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RESEARCH TASKS AND POTENTIALS IN PRODUCT/SERVICE-SYSTEM DEVELOPMENT

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ABSTRACT

Product Service Systems (PSS) research is a growing discipline combining engineering design with economics. PSS widens the scope of traditional product development to encompass the whole range of possible interactions between producer and customer as part of a diffuse design space. In this paper, the authors aim to illustrate research tasks and potentials. A model framework is presented, which might aid the dissemination of PSS concepts. A transfer of implementation know-how and experience from the field of EcoDesign towards PSS is proposed. One of the problems of EcoDesign in the past has been the emphasis on theoretical findings, neglecting considerations of practical application. The presented approach constitutes the basis for future research work at TU Darmstadt. It serves as a frame of reference for a systematic treatment of PSS, their environmental properties and implementation related issues.

Keywords: Product/Service-System (PSS), PSS development, terminology, implementation research

1 INTRODUCTION

Services and products nowadays have become strongly related with each other, and there is virtually no service without employing any physical product and vice versa. The combination of products and services into one offer is generally referred to as a PSS [1], [9], [10]. Related concepts can be found in the research of Functional Products [2], Service/Product Engineering [3], and Functional Sales [4]. In order to take advantage of the benefits of a combined product/service offer, businesses have to generate the offer in one integrated process of product design and service development. This increases the complexity by combining formerly separate processes. Not only engineering design, but also company organisations and marketing need to be incorporated. Furthermore, PSS is seen by many authors as a concept for potentially more environmentally friendly business.

For businesses interested in the PSS concept, little application oriented support can be given at the moment. Due to the complex nature of PSS, information on how to carry out this type of business effectively and efficiently is rarely available at present. The task of research institutes is to prepare generalized knowledge and experiences applicable to such companies. On the other hand, much has already been researched in this field. Therefore this paper aims at identifying the major research tasks and potentials in the PSS-related areas from an engineering design viewpoint.

2 MOTIVATION

Figure 1 shows the four steps approach to EcoDesign [13], [14], extended by a relation of the different research areas: PSS, Functional Sales, Service Engineering, EcoDesign, Design for X, Remanufacture, Recycle to the four steps. By studying the publications of the research community one can assume that there is a trend from the Re-PAIR stage to the Re-THINK stage. Looking at the field of PSS research, one cannot help noticing, that many researchers and research groups, have shifted their focus from EcoDesign to PSS during the past years.

But only a poor amount of EcoDesign approaches or methods are widely applied in industry. In the field of EcoDesign first methods where developed in a scientific way. Afterwards the researchers implement the methods into the industrial practice by matching or customising the methods to the needs of the company. Later on, first examples for the development of environmentally conscious products are realised.

