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PROPERTIES AND CHARACTERISTICS OF PRODUCT-SERVICE SYSTEMS - AN INTEGRATED VIEW

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Abstract

In the following paper, an approach for a consistent classification of the characteristics and the properties both of services and material products is shown. This could be a starting point for a methodology for the systematic development of Product-Service Systems, which consist of services and material products. For this purpose, approaches from business administration and engineering sciences, that deal with systematic development of services and material products and their properties, characteristics and qualities have been examined.

1 Introduction

The integrated view on material products and services both from the developer’s and the customer’s point of view offers various advantages.
Not only for ecological reasons – like reducing resource consumption by replacing material products or even material components of products by services – but also for functional and economical reasons and because the similarity of many products leads to the problem of a required deferral from competitors in the global market
The integration of material products and services – the combination of both being called Product-Service System (PSS) – has been the core of several recent publications, for example [Mont03, Tomiyama02, www1, Weber&Stein&Bot04, Andreasen&McAloone02]. In these publications the increased sustainability, minor environmental impacts and better balance with social constraints are seen as important reasons to enhance or substitute material products by service components. Tomiyama uses the term Post Mass Production Paradigm (PMPP) for this viewpoint ([Tomiyama02a]). But also (global) marketing considerations may

lead to the same conclusion, e.g. to raise a product's profile between many similar competitors by service components.
Consequently, an integrated view on Product-Service Systems as well as integrated engineering methods to develop both the service and the material component of a PSS seems a sensible proposition, both from the developer's and the customer's viewpoints.

Most methodical approaches in engineering sciences base on the assumption that it is possible to create a functional structure of the product. After working out the functional structure and dividing it into sub-functions, the phase of realising these functions by physical principles follows. This consideration may sometimes (but not always) fit purely material products, but regarding PSSs, it becomes obvious, that it is impossible to find physical principles that refer to services.
This paper will show a possibility to have an integrated view on material components and services starting from a consistent classification of characteristics and properties of them.
The distinction between characteristics, which describe the structure and the constituents of a product, and properties, which describe it's behaviour, was originally presented by [Andreasen95], then for purely material products. While the characteristics (in case of material products: product structure, shapes of components, materials) can be directly determined by the designer, the properties (e.g. function[ing], strength, duration, ..., manufacturability, cost) are a result of the chosen characteristics and can not be directly influenced.
This distinction between properties and characteristics is very similar to the distinction between internal and external properties introduced by Hubka/Eder [Hubka&Eder96] and is also similar to Suh's distinction between design parameters and so-called functional requirements [Suh90].
Putting the distinction between properties and characteristics in the centre and putting a particular focus on the (modelling of) the relations between the two, is the core of the concept of Characteristics-Properties Modelling (CPM) and of Property-Driven Design/Development (PDD), which was presented by the Institute of Engineering Design/CAD of Saarland University – again originally to describe material products and to lead through development processes for them, A detailed description of this concept is shown for example in [Weber&Werner02, Weber&Deubel03].
In this paper, it is examined how a classification of characteristics and properties of PSS might be realised.
Unfortunately there is neither a consistent classification of the characteristics and the properties of services nor a common classification for the properties of PSS. In the following, the authors present the results of a common work of the Institute for Information Systems (Institut für Wirtschaftsinformatik, IWi) and the Institute of Engineering Design/CAD (Lehrstuhl für Konstruktionstechnik/CAD, LKT) at the Saarland University, Saarbrücken, Germany.

2 Approaches from business administration and engineering sciences

Despite the fact that the development of an integrated view of material products and services is seen as a research and application field of high interest, there does not exist an adequate methodology which handles the different character of material and non-material products in a holistic way.
Both from engineering side and from business administration side, there exist some approaches which handle material and non-material products as a development object separately, without integrating both sides. Therefore, it is important to examine the scientific

literature to find some reasonable approaches which could help to integrate both material and non-material aspects of a PSS, in our case with regard to their characteristics and properties.

