Technical University of Denmark

Conceptualisation of Product/Service-Systems through Structural Characteristics

Tan, Adrian Ronald; Andreasen, Mogens Myrup; Matzen, Detlef

Published in:
DESIGN 2008

Publication date:
2008

Citation (APA):
Tan, A., Andreasen, M. M., & Matzen, D. (2008). Conceptualisation of Product/Service-Systems through Structural Characteristics. In DESIGN 2008: 10th International Conference on Design

INTERNATIONAL DESIGN CONFERENCE - DESIGN 2008
Dubrovnik - Croatia, May 19 - 22, 2008.

CONCEPTUALISATION OF PRODUCT/SERVICE-SYSTEMS THROUGH STRUCTURAL CHARACTERISTICS

A. R. Tan, M. Myrup Andreasen and D. Matzen

Keywords: product/service-systems (PSS), conceptualisation, service design

1. Introduction

Many manufacturing companies today are considering shifting their business strategy from a product-orientation to service-orientation, where instead of the product itself, the activity and knowledge associated with the use of the product is considered to be of more value to the customer. In the research community, this approach has been dubbed *'product/service-systems (PSS)'*. Until now most of the research has looked at the economic and environmental benefits of adopting such business strategies, whilst little attention has been given to the systematic design and development aspects of PSS [Mont 2005]. In the area of product design, it is essential in the synthesis of new products that theories are formulated about products' structural and behavioural aspects as well as the relations between these attributes. When we want to expand a company's business to also include services that support their products, we are confronted with a problem. It appears that no corresponding theories have crystallised about PSS's structural and behavioural attributes, and there exists no such creation of mindset for conceptualisation based upon the nature of service in design and its interaction with products, users, and the user's or customer's activities.

This paper focuses on the design object in PSS approaches, i.e. the combination of product and service offerings. Our question here is, *what does an appropriate model for design of PSS offerings look like?* Several researchers, mainly from Germany and Japan, have tried to look in to this. Weber et al. [2004] have attempted to model PSS based on what they call a Property-Driven Development approach. The basic principle in this approach is the clear distinction [Mortensen & Andreasen 1996] between *characteristics* (in German: "Merkmale"), which describe the structure and components of an artefact, and *properties* (in German: "Eigenschaften"), which describes the artefact's behaviour. Although the researchers propose a schema for characteristics and properties of services, this has not been well integrated with products; particularily the role of the customer in services is not clarified. Japanese researchers [Shimomura et al. 2003] on the other hand use the approach of 'Service Engineering' that uses the customer's state change as the starting point for design, and then develop activity chain models for capturing the interaction of product, service and customers. The Japanese researchers are currently developing a computer aided design (CAD) tool that assumes a conceptual framework for service design. In this paper, we will investigate the structural characteristics and behavioral properties of service systems that form this underlying conceptual framework for service design. This paper postulates that services and products are bounded together by the user's activities, that services are delivered or executed in a transformation system [Hubka & Eder 1988], and that both products' and services' business aspects are based on value relations to the customer. The objective of this clarification is to allow the conceptualisation of new PSS to happen as a systematic pursuit of new solutions as it is known from engineering design.

2. Research approach

The research in this paper is a review based upon the modelling of PSS in design. We start by considering Hubka's Transformation Model [Hubka & Eder 1988], a dominant model used in the synthesis of products. Here, we attempt to see how this approach can bring the product, service and use activity together in a PSS transformation model showing the conceptual idea of a PSS. We also look at customer-centric approaches used in service design and then discuss how this contributes to an understanding of the conceptual aspects of PSS. Throughout the paper, we will use examples of PSS and their application and towards the end, we explain how we use this understanding when teaching courses in PSS design. Finally, we point to critical directions for future research in PSS design.

3. The synthesis of products

Hubka's Transformation Model [Hubka & Eder 1988] splits traditional function reasoning [Pahl & Beitz 1996] up into two kinds of functionality:

- the product's function seen as the product's ability to deliver desired effects,
- and the transformation created by using the product.

The first one is related to the product's structure, the second one is related to the technology (or activity) of using the product, i.e. the interaction of product, user, context and the operand which is transformed. A drilling machine delivers rotation and torque (functions); it can be used for drilling holes, whipping cream, mixing paint, etc. (technologies) resulting in desired transformations or end results: holes, whipped cream, mixed paint (operands).

Based on Hubka's theory, Andreasen [1992] has proposed that product's structural attributes are called *characteristics*; and the behavioural attributes are called *properties*. Properties in this perspective include function, functional properties and product life oriented properties. To exemplify, a bicycle's characteristics are the materials, shape, dimensions and surface textures. A bicycle's properties are e.g. weight, friction of gears, cost, ease of maintenance, etc. The isolation of the product's use process and the overall focus on activities associated with the product's life cycle has an essential importance when we approach services. The model of the transformation system [Hubka & Eder 1988] is key (Figure 1). It shows the product's primary utilisation activities (preparation, executing, finishing) and that operators transform primary operands and secondary auxiliary operands on the input side; and by-products on the output side – all of these in the form of either material, energy and/or information.

