Product-Service Systems – From Customer Needs to Requirements in Early Development Phases

Å. Ericson[1], P. Müller[2], T. Larsson[1], R. Stark[2]
[1]Division of Functional Product Development, Luleå University of Technology, SE-971 87 Luleå, Sweden
[2]Chair Industrial Information Technology, TU Berlin, Pascalstraße 8-9, D-10587 Berlin, Germany
asa.ericson@ltu.se, patrick.mueller-projekt@ipk.fraunhofer.de; tobias.c.larsson@ltu.se; rainer.stark@ipk.fraunhofer.de

Abstract
Framed by Product-Service Systems (PSS), this paper discuss how needs and requirements are applied in early phases. In product development literature these and closely related terms are mixed, and a focus on gathering customer information about goods and their use guides the development team. This theoretical study highlights that lifecycle commitments such as PSS insist on the generation of a broader information basis. The application of a divergent view on goods, their use and the customers is likely to provide such information basis. The discussion provides a proposal of a simple model to set needs and requirements in relation.

Keywords:
Product-Service Systems, Needs, Requirements, Engineering Design, Early Development Phases

1 INTRODUCTION

An extension of business models to incorporate Product-Service Systems (PSS) is an ongoing movement in manufacturing industry. Briefly, PSS means that the goods remain in the ownership of the provider(s) and what a PSS customer actually buys is the functionality or performance of the goods in form of a service. Therefore, this business scenario is thought of as a special case of servitization, where an integrated product and service offer brings added value to the customer [1] [2]. In general, the development of products (in this case: physical artefacts) and services (in this case: customer/provider activities) are performed sequentially and in isolation from each other. Thus, services are developed to differentiate the core product from competitive products, and, moreover, services occur in aftermarket activities to sustain customer relations. The added value that the PSS customer buys can over time (PSS contracts are signed for a longer time period) be met by different solutions. This has been exemplified by Patnaik and Becker [3], storage of computer data has over time been met by punch cards, magnetic tape, floppy discs and, today, flash memories and, in the future, e.g., web-space, where the customer does not care about the type of media. Different solutions, but the customer is provided with the same main functionality of the goods. The ability for manufacturing firms to successfully meet the kind of functionality that customers perceive as added value seems utterly important for PSS. So, in this scenery, where the product developers have to take a view of the entire lifecycle and innovation in consideration in early phases, they have to really understand information on customers and have supportive methods to apply that information successfully.

1.1 The Voice of the Customer

The customer information, or what is commonly called the Voice of the Customer (VoC) [4] can be categorized in three ways according to the degree of customer involvement and responsibilities in the product development process [5]. *First*, VoC can occur in a design process *for* customers, where the customer is not directly and in person involved in the development process. In this case the design activities are customer oriented, but managing and handling the VoC are department specific tasks. That is, the responsibility for the development of products and services respectively relate to distinct roles within a company, e.g., development and marketing. The approach to customer orientation in product development has received some critique. It has been highlighted that product developers probably describe themselves as customer oriented since they assume that the customer preferences are the same as their own [6][7], which can be described as an 'inside out' perspective. From a service development perspective a customer orientation suggest an 'outside in' view, that is, all activities should be considered from the customer's point of view [8]. *Second*, VoC can occur in a design process *with* customers, the basis for this approach is similar to the previous, but, commonly, the customer is involved in the evaluation phases of suggested solutions and products. That is, the customers are involved in later development stages and usually they evaluate a product which is in a pre-production state. Here, ideas for new services might occur, but the product as such will only be affected by the VoC in minor ways [9]. *Third*, VoC can occur in a design process *by* customers, for this approach the concept of 'lead-users' are vital [10]. In a lead-user approach, the VoC takes the expression of a modified or a new product developed by a lead-user, the company's design process starts from there and the lead-user's product is used as a mediating object for the VoC. In this way, the innovation process is performed 'outside' the product development company, and it can be argued that the VoC will be dealt with in a similar way as in the design with customer approach.