2.1 Service Engineering

In the field of business administration there do exist some approaches which deal with the structured development of services. The development of services, which was known in the American literature as *New Service Development* ([Ramaswamy96, Cooper&Edgett99, Fitzsimmons00]), was introduced in German research in the middle of the nineties. Especially authors like Corsten, Bullinger or Kleinaltenkamp ([Corsten96, Bullinger&Meiren01, Kleinaltenkamp01]) have tried to explain the phenomenon of service in a structured way. The problem was that because of the “*Immateriality*” of services and the required integration of so-called “*External Factors*” (an object or a person the presence of which or whom is necessary to accomplish the service) a significant definition could not be made.

These terms define “services” just in a very conceptual stage, but are not suitable to support a development/design process. In product engineering, the use of methods is an established way to get from an abstract idea to a highly elaborated product description. Design methodologies and product models for material products are in use in many enterprises in various degrees of abstraction and support by computer tools. On the opposite, the development of services by a set of methods and a structured methodology is only in its infancy of scientific consideration. There exist simplistic process models which show the important steps towards a new service, [Kingman&Shostack91]. Apart from that, in definitions of the term ”service“ there exists a certain fuzziness in the scientific literature which is still an obstacle in scientific considerations.

The approach which is seen as the most useful is the constitutive approach of definition which includes three dimensions: potential orientation, process orientation and results orientation. More detailed information about these approaches is described in [Corsten01]. The reason why these dimensions are important for a further look at PSS is, that these dimensions are the base for related kinds of models which can be developed: resource models (dimension of potentials), process models (process dimension) and product models (dimension of results) ([Fähnrich99]). Product models describe the results of a service, process models describe the act of supplying a service and resource models describe the required (enterprise) resources to supply a service. Even if there exist several process models which describe a structured development of services, for example [Schneider&Scheer03], a methodological support, especially in the analysis and synthesis phases of a development process as it is known in engineering material products is hardly given.

Out of these reflections a future research interest is seen in the structured development of bundles, made of physical and service parts. The aim of an integrated development from early phases on would be an overview over the relations between products and services and the implications of variations. Even if in business administration literature the adaptation of technical methodologies to the development of services is considered as a promising way, there do only exist few approaches which describe a possible process for a structured development.

The phenomenon of Product-Service Systems must be seen on the interface between traditional engineering and economics. Studying the scientific literature from both sides, there are some first approaches which can help to understand the modelling of Product-Service Systems. [Shostack77] for example visualizes bundles of products and services from a marketing point of view as a connected system of components and emphasizes their relations. This molecular model leads to the problem of a structured development of this bundle. It assumes this bundle as given in an enterprise. [Hermsen00] shows the process of development of product-related services by the adaptation of existing bundles of products and services. He develops a data model which shows the connections between a service and corresponding organizational, informational, cost and product aspects. This approach refers to adaptation processes. The required properties of the solution for an individual problem must be given. Other approaches for an integrated development of Product-Service Systems like the approach shown by Spath in [Demuß&Spath02] refer to the guideline VDI 2221 ([VDI2221]) and describe the problem of a parallel development. The question, how given requirements can be transferred into characteristics of a Product-Service System is hardly answered, a consideration how to classify these (required) properties and characteristics is not considered at all.

2.2 DIN 75 Technical Report Service Engineering

In 1998 the German Institute for Standardisation (Deutsches Institut für Normung, DIN) tried, according to the increasing importance of services, to establish a standardisation for service engineering [DIN75] and to deliver new viewpoints for the systematic design and modelling of services. Certain service-intensive business branches are considered and their needs are analysed. The integration of services and material products as it is done with the PSS concept is not considered here, [DIN75] just handles with services and even marginally with so-called hybrid products, material products with later, after the development of the material product, attached services. Although there is division of characteristics and properties of services, these terms are not defined and used in a proper way according to the concept of Andreasen.

