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

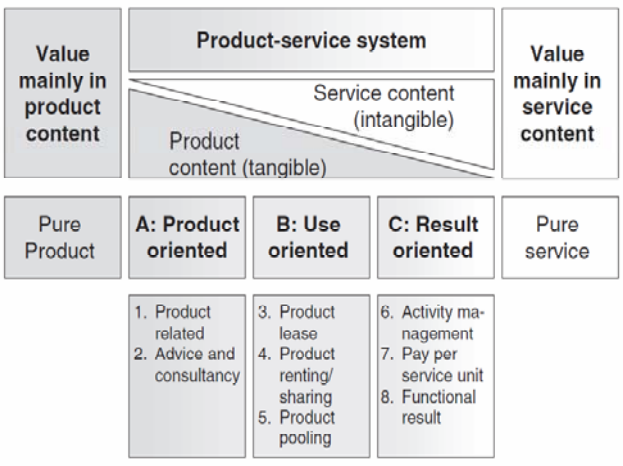

Figure 1: Eight types of PSSs [1]

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.

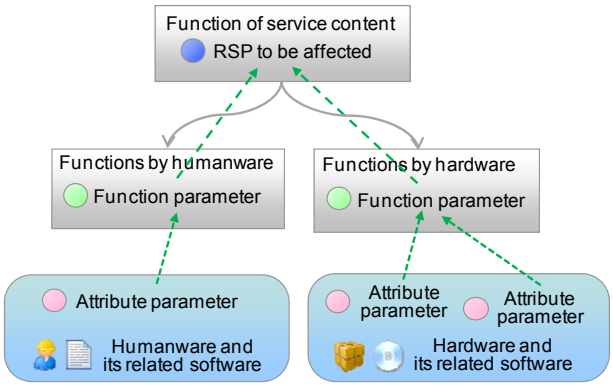

Figure 2: Proposed modular representation of PSS

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	Product renting/sharing	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
5	Product pooling	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.

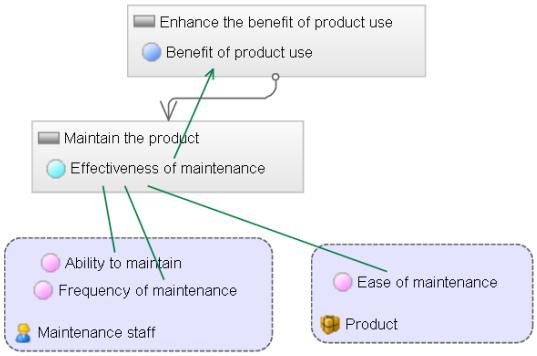

Figure 3: Product-related service for the RSP "benefit of product use."

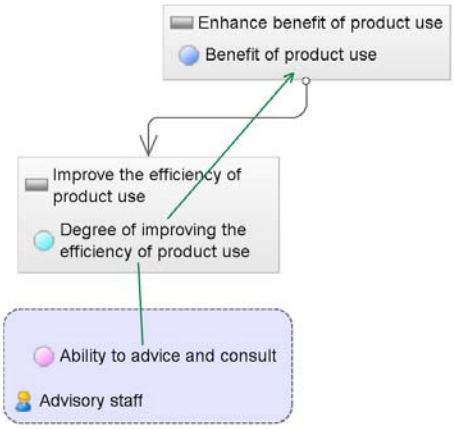

Figure 4: Advice and consultancy service for the RSP "benefit of product use."

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.

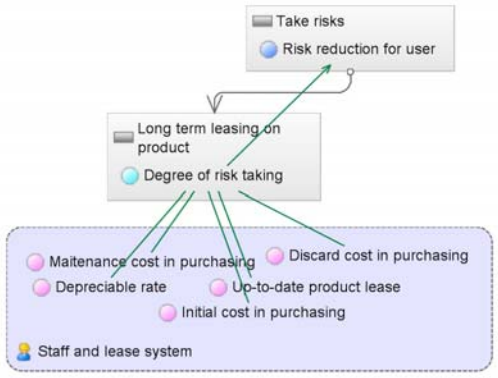

Figure 5: Product lease service for the RSP "risk reduction" for user.

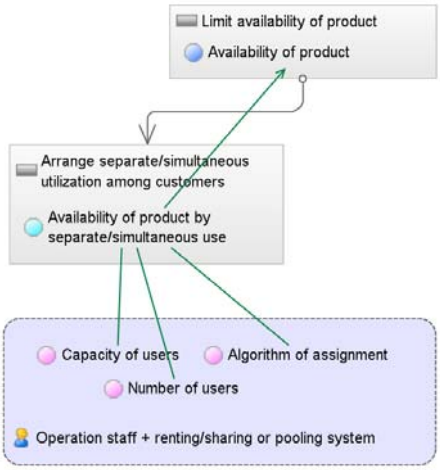

Figure 6: Product renting/sharing and product pooling service for the RSP "availability of product."

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.

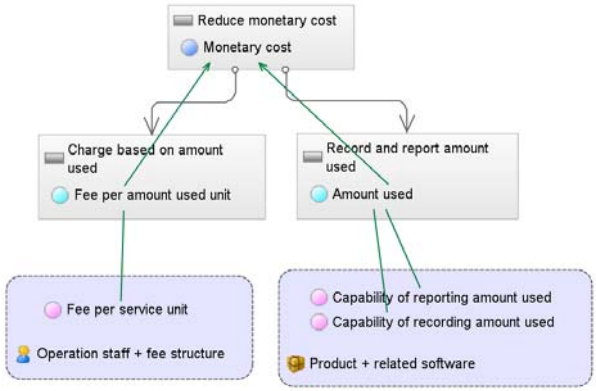

Figure 7: Pay per service unit for the RSP "monetary cost."

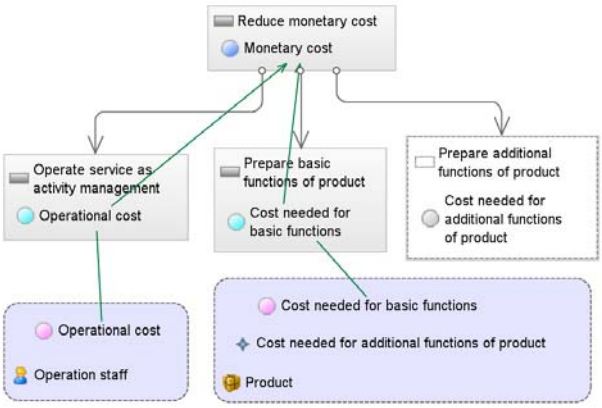

Figure 8: Activity management service for the RSP "monetary cost."

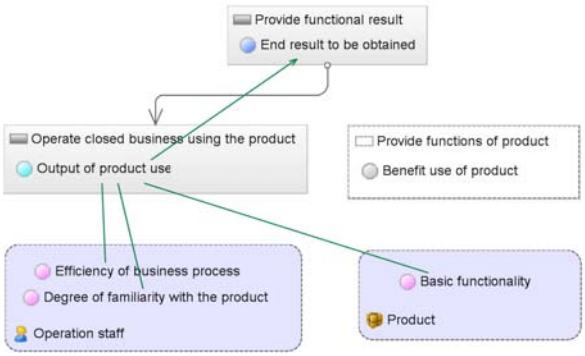

Figure 9: Function result service for the RSP "end result to be obtained.""

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]).

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