1.2 Research questions

Dealing with the VoC is not trivial. Besides possibilities to apply it in different ways, the kind of customer information that is in focus for identification is distinct. The VoC is interchangeably represented by different terms in product development literature, e.g., needs and requirements. In turn, each term is not straightforwardly described, for example, in Ulrich and Eppinger [11] the word need is used to *"…label any attribute of a potential product that is desired by the customer; we do not distinguish here between a want and a need. Other terms used in industrial practice to refer to customer needs include customer attributes and customer requirements"* (p. 61). But, inconsistently, they also describe how to turn customer needs into requirements. Accordingly, there seems to be a difference between the interpretations of the words and, hence it also seems to be a good effort to elaborate on the terms needs and requirements, especially to support the development of PSS commitments. It is likely that these two views of customer information are important to put forward a cohesive development process to fulfil a PSS contract. Thus, three research questions guide the study presented in this paper:

- How do needs and requirements affect the early phases of product development?
- Do needs and requirements correlate, and if so, how?
- How do needs and requirements relate to the design of lifecycle commitments such as PSS?

1.3 Perspective and motivation

In the following the perspective and motivation for the study presented in this paper are outlined. Next, the theoretical frame is presented, including an introduction to a distinct view of needs and requirements. This section provides a basis for the discussion of these terms within the frame of PSS.

The motivation for this study has emerged from discussions within a PSS design research community. The study has a theoretical base, although the choice of theory is inspired by our empirical research projects in product development companies. Earlier, we have identified that these companies' customers express themselves in technical terms related to a product, however in a situation of asking for PSS contracts the customers' expressions have changed and become more elusive.

In product development literature the terms needs and requirements are sometimes used interchangeably with e.g., demands, wants, desires and wishes, to explain the input into the process. These terms are excluded from a close scrutiny in this study, since these words are sparsely used later on in the literature. But, also, because the two first terms can be interpreted as the customer actually knows and can express exactly what he/she demands or wants. And, the two latter terms gives the impression of representing trends and short-term desires and wishes expressed by customers. This is not the case for long-term commitments, and thus not for PSS either, and not for innovations in particular.

The study is performed from an engineering design perspective. Thus, traditional service development is out of our focus in this case. However, our purpose to elaborate on needs and requirements indicates that we would like to highlight different angles, which are (i) the customer point of view and (ii) the product developer point of view. Further, we will draw upon two different principles for systems design to deal with information in early phases of product development. Our effort to discuss needs and requirements from different perspectives is focused on 'calibrating' yet unclearly related viewpoints. The aim is to find a promising scheme, which is applicable in PSS development and which brings both concepts together, describing intersections, differences and interpretations instead of favouring one at the dispense of the other. Adapting new perspective does not make the former obsolete; rather several perspectives are a condition to have something to integrate. Also, for the sake of simplicity the perspectives respectively are presented as opposites, what is idealized and far from a real situation.

2 PRODUCT DEVELOPMENT

2.1 Early development phases

The product developers' ideas, knowledge and skills determine in a significant way not only the technical properties of a product, but also the economic and the ecological [12]. Further, it is argued that people's interaction with every developed product affects our possibilities *"…for actions and our way of being in the world"* (p.10) [13]. Product developers carry a heavy responsibility in the product development process by determining product characteristics which affect the product daily use, as well as having an impact on human lives

A product development process can be viewed as a *transformation* of a market opportunity into a physical artefact available for sale [14]. The process is described as a sequence of steps that a company use to conceive, design and commercialize a product, where the activities begin with a perception of a market opportunity and ends in the sale and delivery of that product [11]. Roughly, a product development process can be outlined as consisting of the steps planning, design, production and launch. The design phase is commonly divided into three phases; conceptual design, embodiment design and detail design. For the purpose in this paper, we focus on planning and conceptual design as early phases; all the remaining phases are here considered as later stages.

Planning is a phase where the product development starts, however, it is suggested that these activities start long before, namely in the moment when a product developer is assigned to a particular design task and start to think about it [12]. Furthermore, the design of the design process *per se* is part of the early phases, where decisions about, for instance, the time spent on early phases and the extent of creative and innovative work, are made. These early phase decisions set the conditions for the subsequent process [13], settle the product as a whole [15], including lifecycle services and after sales [14].