Nevertheless, some useful conclusions for a classification can be drawn. So called development relevant characteristics that can be seen as characteristics in the sense of Andreasen's or the PDD concept are: Qualification of the service provider, duration of the service from the service provider's point of view, cycle, personal expenses of the service provider, degree of customer integration, degree of division of work. In sectiom 3 of this paper these characteristics are explained more deeply and their integration in the authors' approach for a common classification is shown.

2.3 Quality function Deployment

The concept of Quality Function Deployment (QFD) was originally developed in Japan by Prof. Yoji Akao in the late sixties. Japanese industry uses this concept since 1972. In Europe it came up in the early nineties. This concept supports the designer in improving the quality of the product, always regarding the requirements of the customer [Akao92]. The initial point of the development process is the table of customer requirements, where all needs of the customer and all desired qualities are recorded. The partly fuzzy requirements of the customer are analysed, redrafted and structured. Even the application of QFD in the field of service is shown in [Akao92]. But sadly, there is no common consideration of material products and services. Furthermore, a clear classification or at least a uniformity of the product's characteristics (which could be in the QFD approach characteristics as well as properties in the sense of Andreasen) is missing. The concept of QFD can help to collect the requirements of the customer and to relate them to the product and the characteristics of the product or service, respectively, but only if the structure of the product or the service is known.

A completely solution-neutral collection of the requirements is hardly possible when following the QFD concept, a consideration, that should be applied when designing PSS, where it is not clear at the beginning of the development process which requirement will be fulfilled by material and which by service components. The authors' opinion is that QFD could be an analysis tool, when a more or less rough draft of the PSS exists. Then a relation between the customer-desired quality and the characteristics of the PSS can be outlined and the quality of the product or the PSS can be improved. But a consistent classification, as will be shown in section 3 as a basis for the development process to get solution neutral required properties in the sense of Andreasen or the PDD concept can hardly be worked out of the QFD approach.

2.4 Design for Quality (DFQ), Total Quality Management (TQM)

Total Quality Management is a modern quality approach to support a framework for quality management in industrial companies [Andreasen&Hein98, Frehr93]. Originally, this concept refers to purely material products, but most statements could be extended to PSS. Frehr [Frehr93] shows methods how to determine the requirements of the customer. These could be customer interrogations, market studies, examinations of the competitors, systematic evaluation of complaints and proposals out of the own enterprise. But in this approach too, there is no classification made, how this requirements can be structured to support and to improve the design process. In [Andreasen&Hein98] the presented framework is more consistent and delivers a holistic view over the whole lifecycle of a product. There are three categories of qualities, which influence the user's quality perception:

- The obligatory qualities, that have to be realised anyway
- Expectation qualities that are unique to the company and express its image
- Positioning qualities, which are built into the product as sales argumentation and surprise effect on the market.

This classification can help to evaluate the quality perception of the product or the PSS by the customer, but from the development point of view as classes of (required) properties, they seem to be inapt.

A very important consideration in [Andreasen&Hein98] is that the quality perception of a product depends on the degree of fulfilment or actual value of a property. Furthermore, the quality of a product, as perceived by the customer, must be seen in the whole lifecycle of the product. This view can and has to be extended to PSS, where it is possible to adapt the properties of an already shipped PSS by modifying the properties of the service component.

Recapitulating, DFQ and TQM deliver approaches to built quality into (material) products and to enable the designer to collect the requirements of the customer (with techniques similar to the QFD approach). But there is no classification that could be useful for the designer in order to synthesise solutions that fulfil these requirements. The quality framework of Andreasen and Hein is very useful considering the quality perception of a product respectively a PSS through the whole lifecycle, but no classification, useful from the developer's point of view is made.

