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

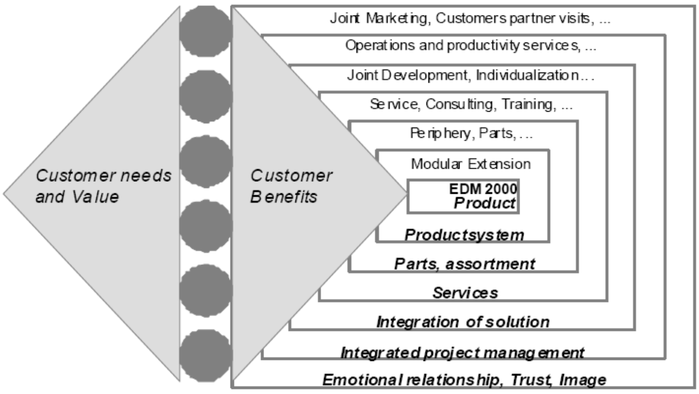

Figure 1: Solution system to deliver value to the customer (Source: [2, 14]).

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.

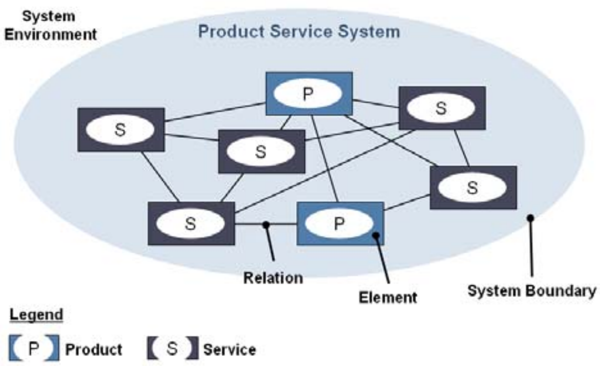

Figure 4: PSS according to System Theory.

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.

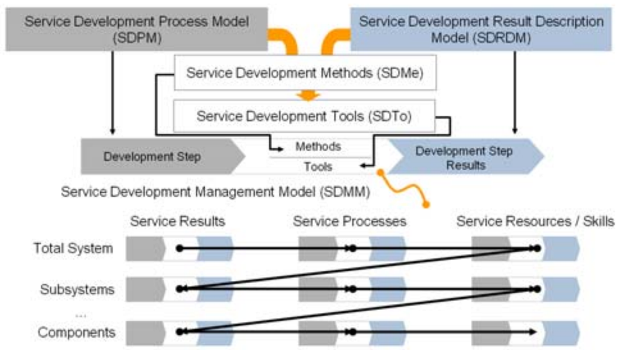

Figure 3: Architecture for service engineering - essential components and service-layers [Source: [20])

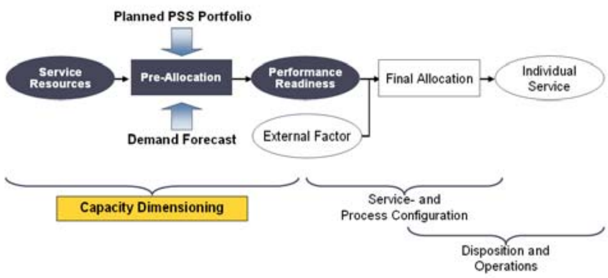

Figure 4: Service Production Process (Source: [4])