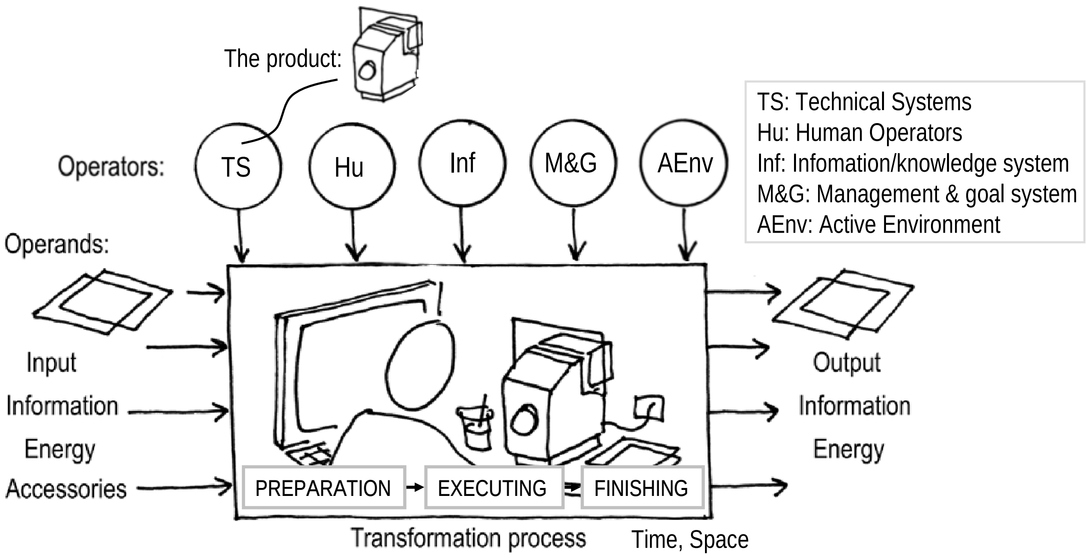

Figure 1. Illustration of the use of a product in a model of the transformation system, showing operands and operators [Hubka & Eder 1988].

The transformation process elapses in time and space based on influence from a series of operators:

- *Technical systems* (i.e. products) based on these systems' functionality.
- *Information systems* that provide the necessary information for the transformation, e.g. installation guidelines, recipes, know-how, instructions, knowledge of the phenomena, reference data, etc.
- *Management and goal systems* that manage and control the activities and the systems' coordination, certification, norms, standards, etc.
- *Active environment and conditions* in the form of physical surroundings, socio-technical conditions, societal conditions, financial circumstances, etc.
- *Human systems* that on one hand can be contributing operators, and on the other, the persons in the transformation process that act as carriers of and channels of information, control, management, etc.

Hubka's model points in this way at the following:
- A product's utility only emerges when it is used or employed in a transformation process or activity.
- The product cannot perform the transformation process on its own, but requires interaction with other operators who are responsible for the product's use.
- The product's utility value for the user is dependent on the output of the transformation process.

Seen in the light of the Transformation Model, the user's perception of value is composed of the activity's output and the factors influencing the achievement of results and the quality of the output; the functionality and quality of the product; as well as the influences and appropriateness of the other factors. The relative importance of these influences is of course dependent on the nature of the product and the actual stakeholder or user in question. For example, a typical leisure product such as a mountain bike may lead to a value perception mainly composed of the emotional (e.g. the thrill of mountain biking), social significance (e.g. identifying yourself with the outdoor environment) and the industrial design aspects of the bicycle.

Andreasen [1992] interprets Hubka's theory as a determination of the structural characteristics in three domains (the Domain Theory): *activity domain* – leading from and interpretating the transformation aspects we have presented above; *organ domain* – the functional entities of the product and their physical realisation; and *parts domain* – the product's production oriented materialisation. In the above we focused on the central use activity, but in actual fact all activities related to the product's life cycle should be taken into account, because they may influence and be influenced by the product's design. This approach is called '*Product Life Thinking Approach*' [Olesen 1992] and applied in Design for Environment approaches [McAloone 2001].

Seen from a conceptualisation point of view the Transformation Model, Domain Theory and the Product Life Thinking Approach are expansions of functional reasoning, mode of action finding and embodiment approaches for conceptualisation. Understanding existing products' actual life cycle and use, or creating scenarios capturing the believed raison d'etre of new products may be used for identifying proper roles, functionalities and qualities of a product, and thereby creating high user perceived value. Summing up the theories introduced here and the rich understanding of relations between product characteristics and properties related to product life aspects (DfX-areas [Olesen 1992]) gives us a good foundation for product design.

4. Identification of structural characteristics in service design

As our focus and intention in this paper is the combination and utilisation of service thinking in industries that traditionally sell physical products, we will in the following take a look at the product's *service period*, i.e. the period in which the product serves the user by being able to do what it is meant for. Supporting, maintaining and ensuring this service may be enhanced, simplified, or ensured by adding services delivered from outside (seen in relation to the user and his/her system). As we shall see in the following, these services may be in the form of physical artefacts, manpower, activities performed, etc. So our questions in this section are: What types of service can be delivered? What are their constitual characteristics? What do they add to the value perception of the customer? Or in other words: Why do they contain new business possibilities?