2.5 Quality Models for services

In the scientific literature about the management of services and their development processes, there exist many approaches that deal especially with the quality of services, for example [Donabedian80, Zeithaml81, Grönroos82, Para&Zeit&Berry85, Berry86, Meyer&Matt87]. All these approaches have in common that they try to consider different dimensions of the service quality. With regard to the character of services with the three dimensions potential, process and results, their immateriality and the interaction with an external factor, there have to be different kinds of quality dimensions. [Zeithaml81] for example defines three different dimensions which influence the possibility of quality perception of a service: search qualities (can be identified before buying), experience qualities (must be experienced during the service) and credence qualities (can never be identified or a long time after receiving the service). This approach seems to be adequate as a base for a future classification of property classes of Product-Service Systems, because the properties of products as well as those of services can be classified in this way, shown in section 3. It seems to be clear that search qualities play an important role in the quality perception of material products, while in the development of services there can be elaborated a higher amount of experience and credence qualities. [Donabedian80], for example, considers the three dimension process, potential and result in his quality model. This could be a good approach for a classification of different service properties, when looking at purely service solutions (even if the allocation of some properties could not be very clear in each case), for the integrated view on Product-Service Systems such a classification is not useful. A detailed view on different quality models for services and a corresponding evaluation can be found in [Corsten01, Hentschel92 or Konieczny01].

3 A common approach

Our opinion is that the characteristics and the classes of characteristics differ depending on whether material or the service components of a PSS are considered. For the properties, it is necessary to find a common classification, because properties more or less "just" mirror the requirements a product, a service or a PSS has to fulfil with no reference to particular components in the first place.

Although the terms "characteristics" and "properties" of services are not defined clearly in service engineering, as shown above, it seems to be very useful to keep on using them in the sense of PDD. The properties refer to the evaluation and the perception of the PSS by the customer, so are of obvious importance. The characteristics describe the structure and constituents of the PSS and are of lesser relevance to the customer (alone they have no meaning at all for the customer). Starting from this concept, certain classes of characteristics and properties of PSSs were identified, based on the examination in the work of Corsten [Corsten01], [DIN75] and various quality models of services presented for example in [Konieczny01] – here mainly the approach of Parasuraman, Zeithaml and Berry.

The results of this examination are shown in Table 1. No claim of completeness is made, as it is an open structure that could be extended if and when it seems useful or necessary.

On the side of the characteristics, a fairly clear distinction between structures and elements relevant for the material components of PSSs and others relevant for non-material components can be made. Apart from that, no general classes of characteristics could be identified. The classes of characteristics of material components of PSS are taken from [Weber&Werner02, Weber&Deubel03], the classes of service characteristics have been extracted from [DIN75] which was already explained in section 2.2. These are not the only classes of characteristics that are (implicit) shown in literature but they seem to be suitable to describe the structure of a service (component) completely.

This classification is intended to be open in the sense of [Knoblich72], i.e. if in a certain case the classification is unsuitable to describe the service completely (which has not happened yet to the authors), it can and has to be extended.

A connection between material and non-material components of the PSS is possible, e.g. a material component could be a prerequisite for the fulfilment of a service component, and also a service could be a prerequisite for certain material characteristics (condition of existence). An example is the application of a particular material that needs specific maintenance. This is, among other things, part of the characteristics class "degree of interaction with material components".

The characteristics of material components in table 1 explain themselves, the service characteristics are described in the following:

- Qualification of the service provider:
  Objective knowledge of the service provider (education, references, testimonials)
- Duration (service provider's point of view):
  Planned time to fulfil the service
- Cycle:
  Regularity of the service, how often has the service to be repeated
- Personal expenses of the service provider:
  Planned human resources costs per time unit
- Degree of customer integration:
  Intensity of the planned cooperation of the customer
- Degree of interaction with material components (of the PSS):
  Degree of autonomy of a service component; dependence between material and non-material components
- Degree of division of work:
  Number of persons who are involved during the service provision and kind of interaction between them