2.2 Managing product development

Roozenburg and Eekels [16] divide product development into two processes: a technical and a commercial. The goal for the technical development process is to produce a number of goods according to a particular design, and the goal for the commercial development process is profit. The link between the two processes is the goods [16], in this way the *cost* of the goods (development, production, distribution and sale) becomes a key in product development processes. Further, the objectives in product development become related to cost, for example, development speed – to shortening lead times, and, product performance – to decrease complaints. Good trade-offs between the objectives in product development can be considered as the art of managing product development [17].

Early phases of product development are often referred to as 'fuzzy-front end' [17], since the information is sparse in

the beginning of the process. A product development processes can hence be described as the design team is gradually building up a body of information to provide a complete procedure to manufacture a new product [17]. However, the search for additional information is not uncomplicated. The starting position for a design task is described as a wicked problem [18], where the dilemma for product developers is to understand what they are going to design, what it should do and who should use it and in what circumstances [19]. Accordingly, information is a vital part of early development phases, and also the kind of information and its application in the process.

Commonly, information flows in product development are described as an over-the-wall approach [20], where information is identified, analyzed and, then, communicated from one department to another (with a lack of transparency). For instance, the customer information is transferred from marketing to product development. Often, a written specification is the holder of the information, thus, also states what kind of information should be applied in product development. A basis for this systematic engineering design approach is that the tasks, activities and development goals should be broken down into sub-tasks, sub-activities and sub-goals [12], thus going from a higher level description of the product into a more detailed specification as early as possible. As a consequence the company's view on the product is likely to be focused on their own manufacturing point of view, in opposite to customers which perceive the product they buy in totality, through the entire product lifecycle, from initial contact with the company to disposal [7].

A lifecycle view on product development, such as e.g., PSS, gives the impression of the design of a system. To identify the kind of information applicable for the design of systems, there are different principles to draw upon. For product development, two basic differences for a systems view are highlighted by Checkland [21]. Yet, for these two views one common picture of the 'ingredients' in a system prevails. A system is viewed to be built up by the 'ingredients' – an input, a transformation process, an output, a feedback loop, it has a system boundary and is surrounded by an environment. Further, a system has interrelated parts which have an effect on the system as a whole. Embarking from that, the two principles on systems design builds on distinct logics. First, one view regards the systems as something that *exist* in the world and the system's boundary to be firm and closed, i.e., a hard systems view. Accordingly, the world in itself is systemic and information can be captured, formalized, broken down and the systems can be engineered. Second, another view regards the world as complex and problematic, and systems are something humans use to bring order to it, that is, the process of inquiry is systemic. From this point of view systems do not exist, rather they are mental models used to cope with a complex world. Thus, information of the world is socially constructed and organized in 'cognitive systems' to build up a holistic view of a situation. In this view, the system's boundary is flexible and open, i.e., soft systems view [21]. The soft systems view emerged as a consequence of the recognition that a hard systems view could not address information about human activities and goals. A vital part in the soft systems view is the recognition and visualisation of different worldviews, these can, in turn, be utilized to develop a shared understanding for the design.

In short, these two views respectively focus on identifying information in relation to technical systems or to human activity systems. Yet, both approaches strive to apply that information in order to develop products.

2.3 Needs

In the Needs Hierarchy developed by Maslow [22] the basic human needs are organized by their relative prepotency. At the bottom level of the hierarchy the physiological needs are represented: *hunger, thirst* etc. Social needs compose a middle section: *recognition from others, sense of belonging* etc. At the top level the self actualization needs are outlined: *meaning, inner potentials* etc. Maslow's kinds of needs are apt to explain a view of a 'complete human being' and what is motivating people to change their situations, but not readily practical for product development.

The fulfilment of basic needs is not dependent on goods or services, so, instead, framed by an economic theory of human needs, Max-Neef [23] has categorized *representations* of needs into a needs matrix. Max-Neef emphasize that human needs have to be understood as a system, since all human needs are interrelated and interactive. To demonstrate the interaction, the need matrix is organized into two categories, i.e., existential and axiological (the latter term can be interpreted as 'based on value or quality judgement'). The existential categories are; Being, Having, Doing and Interacting. The axiological categories are; Subsistence, Protection, Affection, Understanding, Leisure, Creation, Identity and Freedom. Based on these categories a number of satisfiers are suggested to give examples of the way needs are expressed. Based on Doing and Understanding, examples of satisfiers in the matrix are investigating, studying and experimenting. The satisfiers might vary considerably if put together by individuals or groups from diverse cultures [23].