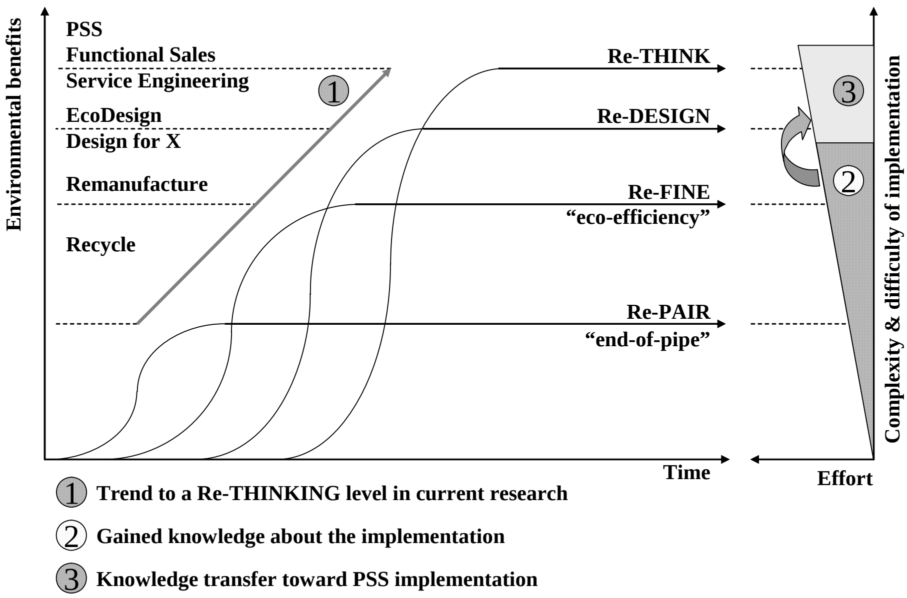

Figure 1: Modified model of the four steps approach to EcoDesign

In contrast, industrial case studies play a large role in PSS research. Since the enlarged focus of PSS makes implementation into companies even more difficult than the implementation of EcoDesign methods, many researchers work very closely with industry. The downside to this is the lack of a common (theoretical) understanding and terminology, which hurts the comparability of the studies.

The aim of our ongoing research is to establish similarities between EcoDesign and PSS, especially concerning the implementation. Thereby, a contribution to PSS research and implementation is intended, that makes the results of EcoDesign implementation research usable for PSS. At the same time, the structure provided by the more theoretical approaches in EcoDesign may be helpful in determining common properties of PSS from different case studies. In the next chapter both fields will be described considering the interrelation and especially the intersection between the research areas. The main aim of this paper is to transfer the gathered EcoDesign knowledge to the PSS field, and to come up with an approach for the implementation by using understandings resulting from the intersections. After the Collaborative Research Centre 392 "Design for Environment – Methods and Tools" [11] a Transfer-Unit 55 (TFU 55) "Optimised Processes, Methods and Instruments for the Development of Environmentally-Friendly Products" was implemented at Darmstadt University of Technology, which is funded by the Deutsche Forschungsgemeinschaft (DFG). The Transfer Unit's goal is to adapt the gained knowledge to industry needs and apply it into practice. The TFU 55 comprises six factually and temporally independent projects. In cooperation, four institutes and five industrial enterprises work on these projects.

3 PSS AND ECODESIGN

In order to establish, whether a utilization of implementation know-how and experience from the EcoDesign field to PSS might be advantageous, a literature study of the research landscape around PSS was conducted. The following sections detail the state of research in EcoDesign implementation gathered during TFU 55, the results of the literature study, and elaborate on the similarities between the two.

3.1 Implementation of EcoDesign

One conclusion drawn from the TFU 55 was that there is a multiplicity of different EcoDesign methods and tools, but only very few are widely applied in industry. Possible reasons for the lack of acceptance may be that the application caused a high expenditure of time and resources. Another reason is that a designer often does not see a connection between their profession and the delivered benefit of the applied methods. One can assume that the supplied methods do not fit very well to the demanded support of a product developer in a company. One condition for a successful implementation is that the EcoDesign methods have to fit the strategy of the company and contribute to the core values. Another condition is to customise the supplied methods to the individual needs of the company and the product developer. Therefore a concept for the implementation was created which considers three different levels. At the "company" level it is important to come up with an EcoDesign strategy for the implementation by defining environmental measures and targets and deriving measures for product categories. At the operational "project" level the strategy have to be broken down to the daily business. The main focus is the application of team based methods, the coordination of the requirements and the integration of measures into processes and structures. At the "developer" level the success factor is to meet the specific and individual requirement of the participating persons [12].

