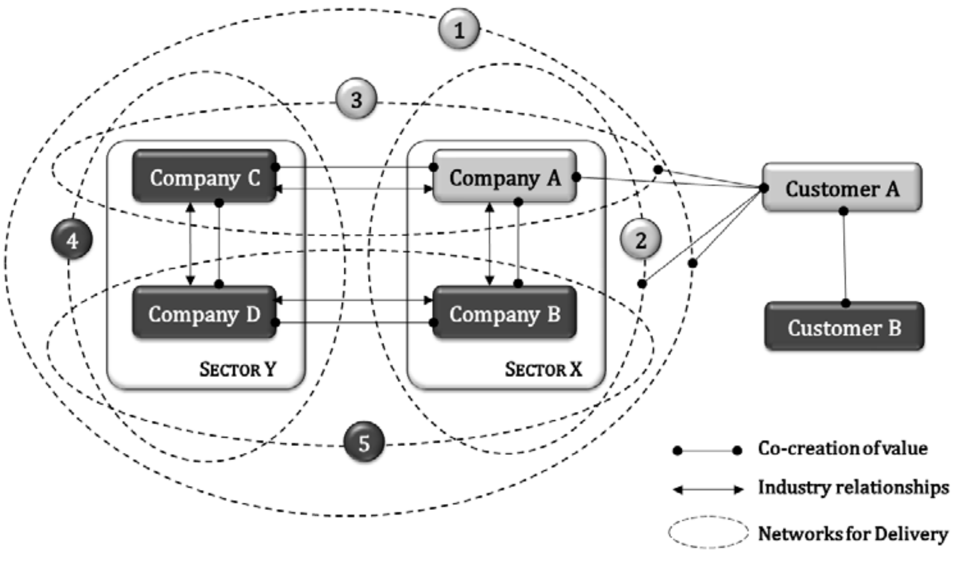

Figure 2: Product-service system relationships and networks.

supported by a network of suppliers who are companies B, C and D. These actors can interact in different ways to generate different scenarios which are described below.

Scenario 1 Industry Networks

The customer(s) could interact with the network of solution providers to create a demand for a PSS solution as well as plan and deliver the PSS solution with Company A being the main point of contact. This could occur in a B2B or B2C (Business-to-Consumer) context. In the B2C context, factors influencing consumer's acceptance of PSS include, perceived advantages compared to alternatives, perception of fixed and variable costs, insight in total life-cycle costs, uncertainty, risk, and relationship between customer and supplier [23]. Some of these factors are also applicable to a B2B context including uncertainty, risk, net present value and earned value [24]

Scenario 2 Intra-Sector Networks

Companies providing products and services could also interact to deliver a PSS solution which adds value to the customer. For example, Company A could work together with Company B within the same sector (consumer goods – automobiles and leisure products) to provide PSS solution to the customer(s). Also the same Company A could collaborate with Company C from a different sector (for instance consumer goods and consumer services– automobiles with travel and leisure services) to provide PSS solution to the customer. Company A being the main PSS solution provider, could also interact with its suppliers, companies B, C and D to co-create value for the PSS solution.

Scenario 3 Inter-Sector Networks

A cross-industry relationship can also occur when Company A interacts with Company C from a different sector to deliver a PSS solution to the customer(s). Company C could be supported by company D through a partnership agreement to provide them with knowledge, infrastructure or expertise to aid the delivery of the PSS. Within another sector, Company A could also be supported by company B through a partnership agreement or a merger to support the delivery of the PSS to the customer.

Scenario 4 Indirect Inter-Sector Networks

Companies C and D can interact to deliver a PSS within the same sector. While these companies can collaborate to support the final PSS, Companies C is higher up in the supply chain for the delivery of the PS as it has a direct relationship with Companies A who is the main PSS provider to the customer.

Scenario 5 Indirect Intra-Sector Networks

Companies D and B can also interact to support the delivery of the PSS to the customer(s). While both firms are at the lower end of the supply chain to deliver the PSS, they provide resources such as knowledge, infrastructure or capital investment to companies C and A which is highly valuable in the delivery of the PSS solution. Companies A interacts with Company C from a different sector to deliver a PSS solution to the customer. Company C could be supported by company C through a partnership agreement to provide them with knowledge, infrastructure or expertise to aid the delivery of the PSS. Within another sector, Company A could also be supported by company B through a partnership agreement or a merger to support the delivery of the PSS to the customer. There is a potential for individual companies or all the companies to interact to co-create value for the PSS solution, although this may not the case in current practice.

5.2 Delivery Packages

Products and services are combined in packages that vary in content depending on the needs of an industry or sector, whilst the outcomes or benefits of a PSS are manifold, as represented in Figure 3. This variation may be captured by shifting the level of combination between product (tangible and intangible) and service. For instance, in the case of integrating an intangible product with service the utilities industry offers examples by integrating operating systems or music catalogue with services such as electronic publications and home shopping. On the other hand, an example that involves the integration of a tangible product and service relates to the consumer services, where food is through a PSS delivered to the customer. As for the example of integrating all three contents, the industrials for example, the defence and aerospace industry sector provides the example of availability contracts, which involves a physical