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

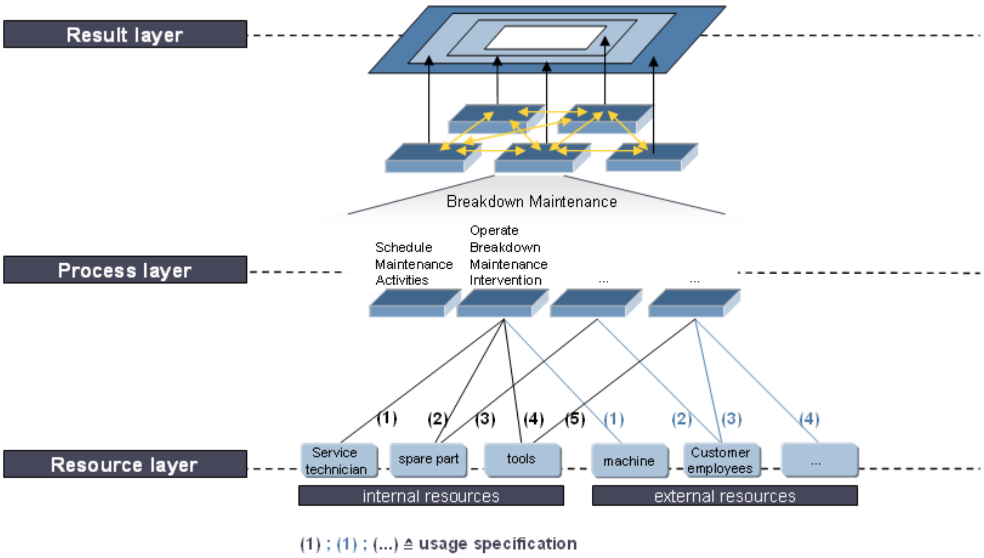

Figure 5: Structural model: usage of resources in PSS

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].

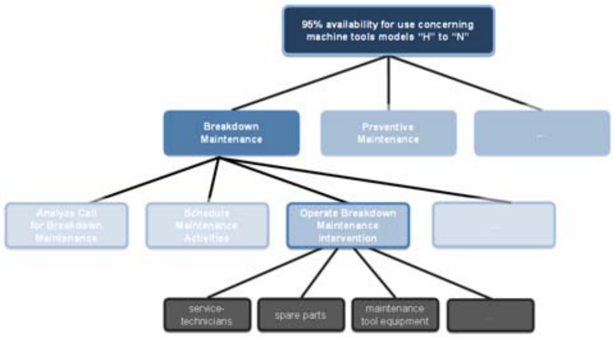

Figure 6: Practical example of structural model [Source: [9])

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.

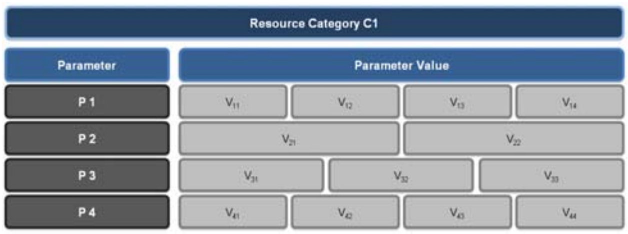

Figure 7: Morphological Box

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.

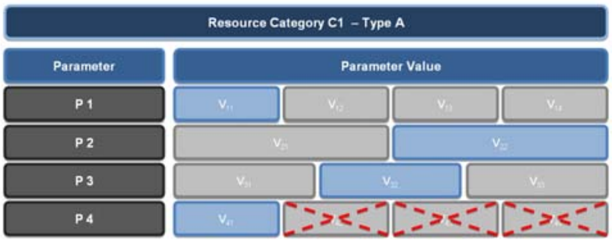

Figure 8: Visualization of a specific Resource Type

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.

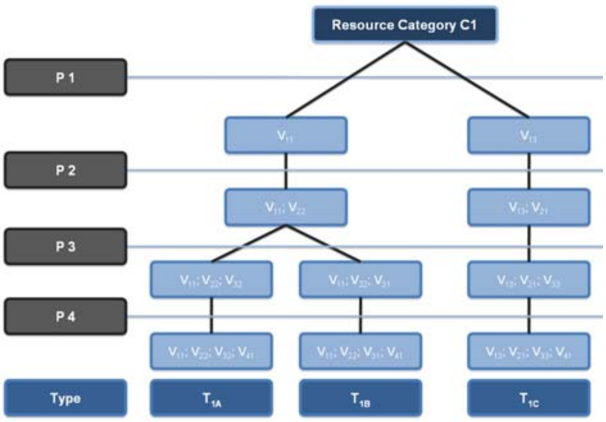

Figure 9: Resource Type Structural Tree

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.

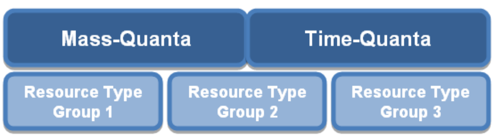

Figure 10: Quantitative Description of Resource Types

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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