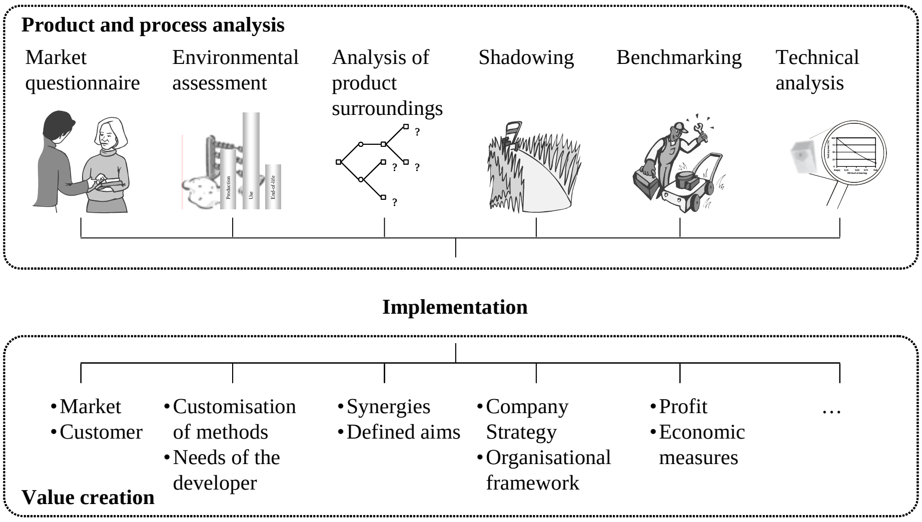

Figure 2: Implementation of EcoDesign methods

It is important not only to focus on a single aspect rather to look on the relations, the interactions and the expectations of the people involved. So we have to widen the focus towards other stakeholders, like the customer, the market, the company strategy, the organisational framework within the company, the processes and of course the market. A very important factor for a successful implementation is getting the people to understand the purpose of EcoDesign.
The existing PSS approaches focuses on the customer's wants and needs and on the process of value creation for the customer. Compared to EcoDesign theory customer's wants and needs are located in the use phase of the product life cycle.

3.2 Structuring the PSS field

First, a literature review was performed in the areas related to PSS development. Then those researches were characterized and analyzed to find out what has been done and what needs to be done. In more detail, 28 features (F) consolidated into four groups (G) were used to categorise the existing researches written about PSS and surrounding areas (see table 1).

Table 1: Groups (G) and features (F)

G	theoretical background	framework	implementation	environment
F	• definitions • characteristics • classification/ categorisation • historical basis	• research motivation • life cycle phases • infrastructure • company • customer • retailer • other stakeholders • other processes relevant for PSS • focused on service and/or product	• development process • management system • methods/tools • case-study (industry) • case-study (others) • benefits • driving forces • barriers • success factors • failure factors • regulation	• sustainable • rebound effects • environmental benefits • trade-offs

There are different models to classify PSSs. Commonly, three main categories (which are often followed by several subsections) can be found in literature (after [19]):

- *Product oriented* services as add-ons to products. The services offer an additional use, e.g. maintenance, warranty or consultancy
- *Use oriented* services without purchasing an artefact, e.g. renting or pooling of products
- *Result oriented* services do not integrate the service receiver into the process of value creation. The receiver sees the result only, e.g. the nightly cleaning of business premises

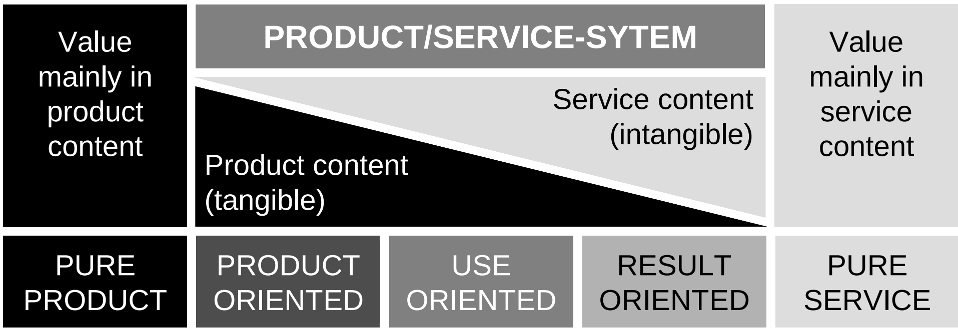

Figure 3: Categorisation of PSS [19]

3.2.1 Service/Product Engineering

A discipline called Service/Product Engineering (SPE), formerly called Service Engineering [3], [6], is being developed. SPE is a discipline to increase the value of artefacts and to decrease the load on the environment by reasons of focusing service. A service is defined as an activity that a provider causes, usually with consideration, a receiver to change from an existing state to a new state that the receiver desires, where both contents and a channel are means to realize the state change (after [18]). Service contents are provided by a service provider and delivered through a service channel. Physical products are either the service contents or the service channel. Thus, selling physical products is also regarded here as a service. Hence, a service receiver is satisfied with just contents, which are any of material, energy, and information. A service channel is used to transfer, amplify, and control the service contents. Note that SPE has both analytical and synthetic aspects. SPE aims at intensifying, improving, and automating this whole framework of service creation, service delivery, and service consumption.
The term “Service Engineering” (SE) – going back to the area of economics – originally describes the systematic development of innovative services [20]. SE is taken as a cross-section assignment which exists independently next to product and software development. By adapting methods and procedures from product development (e.g. standardised procedure models, component based development procedures) to service development, the authors expect a reduction of development cost and time and an increase in quality.
Research into method application has provided theoretical proof, that at least some methods of engineering design can be used in service engineering as well [17]. Among those are e.g. Failure Mode and Effect Analysis (FMEA) and the morphological box.