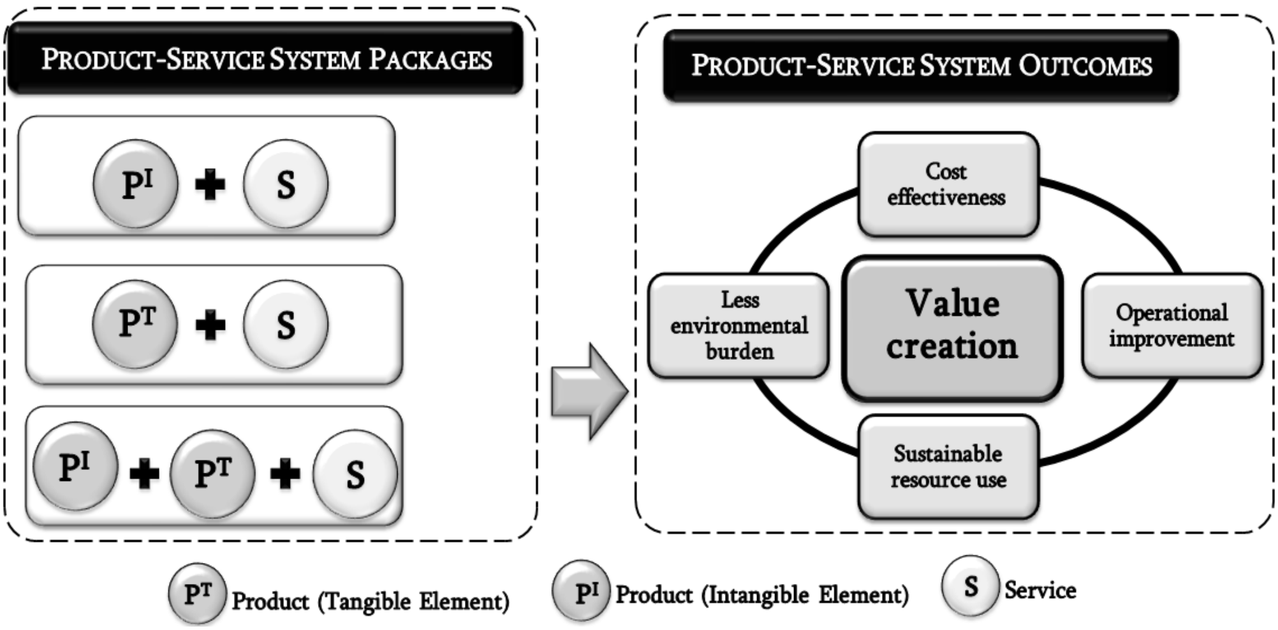

Figure 3: Product-Service System Packages and Outcomes.

product core (e.g. tank), however, due to performance requirements additionally the intangible product content is delivered (e.g. availability or equipment related data), while the performance requirements are further supported through the delivery of services (e.g. maintenance).

In terms of the outcomes of these packages, a PSS is delivered with the objective of achieving the desired value proposition. Thus, the ultimate goal centres on value creation for the customer. The value creation may vary across industries driven by differences concerning customer needs (e.g. cost, environmental or performance driven challenges). However, there are many more potential benefits that a PSS can offer, driven by the orientation of an industry towards environmental burden reduction, enhancing efficiency in processes or both. Although the two due are correlated aspects, the outcomes do not have to in the same manner. Furthermore, these approaches may in common produce cost effectiveness and sustainable resource use. Thus, the outcomes of PSS are rather interlinked, whilst involving social as well as motives that benefit companies. In alignment to the listed potential benefits of PSS there is a need to consider risks that arise from developing delivery packages. These may have an influence over achieving customer needs. The sources of risks in PSS, in integrating product and service, may originate from the supply chain (e.g. delivering spare parts), internal operational effectiveness (e.g. communication between departments), or the customer (e.g. equipment misuse).

6 FUTURE RESEARCH NEEDS AND CHALLENGES

The delivery of products and services that meet customer needs is a complex task that involves considerations for a wide range of issues such as affordability, production schedules and product storage. These considerations are required to ascertain that the customer can support projects through whole life cycles [29]. In industry, the need to balance commercial value for companies and added value for customers is also a major factor that encourages integrating products and services.

For the delivery of integrated products and services in a PSS, networks in industry can aid companies in entering partnerships to better meet customer needs. An industrial classification such as the ICB when applied in the context of a PSS offers opportunities for data collation and sector analysis. This enables a company to form links with other industrial partners for PSS delivery so as to share information, manage supply chains and improve delivery performance.

Furthermore, product and service characteristics can be analysed by a company and used for configuring product-service ‘bundles’ or ‘packages’ for creating value. The packages selected by the company may be based on capability of the company, market trends, industry forecast or even available resources. This could enable companies to scope, manage flows and interactions, and carry out design and delivery functions for a PSS.

6.1 Product-Service Systems Scoping

As mentioned earlier, the organisation of a PSS involves the identification of possible *scenarios* for actors and their roles. The actors involved in a PSS design and delivery are usually the customer, solution provider as well as the supply chain. The role of the customer is crucial in the design of PSS in terms of identifying a need (customer requirement) which creates the demand as well as the procurement and support (financing) of the PSS, usually after delivery. The financial ability of the customer to afford the PSS solution throughout its lifecycle is of important consideration when scoping the PSS [29]. The customer can also collaborate with the solution provider to co-create value in the PSS solution. The solution provider is also an important actor that may assume the role of capturing and transforming the user requirement into design requirement for implementation in the PSS solution. This is illustrated in Figure 2 where Company A the solution provider, works in partnership with Companies B, C and D to deliver a PSS solution to the customer. Companies B, C and D are suppliers to Company A and their role is also important in providing expertise, know-how and other resources required to deliver the PSS solution to the customer.

Also scoping for a PSS involves considering the *context* for business operations (B2B vs. B2C). Generally more research has been done to capture the scope of PSS within the B2B [23]. Existing research focuses on organisations’ view of PSS while there is a need for more empirical studies into the view of individual consumers about PSS. Existing research has revealed some important factors for consumer acceptance of PSS which includes, perceived advantages compared to alternatives, perception of fixed and variable costs, insight in total life-cycle costs, uncertainty, risk, and relationship between customer and supplier. While the factors that influence the affordability of an individual consumer would differ from those influencing the business customer, [29] suggested that a common factor to both categories of customers is their income or revenue. In order to design a PSS solution that would deliver value to the customer and provide suitable financial return to the solution provider, it is important to ensure that the scope of the PSS encompasses the customer need as well as the customer’s affordability.

As shown in Figure 1, the ICB approach classifies companies (PSS solution providers) into various industries and sectors. Based on this classification an overview of the scope of PSS has been provided in Table 1. Consequently, PSS solutions can be provided in every industry mentioned within the ICB and it would be useful for PSS providers to investigate the nature of PSS solutions within and outside their sectors. This would expand their scope and help to identify synergies in operations as they collaborate to provide higher value to the customer, improve their own business processes and facilitate knowledge sharing to help generate better financial return.