Needs are means to an end, i.e., a human goal, to understand the needs the goal has also to be understood [22][24]. Needs are, on the whole and in the average person, more often unconscious than conscious. Thereby, needs are context dependent, and to find them they have to be searched for. To identify, analyze, categorize and communicate needs, which are embedded in routines and difficult for people to articulate, the approaches are building on qualitative methods. One example is Needfinding [3], that applies an intertwined and iterative procedure of observations and interviews, where the key is that those who develop products should participate. However, it is important that no solutions are suggested to the studied people in the first quick iterations. Also, Needfinding affects the whole product development process, e.g., work style, culture, work environment and management style [25]. Needs engage, motivate and mobilize people, hence are considered as a potential for change [23], and, a potential for innovative solutions [3] [26].

2.4 Customer information in product development

Representations of development processes are described in product development literature as customer or market oriented, since the initial input to the early phases is some kind of customer information. Hence, how to manage market research or how to gather information on customers are covered in product development literature. Yet, several terms are mixed to compose customer information. Clausing [4] describes the VoC as including needs, requirements, desires and attributes. Furthermore, it is emphasized that it is important to stay close to the customer's own language and that a need is typically a short phrase.

Questions to support the collection of customer information are, for instance *"If you had feature X, how would you benefit?"* (p. 115) [4], and *"When and why do you use this type of product?"* (p. 59) [11]. Narrowing the amount of information to describe the product as early as

possible is vital in a traditional product development process [13]. But, this is also the content in the main critique, that is, the idea that customers can express their needs and that such information readily exists and is waiting to be obtained [9].

Ulrich and Eppinger [11] suggest that the collected customer information should be interpreted into written statements that convey what the technical artefacts have to do, not how it might do it. For instance, the customer expression, *"I need to drive screws fast, faster than by hand"*, becomes interpreted into the statement *"The screwdriver drives screws faster than by hand"* (p. 62). However, the written statements are established by the development team into a specification. In turn, the specification depends on the selected concept and consists of a metric and a value. The specifications convey the precise description of what the product has to do, but give no guidance to the development team for how to address the customer information in it.

Customer information is translated into statements and listed in a specification. These specifications have a vital communicative role in the development process. Andreasen and Hein [15] have suggested that specifications should have broader contents and have to be formulated in another way. From a PSS point of view, such a specification is identified to encompass a broader set of customer information.

3 DISCUSSION

Since the, in product development literature, suggested statements differs radically from both Maslow's needs and Max-Neef representations of needs, they cannot be categorized as 'needs' in that sense. Accordingly, this kind of customer information might be lacking in specifications. In turn, this calls for consideration of what is actually communicated into the early development phases. The customer information used as input in product development models are intertwined with several terms, thus not easily identified as a distinct entity and, perhaps, contributing to a fuzzy front-end.

To support the development, the VoC has to be carefully analyzed. The customer information has to be translated into representations of needs *and* formalized into requirements. Thereby, a broader set of customer information has to be generated and needs has to be sorted out. Representations of needs can help to 'abstract the design task', to find the main function which provide added value (cf. [12]). Further, by iteratively 'designing' representations of needs and formalize requirements, the needs provide a basis (grounded in the VoC) for design decisions, e.g., contradictions and trade-offs.

Products and services are developed by human beings that, oftentimes, have to collaborate. Early on, the development team has to create a shared design vision, so that the decision providing a PSS solution or another solution can be made. PSS is a widening in business for manufacturing companies, whereas previous business models are still valid, but not all customers are willing to sign in for PSS. PSS is commonly viewed as an integration of products and services, but such a view can give rise to the idea that it is just a matter of simply combining these 'elements'. Seeing product development processes, and especially early phases, as the creation of a body of information to provide a complete procedure to manufacture products [17], highlights the social aspects and the challenges of sharing information. Human beings have different perspectives, or worldviews [21], in turn, these affect what customer information is searched for and how it is interpreted, translated and communicated within the team. For PSS, a heterogeneous team, possessing divergent expertise, has to collaborate in early development to nourish both a service and a product perspective.