3.2.2 Modelling method of SPE

So far, a modelling methodology, an evaluation methodology, a design methodology of services and a computer aided design tool in a general form named Service Explorer have been proposed. Using Service Explorer, designers can describe services, and register them in a database, reload them, evaluate them, as well as design services from scratch using guidance functionality. In addition, they have been verified through several cases in industries such as a logistic industry [7] and an accommodation industry [3]. Verifications are being conducted at present, too, in Sweden, Germany, and Japan.
One of the most remarkable deliverables of SPE research is that a computer aided design tool has been developed. This implies that those methodologies to model, evaluate and design services, which are implemented to form a part of the software, are proved to be rigorously logical. Having implemented a computer tool has brought two benefits; one is the ability to manage various types of information effectively. The other comes from taking advantage of the power of computing. For instance, a

reasoning engine for abduction [8] would be able to discover a good analogy in a different field to let designers notice some clues towards innovative ideas in the concerned field. A service model in SPE consists of several sub-models; "flow model", "scope model", "view model", and "scenario model". The rest of this section highlights the view model after describing an important concept called "receiver state parameter". The reason for modelling "receiver state parameter" is as follows. Conventional design regards mainly the performance of physical products; it does not consider the state change of the receiver. Designing a service must be based on the degree of satisfaction with the state change of a receiver. Therefore, it is necessary to express receiver's state changes.

Receiver's state parameter

Receiver state parameters (RSPs) are classified into value and cost depending on whether the customers like them or not. The term "value" here is different from that in Value Engineering [15], where it is defined as function over economic cost. In SPE, value is defined as change of a receiver's state that he/she prefers, so that function is just a realization method to provide the value in SPE.

Flow model

When we focus on the relationship between a receiver and a provider, many intermediate agents exist among them. We call the sequential chain of agents "a flow model" of a service. This model is needed because in SPE designers are supposed to consider how organizations participating in a concerned service can be successful in their business.

Scope model

It is necessary to specify the effective range of the service from an initial provider to a final receiver. In comparison to the view model in which a single RSP is expressed, the scope model deals with all the RSPs within the provider and the receiver. In other words, a scope model handles multiple view models, namely multiple RSPs. Thus, it helps designers to understand the activities between the provider and the receiver.

Scenario model

This model represents receivers themselves using the concept of Persona [16] and their behaviours in receiving the service. This is necessary because the grounds behind RSPs of service receivers should be understood. In other words, scenario model serves as a direct source for producing a variety of RSP sets depending on customers' properties. Therefore, this will be a key element for understanding customers' needs and wants.

View model

A view model expresses the relationships among the elements of the service; i.e., the mutual relationships among the RSPs and FPs (Function Parameters: CoPs and ChPs). It should be emphasized that not only products but also service activities are modelled as measures to realize the service. Physical structures are represented using functions. It should be emphasized that view model works as a bridge between value represented in the form of RSP and physical structures and service activities.