6.2 Intra- and Inter-Sector Flows and Interactions

Using the approach provided in Figure 2, a PSS could be designed and delivered by a single company or based on relationships between companies. In addition, relationships to deliver a PSS may be formed between two or more companies within a single industry sector or across two or more industries.

Subsequently, rules and policies that govern the *flow* of materials, products, services and information between these companies are an important issue that require research within the context of a PSS. As an example, information flow research for inter-sector flows could consider how business and technical information are accessed and exchanged between companies and customers in a PSS.

Furthermore, considerations for communication and information flow could also be made prior to entering industry relationships with companies. These considerations are important to ensure product-service systems are correctly configured to deliver customer solutions. For instance, if two companies A and B decide to form a partnership, common representations and communication schemes are required. If company A applies face-to-face interaction and company B relies on electronic mail to communicate with customers, then a consensus must be made as to a common means for interacting with customers. A failure to reach a consensus could result in a conflict of interest or conflict between organisations and personnel.

Another possible area for future research could look at the factors that determine how companies within the context of a PSS, *interact* within and outside their sectors. Possible topics may consider factors such as organisational culture [30], self-organisation [31] and organisational learning [32]. Organisational culture refers to ethics, habits and behaviour patterns of organisational members. These ethics, habits and behaviour are motivated by the configuration of the organisation and contribute to the performance of the organisation. Self-organisation describes a constantly changing and modification process that allows a system to internally maintain its structure. Organizational learning describes the learning process of individuals within an organisation whereas a learning organisation means the ability of an organisation to learn as a total system.

6.3 PSS Design and Delivery

A main goal of a PSS will be to make use of available resources to attain and maintain the competitiveness of the company. This is because, no matter which industry is considered the design and delivery of PSS requires consideration for the integration of products and services to for the life cycle of the product. Furthermore, the drivers of adopting product-service systems across industry is also constant, which include ecological or environmental motives, or economic (e.g. competitive advantage and profitability) or social reasons (e.g. generation of knowledge). Other factors that affect the delivery of PSS solutions to customers include: affluence, education, technology, value of time, customer expectation, and competition [33].

It is also interesting to note that conceptually the steps to integrate products and services are similar. For instance, for services, typically, the design process begins with concept development, which is followed by system design, testing and implementation. On the other hand, product design begins with identification of customer needs, followed by specification of requirements, concept design and detailed design that ends with testing [34].

In terms of PSS design and delivery, differences across sectors may arise from a number of areas.

Firstly, the degree of product and service *content* may vary driven by customer needs. This requires adaptation of the material (e.g. components) that is considered, as well as the degree of customer willingness to transfer responsibilities to suppliers in the operational phase. This relates to the customers ambition to transfer risks and uncertainties, which hinder the performance of the PSS delivery. The sources of uncertainties may relate to the customer (e.g. requirements) as well as supply based issues that may be related to internal (e.g. processes) or external (e.g. supply chain) matters to industry. This challenge is particularly driven by the dynamic nature of drivers that affect the delivery. Thus, there is a need for processes that enable continuous management of uncertainty in PSS delivery, while the design process needs to consider scenarios that build flexibility to the delivery. Consequently, PSS processes will need to support the identification, prioritisation and management of uncertainties. At this point, recognition of differences between sectors will be necessary, in order to customise approaches.

Differences between PSS design and delivery across sectors could also arise from a *financial perspective*. For instance, the price of the product and service combination and the means for funding varies across sectors depending on the characteristics of the products and services in the PSS solution. This influences the development of the PSS in terms of the time it takes to build and the quality of the parts that are used.

Another difference between PSS design and delivery across industries and sectors relates to the *length of the life cycle*. For instance, there are differences between the nuclear industry and automobile industries driven by the length of the life cycle. The interaction across the supply network is also an area that differs across sectors. This involves understanding the structure of a sector (e.g. monopoly). Such information could act as guides for understanding the interaction over the life cycle of products. This may influence issues such as capability, obsolescence. A final difference across sectors may arise from the abilities to achieve flexibility in delivering customer needs along the product life cycle. This means that some industries are less flexible (e.g. defence) compared to others (e.g. automobile), due to financial and technical constraints.

7 SUMMARY

A product-service system (PSS) is a business model that offers a generic approach to delivering products and services in configurations that provide functionality, availability or results to customers. This delivery process is dependent on the characteristics of the products and services provided. Using the Industry Classification Benchmark (ICB), examples of products, services and product-service systems across industry sectors were highlighted.

Driven by this classification, this paper has attempted to propose an approach to aid the delivery of product-service systems across industries and industry sectors. The approach is made up of two main parts. First, a description of industry relationships and networks that define at an organisational level, how actors, roles and scenarios can be configured to deliver a PSS. Secondly, an outline for delivery packages that detail how products and service can be combined for PSS solutions.

Possible areas and challenges for future research were identified and discussed in terms of: differences arising from the scoping of activities for PSSs, intra- and inter-sector flows and interactions, and design and delivery of product-service systems across industries and industry sectors.

8 ACKNOWLEDGMENTS

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9 REFERENCES

[1] Durugbo, C., Tiwari, A. and Alcock, J.R., 2009, An Info-dynamic Engine Approach to Improving the Efficiency of Information Flow in a Product-Service System in Proceedings of the 1st CIRP IPS2 Conference, Cranfield: 107-112.

[2] Mont, O.K., 2002, Clarifying the concept of product-service system, Journal of Cleaner Production, 10 (3): 237-245.

[3] Morelli, N., 2009, Service as value co-production: reframing the service design process, Journal of Manufacturing Technology Management, 20(5): 568 – 590.