A distinction of the two terms, needs and requirements, is likely to sustain for the broader basis of customer information that is identified as crucial for PSS in order to deliver added value. Needs can be viewed as basic needs, as described by Maslow [22], these needs are recognised as fundamental for all humans. To support product development, Max-Neef [23] suggest that needs should be seen as representations, since people cannot articulate needs [3]. Needs are often embedded in 'things we just do', routines etc., thus people are not aware of them; rather they face a problematic situation and cannot find a satisfying solution. Besides being incorporated in routine tasks, a number of such needs prevail in, for instance, organizational culture, ideology and values. For the purpose in this paper, needs can be viewed as an expression of a perceived problematic situation. Thus, the information that the customer is able to provide is elusive, and, if the expressions are not sufficiently analyzed and categorized they can mislead the development team. As an opposite, requirements are structured and formalized information about a product. In traditional product development, the customer information is collected by asking questions about, for example, features and preferences of an existing product, as exemplified by Clausing [4] and Ulrich and Eppinger [11]. A prototype of the intended product or a similar product can be used to make customers express themselves in a more structured way. Requirements are represented in specifications, which are even more formalized into a precise description of the product. Here, two contexts become discernable. First, the customers' context where values and needs are perceived by the users, and, a second context, the product developers', where requirements and specifications are designed by the development team (see Figure 1). In between these two 'worlds', representations of needs appear. These needs are generated and designed by the heterogeneous development team on the basis of what has been found in the customer's context. For PSS, providing added value is crucial, and to get insights into values a key is to take needs into consideration.

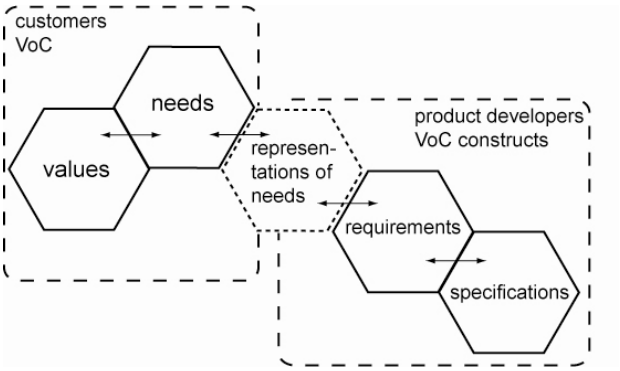

Figure 1: Distinction and correlation model.

However, and reasonably for the development of goods, the information from customers in product development literature is focused on goods. Our argument here is that such a focus is not enough for PSS. The suggested customer expression *"I need to drive screws fast, faster than by hand"*, and the interpreted statement *"The screwdriver drives screws faster than by hand"* (p. 62) [11], can be expanded framed by PSS. First, the perspective for this 'fabrication' is a business-to-business situation, that is, the provider develops tools and the customer uses the tools in their manufacturing activities and processes. Second, since the gathered customer information captures the activity *'drive screws'* and the

description *'fast',* the interpreted statement include a solution *'screwdriver'* and a requirement *'faster than by hand'*. Thus, already in this early phase a design mindset of a screw driving machine appears (a hand toll is excluded in the requirement). In this way, the customer information, i.e., requirements, delimits the development to goods 'as usual'. The first row in Figure 2, highlights that the customer information collected from the viewpoint of technical artefacts give rise to a design view that focuses on, e.g. features and attributes of *that* artefact. The potential for new and innovative products seems delimited by this view.

From an engineering design perspective, a service is developed to enhance the goods in the eyes of the customer; in this case, for example, spare parts like bits for the screw driving machine can be delivered to the customers place based on the usage pattern. In this way, the customer does not have to spend resources on ordering spare parts and the manufacturer can be confident that the customer is contracted to use original spare parts. Let us say, that a competitor's bits are as good as the original parts, but cheaper. Thus, price might become a crucial aspect for competition, unless the manufacturer can find a better service solution that the customer perceives as worth paying for. In this situation, customer information about the use of the tools in the customer's processes is vital; where is it used, when is it used, who is using it etc. In the middle row in Figure 2, the design view for services related to particular goods insist on additional customer information than what is commonly collected for the development of goods. So, there is little guidance for service solutions to enhance the *use* of a screwdriver in the initially exemplified customer information. New and innovative services might be possible for the manufacturer to identify here. But, the potential to find innovative products is even more delimited here, since the goods have to be decided on and settled for the developers to be able to add services to it.

