Towards Consolidation on Product-Service Systems Design

P. Müller[1], T. Sakao[2]

[1] Dept. of Machine Tools and Factory Management, TU Berlin, Pascalstr. 8-9, 10587 Berlin, Germany, patrick.mueller@mailbox.tu-berlin.de

[2] Dept. of Management and Engineering, Linköping University, Linköping, 581 83, Sweden tomohiko.sakao@liu.se

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 *).

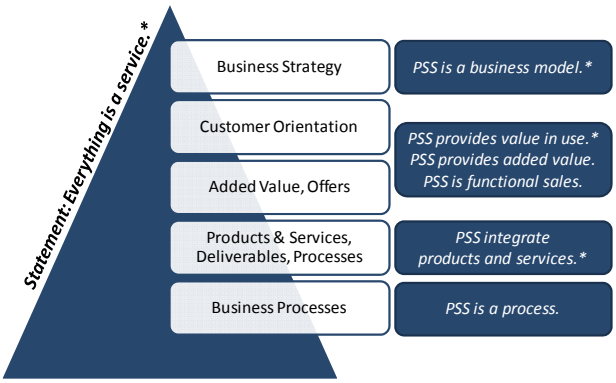

Figure 1: PSS abstraction levels.

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.

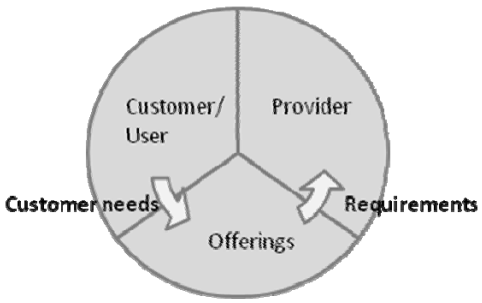

Figure 2: Influences among the three dimensions.

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).

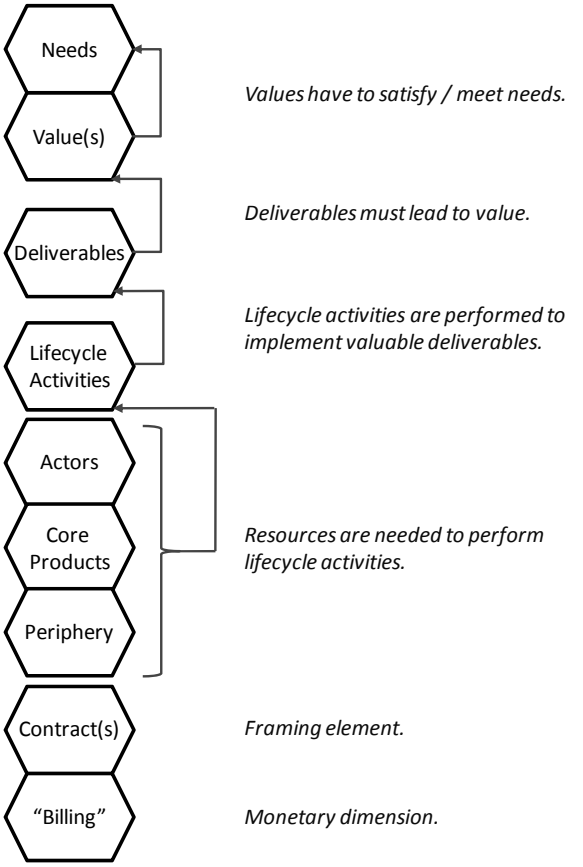

Figure 3: PSS design dimensions and relations.

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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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.