[4] Baines, T., Lightfoot, H.W., Evans, S., Neely. A., Greenough, R., Peppard, J., Roy, R., Shehab, E.,

Braganza, A., Tiwari, A., Alcock, J.R., Angus, J.P., Bastl, M., Cousens, A., Irving, P., Johnson, M., Kingston, J., Lockett, H., Martinez, V., Michele, P., Tranfield, D., Walton, I.M. and Wilson, H., 2007, The state-of-the art in Product Service Systems, Proceedings of the I MECH E Part B Journal of Engineering Manufacture, 221(10):1543-1552.

[5] Tukker, A., 2004, Eight types of product-service system: eight ways to sustainability? Experiences from SusProNet, Business Strategy and the Environment, 13(4):246-260.

[6] Morelli, N., 2006, Developing new product service systems (PSS): methodologies and operational tools, Journal of Cleaner Production, 14(17): 1495-1501.

[7] Manzini, E., Vezzoli, C., 2002, Product-service systems and sustainability: Opportunities for sustainable solutions. UNEP TIE, Paris. Available at: http://www.uneptie.org./scp/design/pdf/pss-imp-7.pdf. Accessed 15 May 2009.

[8] Becker, J., Beverungen, D. and Knackstedt, R., 2008, Reference Models and Modeling Languages for Product-Service Systems Status-Quo and Perspectives for Further Research, Proceedings of the 41st Annual Hawaii International Conference on System Sciences: 105 – 105.

[9] Ulrich, K.T. and Eppinger, S.D., 2003, Product Design and Development 3rd Edition. McGraw-Hill, USA.

[10] Roozenburg, N.F.M. and Eckels, J., 1995, Product design: fundamentals and methods, Wiley, Chichester

[11] Tarasewich, P., Nair, S.K., 2001, Designer-moderated product design, IEEE Transactions on Engineering Management, 48 (2): 175-188.

[12] Theodore, L., 1981, Marketing Intangible Products and Product Intangibles, Harvard Business Review. Boston: May/Jun 59, (3): 94 – 103.

[13] Zeithaml, V. A., 1988, Consumer perceptions of price, quality, and value: a means-end model and synthesis of evidence. Journal of Marketing, 52: 2–22.

[14] Zeithaml, V. A., and Bitner, M. J., 1996, Services marketing. McGraw-Hill, USA.

[15] Gallarza, M.G. and Saura, I.G., 2004, Value dimensions, perceived value, satisfaction and loyalty: an investigation of university students, travel behavior. Tourism Management, 27: 437–452

[16] FTSE (2009), The Industry Classification Benchmark, http://www.ftse.com/Indices/Industry_Classification_Benchmark/index.jsp Accessed 22 October 2009

[17] Kozak, M., Rimmington, M., 1998, Benchmarking: destination attractiveness and small hospitality business performance, International Journal of Contemporary Hospitality Management, 10(5):184-188.

[18] Smith, G.A., Ritter, D. and Tuggle, W.P. (1993), Benchmarking: the fundamental questions, Marketing Management, 2 (3): 43-8.

[19] Malakata, M., 2007, Electronic banking prepares the way for e-commerce in Zambia, ICT Update, Financial services, Issue 36: April 2007.

[20] Ajai, O., Tiwari, A. and Alcock, J.R., 2009, Informatics-Based Product-Service Systems for Point-of-Care Devices, Proceedings of the 1st CIRP Conference on Industrial Product Service Systems, 94-99.

[21] Evans, S., Partidario, P.J. and Lambert, J., 2007, Industrialization as a key element of sustainable product-service solutions, International Journal of Production Research, 45 (18–19): 4225–4246.

[22] Tasaki, T., Hashimoto, S. and Moriguchi, Y., 2006, A quantitative method to evaluate the level of material use in lease/reuse systems of electrical and electronic equipment, Journal of Cleaner Production, 14 (17): 1519-1528.

[23] Rexfelt, O. and Ornas, V.H., 2009. Consumer acceptance of product-service systems- Designing for relative advantages and uncertainty reductions, Journal of Manufacturing Technology Management 20(5): 674-699.

[24] Erkoyuncu, J.A., Roy, R., Shehab, E. and Wardle, P., 2009, Uncertainty challenges in service cost estimation for products-service systems in the aerospace and defence industries, Proceedings of the 1st CIRP IPS2 Conference, Cranfield: 200-206.

[25] Wirtz, B.W., 2001, Reconfiguration of value chains in converging media and communications markets Long Range Planning, 34 (4): 489-506.

[26] Neely, A., 2009, Exploring the financial consequences of the servitization of manufacturing, Operations Management Research, 1: 103-118.

[27] Tukker, A. and Tischner, U., 2006, Product-services as a research field: past, present and future. Reflections from a decade of research, Journal of Cleaner Production, 14 (17): 1552-1556.

[28] Ng, I., Guo, L., Scott, J. and Yip, N., 2008, Towards a benefit-based framework for understanding B2B services and its impact on contract and capability, Proceedings of the 10th International Research Seminar in Services Management, 27-30 May 2008, La Londe, France:

[29] Bankole, O.O., Roy, R., Shehab, E. and Wardle, P., 2009, Current Practice in Affordability Assessment of Product-Service Systems within the Aerospace and Defence industries, Proceedings of the 1st CIRP IPS2 Conference, Cranfield: 230-237.

[30] Awad, M.F.C., 2008, Information field complements information flow paradigm in getting requirements of networked information systems, 3rd International Conference on Information and Communication Technologies: From Theory to Applications, ICTTA, art. no. 4530319.

[31] De Wolf, T. and Holvoet, T., 2007, Designing self-organising emergent systems based on information flows and feedback-loops, First International Conference on Self-Adaptive and Self-Organizing Systems, SASO 2007, art. no. 4274916:295-298.

[32] Levine, L. and Monarch, I., 1998, Collaborative technology in the learning organization: Integrating process with information flow, access, and interpretation, Proceedings of the Hawaii International Conference on System Sciences, 1:444-459.

[33] Rajkumar, R. and Cheruvu, K., 2009, A competitive framework for Industrial Product Service Systems, International Journal of Internet Manufacturing and Services, 2(1): 4 - 29.