VIEWPOINT	OUTCOME	KEY WORDS	CUSTOMER INFORMATION	DESIGN VIEW
Product	Goods	Excellent Robust Reliable	Preferences Use of similar goods	Features Attributes Appearance
Service	Activity	Swift In-time Trustworthy	Schedules Actors Places	Interfaces Interactions
System	Performance/ Functionality	Effortless Efficient Productive	Goals Means Context	Troublefree Use Lifecycle

Figure 2: A PSS integration matrix, examples of additional information influenced by the viewpoint.

PSS incorporates both products and services; this is captured by the view of a system. From systems theory, two views on systems can be identified [21]. One view, hard systems view, is apt to deal with information related to technical systems, since the boundary of such a system can be recognised, thus useful for the development of technical artefacts. The other view, soft systems view, has the capability to address the goals that humans strive to achieve by performing activities. A visualisation of distinct worldviews can be used to make the actors in the development team aware of the underlying assumptions that affect how each actor addresses a design problem. Considering customer information 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 goods for specific purposes. At this level of abstraction and framed by PSS, the example of the customer information, *'fast'* can be interpreted as the customer perceives the activity as time-consuming. If so, the customer information can represent the need to release resources, e.g., staff, for other activities. In order to identify such a situation, additional information, for instance, about goals, means and context, have to be generated. A solution might be that the tasks where screwdrivers are used are bought as a 'full-fledged' PSS. That is, the manufacturer takes the responsibility for and performs the activities at the customer's place where their tools are used. Doing so, not only the development of the tools, but also what tools and the whole procedure become the manufacturer's responsibility. It becomes possible to find and apply other solutions than 'screws' and 'screwdrivers' to achieve the desired outcome, of course, under the condition that the contract is signed on a long-term basis. Over the life time, PSS contracts are likely to be based on varying degrees of services or products. For the case exemplified here, another solution might be that the customer remains responsible for performing the tasks where screwdrivers are used, but the manufacturer takes a system perspective on the development. That is, the additional customer information is used as input into the development of screwdrivers. In turn, and early in the product development process, such perspective give rise to questions like: If the need can be interpreted as 'releasing resources', how can we contribute to that? What solutions can we find? And, if our solution is a screwdriver, how is it used, how does the use affect the process and the desired outcome? In Figure 2, the last row, a systems perspective on the development put forward yet another abstraction level of the design. A solution independent state of mind is a key to generate customer information at this level. A lifecycle approach offers a way for 'back-end' information, such as distribution, use and disposal to be considered early on. However, in early development, when applying a lifecycle approach a challenge is generate solution independent information, i.e., studying distribution, use and disposal from several perspectives, not only from the perspective of existing goods, in our example 'screwdrivers'. Still, to develop goods for PSS contracts, the suggested matrix as a whole has to be considered, i.e., continuously going up and down in abstractions until a satisfying solution that provide added values is found.

4 CONCLUDING REMARKS

In this paper, the interpretation and application of needs and requirements in relation to early development phases has been discussed in general, but for PSS in particular. A main point has been highlighted, namely lifecycle commitments such as PSS insist on the generation of a broader customer information basis. A divergent view on customer information, e.g., needs and requirements, is likely to provide that broader basis. A view of needs as a construction, even though grounded in 'real' not readily available needs, is suggested in Figure 1 as a link between customer information and information created and applied in product development. In this way, needs as such are designed in early development phases, and, accordingly, a product development process has to encompass the design of needs. For PSS, a holistic approach has been suggested, integrating abstractions and details. Further, an integration of services and products is emphasized as a social design activity. A challenge is to facilitate a communication process which links needs and requirements effectively for design tasks.

In this study, there are things that we have not considered, but found interesting for future research. Besides having an affect on product development activities and processes, PSS is likely to affect the company as a whole. For example, how to organize for

PSS? Also, if a PSS customer buys the performance or the function, and the PSS is really successful, the customer will only be aware of the PSS in terms of an invoice. Another future research question is how to maintain a PSS business relationship?

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