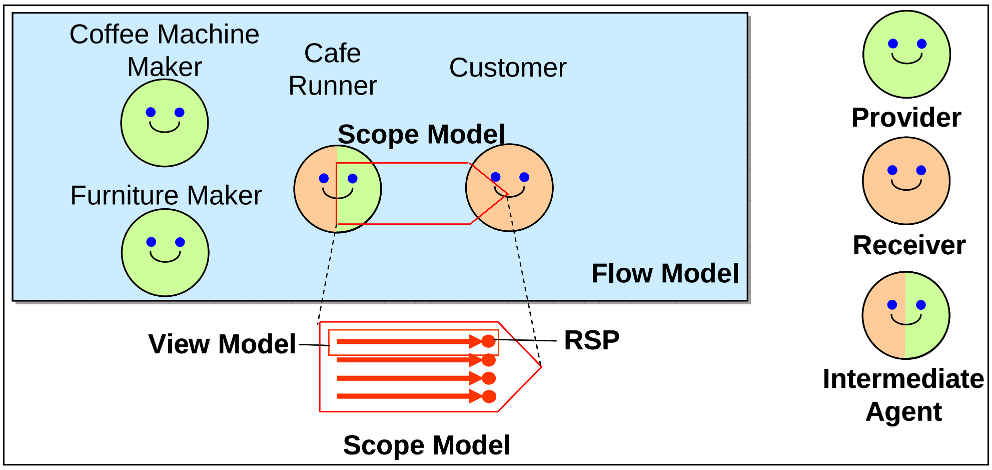

Figure 4: Sub-models of the service model in SPE

3.3 Similarities of PSS and EcoDesign research

In comparing EcoDesign and PSS approaches, a number of similarities were found. From an implementation viewpoint, the business functions and participants are of special interest. In EcoDesign, solutions need to be commercially viable; therefore a strategic decision is needed, weighing cost and market targets against environmental targets. This means, that the entry point for EcoDesign into the design process is (ideally) at the very start of the deliberations about company policies. The same applies for supplying Product Service Systems, since providing services in addition to or parallel with products touches basic business processes and competences.

Another similarity is in the focus on the customer. For the same reason of commercial viability, a lot of work in EcoDesign has been put into reconciling customer expectations with ecological targets. As an example, the various different forms of Eco-QFD (Quality Function Deployment) methodologies may be considered, e.g. according to Masui [22], Christofari [24], Zhang [23], and Ernzer [21]. Not only the customer, but specifically the use phase is at the centre of EcoDesign considerations. Since this phase is usually not within the control of the provider of goods, some work has been put into gathering information on, and influencing, user behaviour. This means that some of the addressees of EcoDesign processes and concepts are in marketing and after sales services. The question of how best to provide value to customers is also at the heart of PSS, meaning, that people in similar functions within the business need to participate in PSS provision. This suggests, that PSS implementation might run into some of the same problems, EcoDesign implementation is trying to solve now.

Lastly, it has been pointed out in chapter 3.2.1, that even some methods from the engineering domain have been shown to work in a service context.

In total, the similarities range from the business functions affected to the participants, the used tools and methods, the type of strategic decisions required and likely to the adverse preconceptions encountered in business process participants.

4 RESEARCH TASKS AND POTENTIALS IN PSS

The central issue of this paper is that development of PSS methods and tools has to be accompanied by an effort to develop implementation strategies. Experiences from EcoDesign implementation suggest that a development focused on resolving the conflicts of interest through theoretical deliberations will leave a gap between theory and practice, which will be hard to bridge once the developed methods reach the stage of evaluation in industrial application.

Given the current state of affairs in PSS research, the work at pmd is intended to promote utilization of PSS concepts in industry practice. Specifically, it is intended to support preparing and evaluating industry case studies in a way that improves the comparability and contributes to the building of a PSS theory with explanatory and, further down the line, prescriptive qualities. To this end, a framework model is proposed.

Furthermore, competences gained in EcoDesign implementation are to be utilized for future PSS projects. In the authors' opinion, the connections and similarities between EcoDesign and PSS, established in chapter 3.3, justify further efforts in transferring implementation know-how from one to the other.

4.1 Research Approach

Implementation, in the sense in which it is used here, means establishing the boundary conditions necessary to conduct a research project and evaluate it. In the context of an industry project, preparing both the theory being implemented and the company for the forthcoming project.

This includes:

- Determining the company processes and actors relevant to the project
- Determining the major outside influences, which may affect the outcome
- Adapting methods and tools to the specific requirements posed of the company, the actors, and the boundary conditions
- Providing information and tools to the actors involved

In order to formulate a theory about PSS, which allows analysis and comparison and, in consequence, generalizing findings from research projects, a careful and comprehensive stocktaking of these boundary conditions is necessary.

The step from determining descriptive findings to compiling an analytical theory is depicted in figure 5.