[34] Alonso-Rasgado, T. and Thompson, G., 2006, A rapid design process for total care product creation, Journal of Engineering Design, 17(6):509-31.

A New Approach to Executive Information Management as Part of IPS² Lifecycle Management

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Abstract

The characteristics of IPS² pose new challenges to top managers in IPS² enterprises. However, current commercial EIM systems mostly focus on finance and business operations. In this paper introduced is a new approach to Executive Information Management (EIM), based on an IPS² Lifecycle Management (LM) system. It offers top managers an integrated IT environment about offered IPS², and thus has the potential to enhance their work. The approach, the IT architecture, and the meta-information model for IPS² lifecycle management are explained in detail.

Keywords

Executive Information Management (EIM), IPS², Lifecycle Management

1 INTRODUCTION

The main characteristics of the Industrial Product-Service Systems (IPS²), the close interaction between providers and customers and the high change dynamics during the delivery and use phase, pose new challenges to top managers, e.g. more complex decision-making processes and new IPS²-related decision tasks in comparison to pure products or services[1]. As top managers' existing experiences cannot be fully used to make IPS²-related decisions, they urgently need a suitable Executive Information Management (EIM) system to support their work. Unfortunately, current commercial EIM systems mostly focus on financial information and business operations, and thus cannot fully meet the requirements of top managers in IPS² enterprises [2-5]. In these companies, many commercial IT enterprise applications (such as ERP, PDM, SCM, CRM, etc.) are deployed at operational and tactical levels. Only with a few of them special modules are available to meet the information demand of top managers, but these special modules can only integrate and analyze the data, which is stored in single systems. Top managers of IPS² providers cannot obtain comprehensive IPS²-related information from these single IT systems. Generally, the EIM system for IPS² providers should include all IPS² data along its entire lifecycle and should provide top mangers with the right IPS² data for supporting IPS²-related decision-making at the right time.

Due to these IPS² characteristics mentioned above, the Lifecycle Management (LM) system for IPS² has been extended to cover all phases along the IPS² lifecycle. Classical PLM systems only cover value-added processes with a focus on product development and manufacturing [6-8]. Thus, the IPS²-LM system manages all planning, development, delivery/use and also recycling data of IPS² [9, 10]. These data can be used not only for operational engineering tasks, but also for IPS²-related decision-making of top managers.

This paper introduces a new approach for an Executive Information Management (EIM), based on an IPS² Lifecycle Management system. As an extended part of the IPS²-LM system, the EIM module can seamlessly access all IPS² data that is stored in the IPS²-LM system. In addition, relevant data from ERP, CRM, SCM and other data sources are also needed. By acquiring, integrating, analyzing and visualizing executive information, the EIM module offers top managers an integrated information environment about IPS² for IPS²-related decision-making and controlling.

2 REQUIREMENT ANALYSIS OF THE EIM MODULE FOR IPS² PROVIDERS

2.1 Definition of EIM system

The idea of EIM systems was first enunciated by Rockart and Treacy in the early 1980s [11]. The initial definition of an EIM system was an information support system for top managers. The scope of EIM systems has evolved in the last 30 years. The meaning and tasks of EIM systems have been greatly extended. The latest definition of an EIM system was given by Klaus Ballensiefen [3] in 2002:

"An EIM system is a company-specific and dynamic information support system, based on various internal and external data, which is used to supply flexible support information to top managers with a high operating comfort."

According to this definition, an EIM system is not common software, but company-specific or field-specific software. Thus, a careful requirement analysis is the key to its successful development. The first step in developing an EIM system is to take into account the specific information requirements of top managers in various areas [12]. Secondly, executive information is gathered from various sources and conforms to the characteristics of the work of top managers. On a single day, a top manager is involved in a variety of tasks, e.g. meetings, appointments, business negotiations, report-reading and decision-making [13]. These tasks always require an overall support of useful information. Thirdly, EIM systems only provide information support to top managers, but they do not provide decision models. How to use the data and how to make a decision are still the responsibilities of top managers. Finally, the interface of an EIM system must be very intuitive and easy to use.

2.2 IPS²-related information for top managers of IPS² providers

The core problem for a top manager of an IPS² provider is how he or she can optimize the structure of IPS² and improve customer satisfaction in order to make long-term profits, while in classical industrial enterprises the main goal of top managers is to maximize profit in a financial year. The great change of the main goal leads top managers of IPS² providers to pay more attention to IPS²-related information. Raw EIM data can be gained inside and outside IPS² enterprises, and then processed and visualized to meet the new information requirements of top-managers of IPS² providers. The categories of IPS²-related data can be defined as follows:

- IPS² component data (e.g. up to date status of IPS² and different IPS² components, data of IPS² structure)
- IPS² process data (e.g. status of IPS²-processes, implementation and release status of IPS², time interval between two releases)
- IPS² project data (e.g. allocation of staff in projects or project phases, demands on resources for IPS²-projects, schedule of IPS² projects)
- IPS² staff data (e.g. age, ability, skills, training and performance appraisal of IPS² staff)
- IPS² customer data (e.g. the number of change requests from customers, application data of IPS² by customers)
- IPS² IT system data (e.g. investment of IT systems for IPS², number or errors of system downtime)
- IPS² external data (e.g. data about competitors, market, economy and politics)

These IPS² data can be extracted from different IT systems, which have already been applied in IPS² enterprises. But the same type of data can be distributed in different IT-systems, e.g. IPS² customer data are distributed and stored in HLB-LM and CRM (Customer Relationship Management). Thus, comprehensive data about a special topic cannot be obtained from a single data source. So, the EIM module for IPS² provides a powerful, dynamic data processing module (see chapter 4). It is designed to compress, aggregate and analyze EIM data, which is extracted from different data sources.

2.3 Functional requirement of EIM from top managers of IPS² providers

Upon extensive research and empirical studies, three main functions have been found to help top managers of IPS² providers make IPS²-related decisions. They are: IPS² monitoring, IPS² analysis and reporting.