Table 1: Characteristics and Properties of PSSs

Characteristics		**Properties**		
Material components	Non-material components	Search-properties	Experience-properties	Credence-properties
Position Orientation Geometry: - Nominal - Deviation Surface: - Roughness - Waviness Material: - Mechanical - Electrical - Optical	Qualification of the service provider Duration (service provider's point of view) Cycle Personal expenses of the service provider Degree of customer integration Degree of interaction with material components (of the PSS) Degree of division of work	Functional properties Stability, stiffness Ergonomic properties Aesthetic properties Dimensional properties Manufacturing/ assembly properties Maintenance properties Repair properties Cost properties (claimed) Resource consumption (claimed) Environmental properties …	Reliability properties Environmental properties Resource consumption (experienced) Cost properties (experienced) Know-How transfer (from the service provider to the customer) Duration/ communication/ integration (customer's point of view) Customer understanding (understanding of the customer's needs by the service provider) Functional properties (experienced) …	Safety properties …

On the side of the properties, a distinction between three main-classes and subsequently some sub-classes seems promising – all of them described in literature on service engineering, but fitted here into the PDD concept. Following the quality approach of [Zeithaml81], these are the three main classes of properties:

- Search properties are such properties that are obvious in advance (before buying or using the PSS), therefore the costumer might utilize them to search for a product/PSS. Most properties of material products are search properties.
- Experience properties are properties that cannot be judged a priori, but only by or after using the PSS.
- Credence properties cannot be evaluated by the customer at all, because he/she has not the knowledge and means to judge them, or because they could only be evaluated in the indefinite future. With regard to credence properties the customer has to trust the fact that the PSS has them (e.g. because the provider of the PSS has gained credibility in the past).

Certain properties can be arranged in several sub-classes, depending on the customer's priorities (or the customer's "profile"). For some customers the environmental properties of a PSS are of prevailing importance – for these customers they are search properties. Another example is the resource consumption: The resource consumption claimed by the manufacturer/provider plays the role of a search property, the resource consumption experienced when using the PSS is an experience property (and might not have the same value).

It should be mentioned that the classification of properties shown in table 1 is seen from a developer's point of view. From the customer's point of view, his perception in form of certain qualities of the PSS is important, as said in section 2.4.

Depending on the focus or branch of the company that wants to develop the PSS or the (demanded) type of PSS, it is favourable to use a more service-oriented or a more material-oriented view to work out the properties of a PSS. Some sub-classes of properties refer more to material oriented solutions, like "dimensional properties", some refer more to a service solution, for example "know-how transfer". Important is, that all qualities of the PSS required by the customer and all actual properties are considered adequately. Further on, it seems that, depending on the phase of the PSS's life-cycle, different classes of properties are of different importance or of different quality perception, respectively. For example, maintenance cost of a PSS may differ with the age of the material components of the PSS. With this classification it is possible to consider these facts and to integrate them into the product model. Thus, it is possible to capture knowledge about the behaviour of the PSS in all phases of its life-cycle.

The classification of characteristics and properties of PSSs presented in table 1 offers the possibility of analysing possible marketing effects of certain defined characteristics. In a very early phase of the development of a PSS marketing experts and designers are able to concentrate on the fulfilment of a certain class of properties which is thought to be the most important. This fact is especially important because the technical similarity of material products is increasing and customers' decisions are often influenced by the service components of a PSS. As mentioned before, in later phases of the PSS's life-cycle other classes of properties may gain importance.

This approach must be seen as a first step towards a consistent methodology for modelling PSSs. Although it has been worked out of well established literature, both from engineering science and business administration, its suitability for describing the properties and characteristics of PSS from a developing point of view has to be evaluated more deeply.

4 Conclusion

The potential of product-service systems (PSSs) is undisputed. Today, products like mobile phones are only working because of the integration of services and (material) products. In the future, PSSs will enable solutions which are more flexible and adaptable to individual demands and needs. In this paper, the authors outlined a first step towards a consistent classification of characteristics and properties of PSSs as a starting point for developing them.
A framework for the designing of PSS based on the presented classification already exists [Weber&Stein&Bot04].
A next step is the detailed examination of the relations between properties and non-material characteristics of PSSs. While the synthesis of material characteristics out of required properties is, in principle, a well known topic in engineering (design) research and practice, methodologies to synthesize services systematically only exist in a very preliminary stage.
Furthermore, the whole life-cycle of PSSs and their quality perception by the user seems to be a very interesting field for future consideration.

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