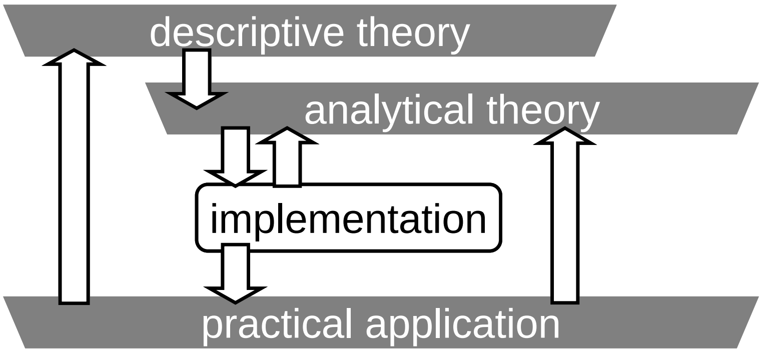

Figure 5: Implementation linking theory and practical application

4.2 Model Framework

A basic framework for PSS research could improve the comparability of research findings. We propose to utilize the product model pyramid and extend it in order to encompass PSS concepts.
The product model pyramid (PMP) in mechanical engineering illustrates the different levels of abstraction, on which a technical system can be considered.
The topmost tier in the PMP according to [25] is the "function" level, encompassing (see figure 6).

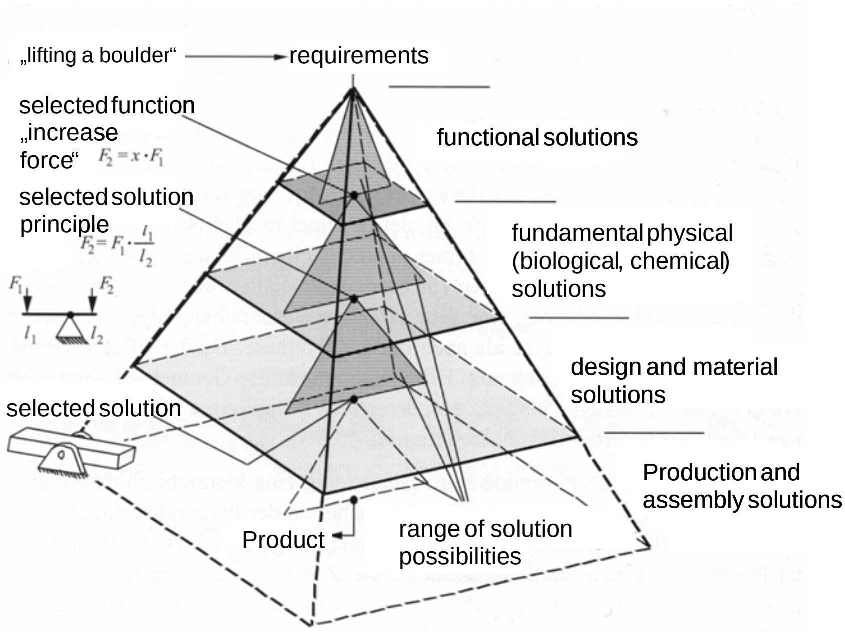

Figure 6: product model pyramid according to Ehrlenspiel [25]

In previous research [26] at pmd, another level above the functional description has been added. On this "process" level, the product is represented as a black box with the surrounding product system and the exchange processes in terms of material, energy and information streams. This representation incorporates the process model according to Heidemann (see figure 7).