- IPS² monitoring

The aim of IPS²-monitoring is to offer top managers integrated information on a dashboard to monitor and control statuses and processes of IPS², IPS²-components and other IPS²-related resources.

- IPS² analysis

The function of IPS²-analysis is designed to predict the future development of IPS² by means of mathematical methods and based on existing IPS² data and important external data. The forecast results will be taken as important references for IPS²-related decision-making.

- Reporting

The aim of reporting is to automatically provide top managers with the right reports at the right time according to their demand. Thereby, unnecessary reports are avoided and the time for preparing the reports is greatly decreased.

3 IPS²-METRIC SYSTEM FOR EIM

As previously stated, on a single day, a top manager may deal with various IPS² tasks. The character of these tasks is discrete. There is no or very little relation between them. The paper in hand introduces a metric system (see figure 1) to externalize the information requirement of top managers and to supply exact data to support these discrete tasks. Each information demands of their task can be abstracted to several indicators automatically or manually by their assistants. The EIM module provides them with information support by supplying exact data to IPS²-metrics.

On the basis of the categories of IPS²-related data, 7 types of IPS²-metrics can be distinguished:

- IPS² character indicators (e.g. amount of engineering change per IPS² module, share of products and services in IPS², share of standard components in IPS²)
- IPS² process indicators (e.g. processing time of single process step, share of productive process steps in total IPS²-LM, reaction time of customer changes)
- IPS² project indicators (e.g. adherence to schedule of single project phase, assignment of staff in projects)
- IPS² staff indicators (e.g. staff productivity, failures per staff, adherence to schedule)
- IPS² customer indicators (e.g. amount of customer satisfactions and reclamations)
- IPS² IT system indicators (e.g. downtime of IT systems, availability of IT systems)
- IPS² external indicators (about competitors, market, economy, politics, etc.)

According to methods of data processing and data features of indicators, IPS² metrics can further be divided into four types:

- Direct indicators

Data of direct indicators (e.g. adherence to schedule, amount of engineering change) is directly stored in clear data sources. After extraction from data sources these indicators can be displayed to top managers in a user-friendly format.

- Statistical indicators

Data of Statistical indicators (e.g. share of products and services in IPS²) have clear data sources and can be obtained by calculation with suitable statistical methods.

- Summary indicators

Summary indicators (e.g. staff productivity, availability of IT systems) reflect the status of IPS² by point or grade (e.g. 0 to 9), but not the direct description of raw data. The point or grade is given depending on raw EIM data and according to special standards or experiences.

- Event indicators

The term event indicator (e.g. important market change, important events of competitors) describes important events related to IPS². Their abstracts are given directly in EIM. Thus, top managers can easily obtain the context of event indicators.

Hence, each IPS² metric has two classification attributes: Classification by data type can fix its data source. Classification by data processing can fix the data processing method of its raw data. According to these two attributes, raw data and processing method of each indicator become clear.

4 DATA PROCESSING METHOD OF EIM MODULE

Raw EIM data extracted from various systems can be stored in different formats and may have redundancies,

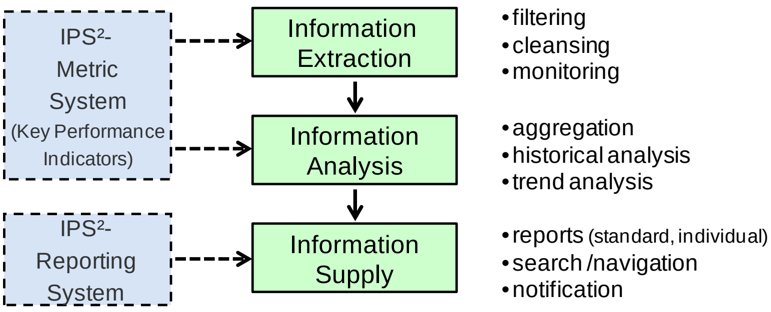

Figure 1: Three-layer structure of data processing method

conflicts, errors, and gaps. The paper in hand introduces a three-layer data processing method designed to process raw EIM data and supply exact data to different indicators with different densities and formats (see figure 1). The three layers are: information extraction, information analysis and information supply.

In the layer of information extraction, data filtering and cleansing are the standard processes to all raw EIM data. They are implemented to obtain cleansed data free of redundancies and errors. As direct indicators do not require further processing, values of direct indicators can be obtained upon information extraction. Most direct indicators related to IPS² are used to monitor the situation of IPS² and to meet the requirements of the IPS² monitoring for top managers.

In the layer of information analysis, choices of method of data processing depend on the attributes of IPS²-indicators. For example the value of indicator "share of products and services in IPS²" can be obtained by simple statistical methods. The most important duties of information analysis are listed as follows:

- Calculation of values of indicators
- Comparison between actual values of indicators and their given values
- Comparison between actual values of indicators and existing benchmarks (e.g. of competitors)
- Historical analysis of progresses
- Trends analysis of IPS² and IPS² processes

These methods of information analysis can process complex data of indicators and realize the function of IPS² analysis in the EIM module.

The layer of information supply provides methods of data visualization. The IPS²-reporting system is introduced to configure, create and display standard and individual reports, which top managers require. Here, a search/navigation portal can be realized based on processed IPS² data, to provide IPS² information according to the entered keywords.

5 THE IT STRUCTURE OF THE EIM MODULE FOR IPS² PROVIDERS

Figure 2 provides an overview of the IT structure of the EIM module, which is an extended part of IPS²-LM basic methods.

There are two types of data sources: structured data sources and unstructured data sources. They are defined as follows:

- Structured data sources

Sources for structured data are all sorts of database

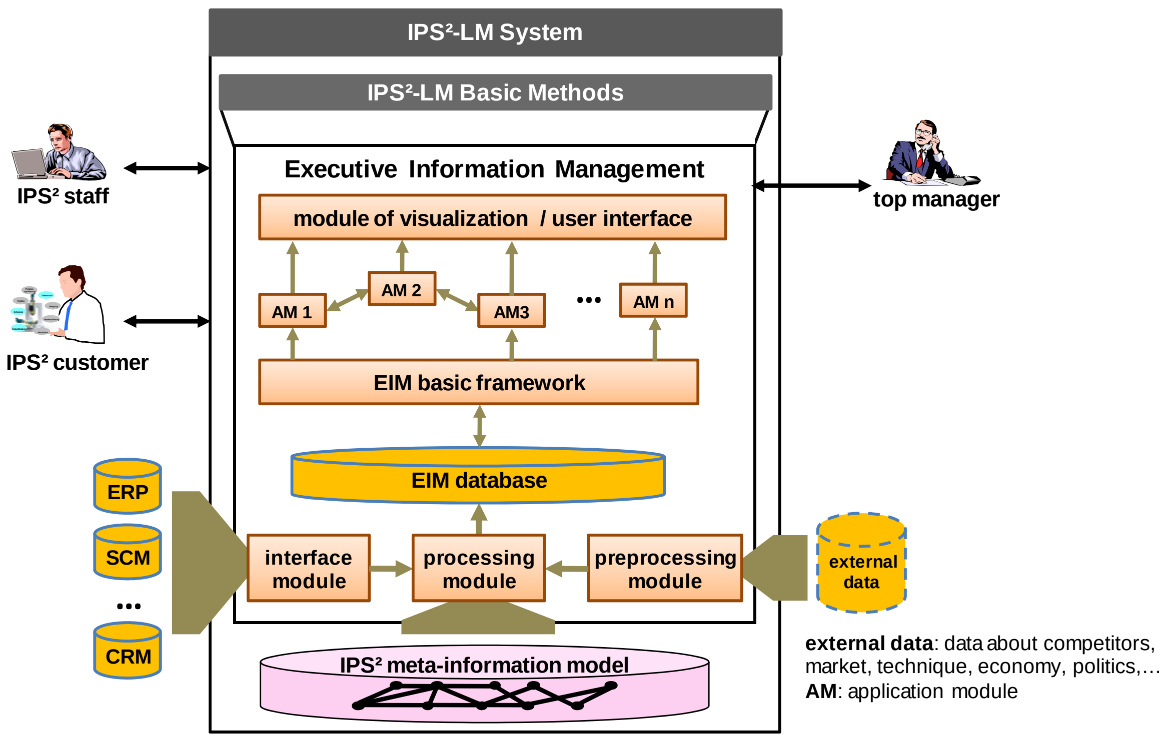

Figure 2: The IT structure of the EIM module for IPS² providers

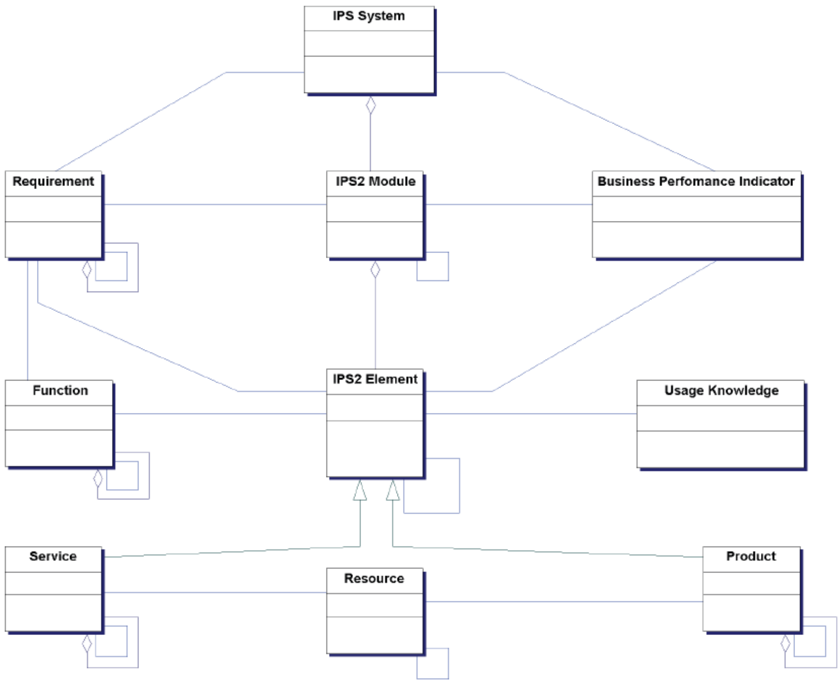

Figure 3: Top level of meta-information model for IPS² lifecycle management

systems in IPS² enterprises. Databases in IPS²-LM, ERP, CRM, etc. are all concrete sources. The extraction of data from concrete sources can be automatically implemented with the help of a special program. In the IT structure, interface modules are designed to process the data from these sources. While the EIM module is an extended part of IPS²-LM, data in the IPS² meta-information model can be processed directly without the need of an interface module.

- Unstructured data sources

Unstructured data sources exist inside or outside IPS² enterprises, but data are not stored in a database system. The process of gaining and handling such data is rather complex. Thus, a preprocessing module is designed to extract and preprocess the data semi-automatically or manually.

While data extracted from different sources have different formats, there are a lot of redundancies, errors, and gaps between them. Thus, the extracted data must be further processed and integrated. For that purpose, a processing module has been designed. The interface module, the preprocessing module and the processing module constitute the information extraction as introduced in chapter 4. After that, an EIM database was designed to store the extracted EIM data. The independent EIM database can highly contribute to the reuse of data und can increase the speed of data access.

In the software structure, the EIM system framework is used to access data in the EIM database and to manage all application modules. Application modules are designed to realize one or several IPS² indicators. Each application module can be adjusted, modified, added and deleted dynamically to meet the new requirements of IPS² indicators for top managers. On the other hand, an application module can be designed that is based on a different application module or that uses the results of other function modules. The interface module is designed to realize the user-friendly interface and to visualize the result in property format. In general, the EIM software framework, all application modules and the module of visualization realize the function of information analysis and information supply.