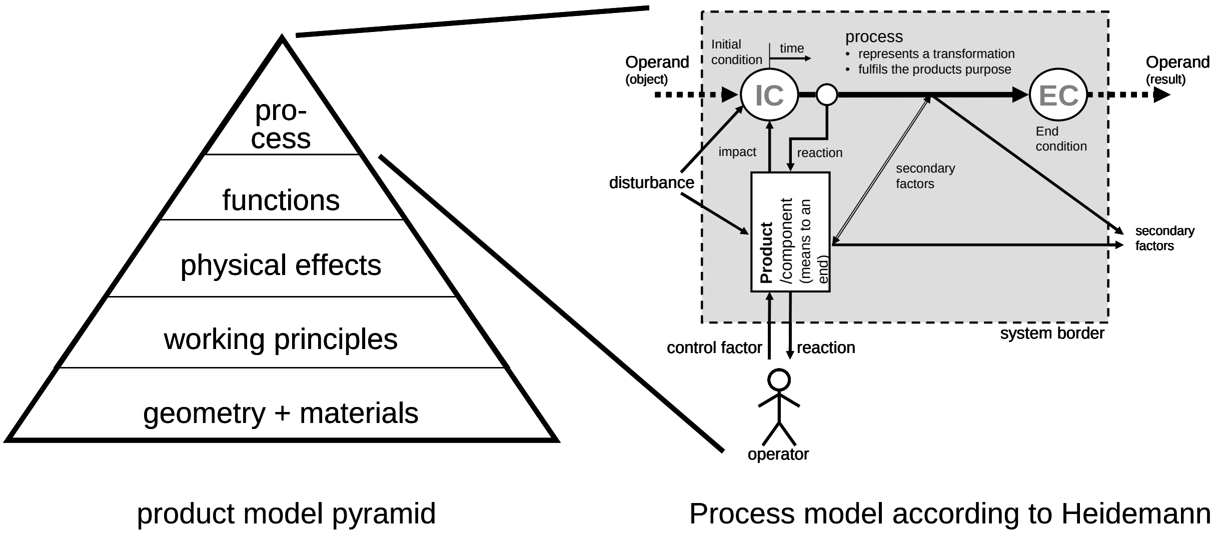

Figure 7: PMP and process model according to Heidemann [27]

The process model describes a state change of an object from an initial condition to a final condition through interactions with the product (deliberate and involuntary in form of side effects). Furthermore, interactions with the surroundings (disturbances, user interaction) are included. Although not technically a "product model", the product being represented only by a black box, the process model still defines the purpose of the product and its outward functions, and thereby contains information about the product on a distinct level of abstraction, above that of the functional level. Therefore an inclusion in the pyramid seems appropriate.

The process model bears a marked resemblance to the PSS definition according to [18] given above. Both product and service are described in terms of a state change. The question arises: What is the common denominator and might in consequence be defined as the new uppermost tier of the pyramid? As one possible answer, the concept of "value" is currently under investigation. If a conclusive model was to be found, it could serve to integrate product and services neatly into the model hierarchy. Given the level of abstraction that the PMP itself holds, it can not supplant practical approaches to PSS research such as descriptive case studies or developing simulation models like the service explorer. It may, however, provide a valuable basis for determining common features between different approaches and help bridging gaps between them.

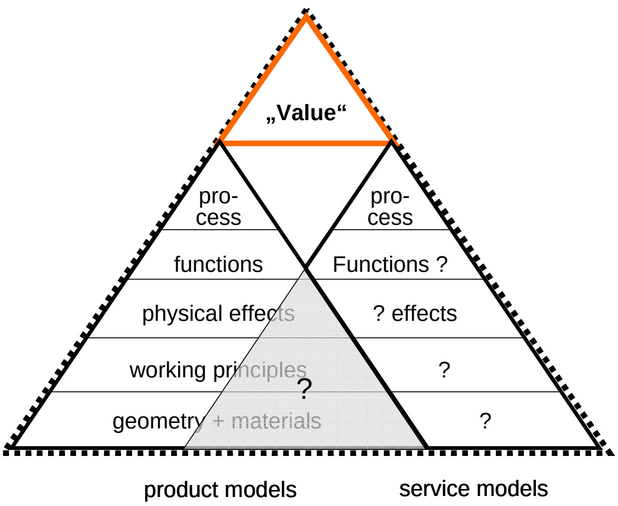

Figure 8: product and service hybrid model pyramid

5 CONCLUSIONS AND OUTLOOK

Although products and services are offered in a wide variety of combinations, a methodology of integrated PSS development is still in the early stages. In this paper, the congruence between EcoDesign and PSS has been discussed and a case has been made for PSS research to consider implementation issues from the start. It is the opinion of the authors, that thereby some of the problems facing EcoDesign implementation today may be avoided in PSS application.

Furthermore, an approach for supplementing the ongoing research efforts (e.g. [5]) by enhancing the comparability of research findings has been outlined. It may be used as a tool for collaboration between the different research initiatives.

Future work will aim to clarify the model of value and investigate the other service models in the lower tiers of the pyramid as depicted in Figure 8.

6 ACKNOWLEDGMENTS

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