User groups are another essential part of a system. Here, top managers constitute the most important user group, but there are other important user groups. They are IPS² staff (e.g. IPS² project managers, IPS² developers, IPS² service engineers) and IPS² customers. Although they have not enough authority to access the EIM module directly, they can access IPS²-LM with respective authorities. As a part of IPS²-LM, EIM module can exchange data with IPS²-LM seamlessly. So IPS² staff and customers can gain EIM data by the transport of IPS²-LM. Then the decisions made by top managers in EIM module can reach managers, IPS² developers and engineers in IPS² enterprise and also IPS²-customers via the IPS²-LM software.

6 META-INFORMATION MODEL FOR IPS² LIFECYCLE MANAGEMENT

Upon extensive research and empirical studies, most raw IPS²-related data are stored in the IPS² meta-information model, and required by most IPS²-related indicators. So IPS² meta-information model is very important to the EIM model and is introduced in this chapter.

For the lifecycle management of IPS² a meta-information model has been developed within the research project Transregio 29 "Industrial Product-Service Systems – Dynamic Interdependency of Product and Service in the Production Area". It is based on the UML (Unified Modelling Language) object-oriented notation. Figure 3 shows the top level structure of the IPS² meta-information model. In order to make the model more simple, obvious classes for data management and subclasses of each main class have been omitted.

Each IPS² is represented by the class IPS_System, which consists of several IPS2_Modules. In turn, IPS2_Module is composed of different IPS2_Elements, which may be Services or Products. The class IPS2_Element is an abstract class that is never instantiated. In order to support the IPS² engineering process, a few classes are introduced: Resource, Function, Usage_Knowledge, Business_Performance_indicators and Requirement. These five classes can be associated with individual IPS_Systems, IPS2_modules, Services, and Products. A comprehensive description of IPS² classes and relations mapping in the meta-information model has already been presented in a previous paper [15].

7 CONCLUSIONS AND OUTLOOK

The new approach to the EIM module presented above is based on a variety of empirical studies that were conducted with several IPS² providers. In the EIM module, the IPS² metric system and data processing methods ensure the supply of executive information and its correctness. A dynamical system structure of the EIM module ensures sufficient flexibility to meet flexible information requirements of top managers. As a part of IPS²-LM system, it reduces the difficulty of developing the EIM module. The integration of the EIM module can extend the use range of the IPS²-LM system from engineers to top managers.

Though an EIM system can provide all IPS²-related information to top managers, other managerial tasks are not considered, e.g. HR management, strategic planning and investment. Fortunately, the dynamical IT structure ensures the extension of the EIM module. Other functions and information can be added and improved during its use phase. The ultimate goal is to develop a comprehensive IT environment for top managers in IPS² enterprises.

8 ACKNOWLEDGMENTS

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9 REFERENCES

[1] Abramovici, M., Michele, J., Neubach, M., 2008, Erweiterung des PLM-Ansatzes Für Hybride Leistungsbündel, In: ZWF, Carl Hanser Verlag, 103: 619-621

[2] Ballensiefen, K., 2000, Informationsplanung im Rahmen der Konzeption von Executive Information System (EIS), Josel Eul Verlag, Köln

[3] Nandhakumar, J., 1996, Executive Information System Development: a Case Study of a Manufacturing Company, Journal of Information Technology, 11:199-209

[4] Leidner, D., Elam, J., 1994, Executive Information Systems: Their Impact on Executive Decision Making, Journal of Management Information Systems, 10:139-155

[5] Friend, D., 1994, Executive Information Systems: Successes, Failures, Insights, and Misconceptions, Decision Support and Executive Information Systems, Prentice-Hall, New Jersey

[6] Jörg Feldhusen. J., Boris Gebhardt. B., 2008, Product Lifecycle Management für die Praxis: Ein Leitfaden zur modularen Einführung, Umsetzung und Anwendung, Springer, Berlin

[7] Abramovici, M., Schulte, S., 2007, Study “Benefits of PLM – The Potential Benefits of Product Lifecycle Management in the Automotive Industry”, IBM BCS, Detroit.

[8] Abramovici, M.; Schulte, S., 2007, PLM – Neue Wege zu kundenorientierten Produkten und Dienstleistungen, CAD-CAM Report, 6

[9] Aurich, J.C., Schweitzer, E., Fuchs, C., 2007, Life Cycle Management of Industrial Product-Service Systems, 14th CIRP Internationalal Conference on Lifecycle Engineering (LCE 2007), Tokio, Japan, 11-13: 171-176.

[10] Abramovici, M.; Schulte, S., 2006, Lifecycle Management für hybride Leistungsbündel (HLB), Werkstattstechnik online, Springer, Düsseldorf

[11] Rockart, J.F., Treacy, M.E., 1982, The CEO goes Online, Harvard Business Review

[12] Lungu, I., Bara, A., 2005, Executive Information Systems Development Lifecycle, Economy Informatics, 1: 19-22

[13] Wang, S.Z., 1999, Research on Executive Information System (EIS) for Enterprises, Jiantong University Xi´an, Xi´an

[14] Burkan W.-C., 1994, Making EIS Work, Decision Support and Executive Information Systems, Prentice-Hall, New Jersey

[15] Abramovici, M., Neubach, M., Schulze, M., Spura, C.,2009, Metadata Reference Model for IPS² Lifecycle Management, Proceedings of the 1st CIRP IPS² Conference, Cranfield, UK, 268-272.

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Manufacturers in developed countries today regard services as increasingly important. Some manufacturing firms are strategically shifting from a "product seller" towards a "service provider". In this context, the Industrial Product-Service Systems (IPS^2) and its way of development provide opportunities for companies and their customers to design more innovative solutions. The proceedings show the cutting edge of research and development in the area including new concepts, models, methods, and tools for the successful development of IPS^2.

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- PSS design
- PSS education and training
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- PSS in the business-to-customer industry
- PSS management
- PSS manufacturing
- Quality management for PSS
- Service engineering
- Service infusion
- Strategy for PSS
- Sustainability through PSS

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