If we look for services in Figure 1, we can imagine that we as an outside supplier may substitute any of the following and thereby act as a service supplier:

Delivery of goods:

- Technical systems (e.g. auxiliary equipment in a printing house)
- Primary operands (primary input material, e.g. paper for printing)
- Auxilary input (e.g. lubrication, colours, adhesives, cleaning agents)
- By-product operands (e.g. packaging removal, air filtering)
- Hardware as carriers of information and management systems

Delivery of non-goods:

- Information flow and processing (e.g. printing texts, layouts, pictures)
- Management flow (e.g. control, proof reading, production planning)
- Space (e.g. rented facilities, warehousing, internet, utilities, road access)
- Time (e.g. services accessibility and readiness, timeliness, response)

Delivery of man-power:

- Human systems (e.g. operators, support, managers, organising)

This 'service' interpretation of the Transformation Model, however, does not lead us to all types of services. First and foremost, services are not only deliveries, but can also be "insurance", i.e. services that are only prompted and provided in the case of failure, late delivery, machine down time, accidents, etc. From this perspective, financial support to maintain operation or compensation for down time is also a service. The above model of products' and services' interaction and importance to the customer's activities is to start with very fundamental and does not tell us much about the customer's activity cycle, service content and channels or their value to the customer. We choose therefore to include four other contributions to PSS design in order to attempt to integrate the different perspectives. These are *Service Blueprinting*, *Customer Activity Cycle*, *Network of Actors* and *Service Engineering*.

4.1. Service Blueprint approach

One of the early researchers in the area of service design, Shostack [1982] proposed a conceptual model for deploying a service idea. It maps user experience in relation to time, resources, and stakeholders. Figure 2 shows an excerpt of an illustrative example of a service blueprint. The user's or customer's chain of activities is laid out as the backbone of the model and the related physical evidences are denoted (we call these the active environment and conditions in Figure 1). The blueprint's service activities are modelled as person related activity chains that are engaged with the customer's activity chain. This form of modelling allows – as Shostack shows in other examples – an integration of artefacts and activity types of services, but do not show the reasons (or value relations) for the customer's interest in services.

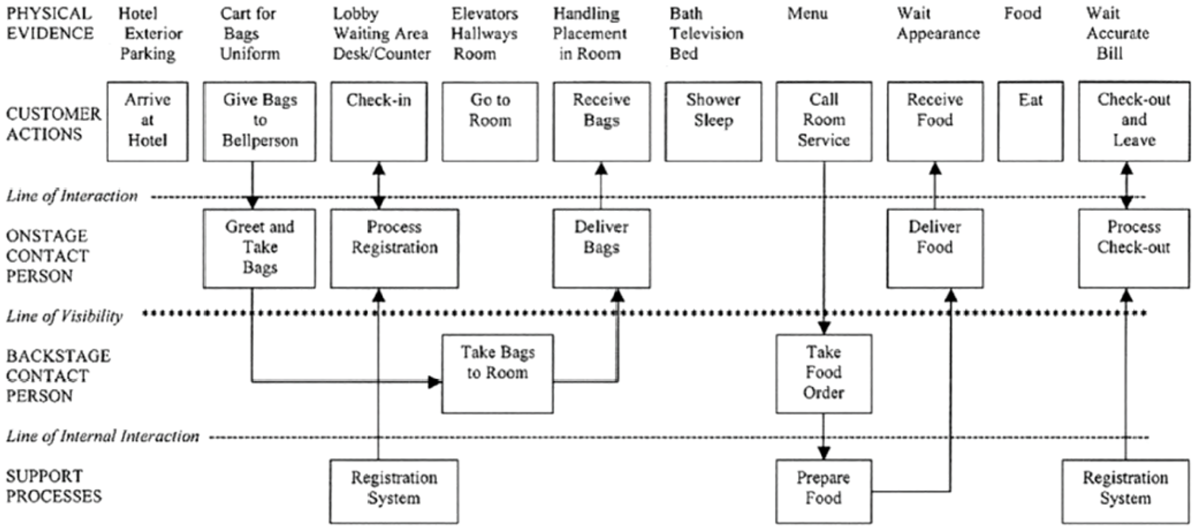

Figure 2. Excerpt of a Service Blueprint for service activities related to a hotel stay [Shostack 1982].

4.2. Customer Activity Cycle approach

Vandermerwe [2000] elaborates on how companies may focus on customer relationships through a methodology called *'Customer Activity Cycles'*. Its focus is on the activities that customers go through to get the benefits of the offered products and services. A customer activity cycle consists of three stages; *pre* - what goes on before the customer achieves the result; *during* – what happens while the customer derives the core benefit; and *post* – what happens after the experience. Vandermerwe states that the Customer Activity Cycle model can help to enable companies to identify offerings that they should strive to provide with value - either directly or indirectly.

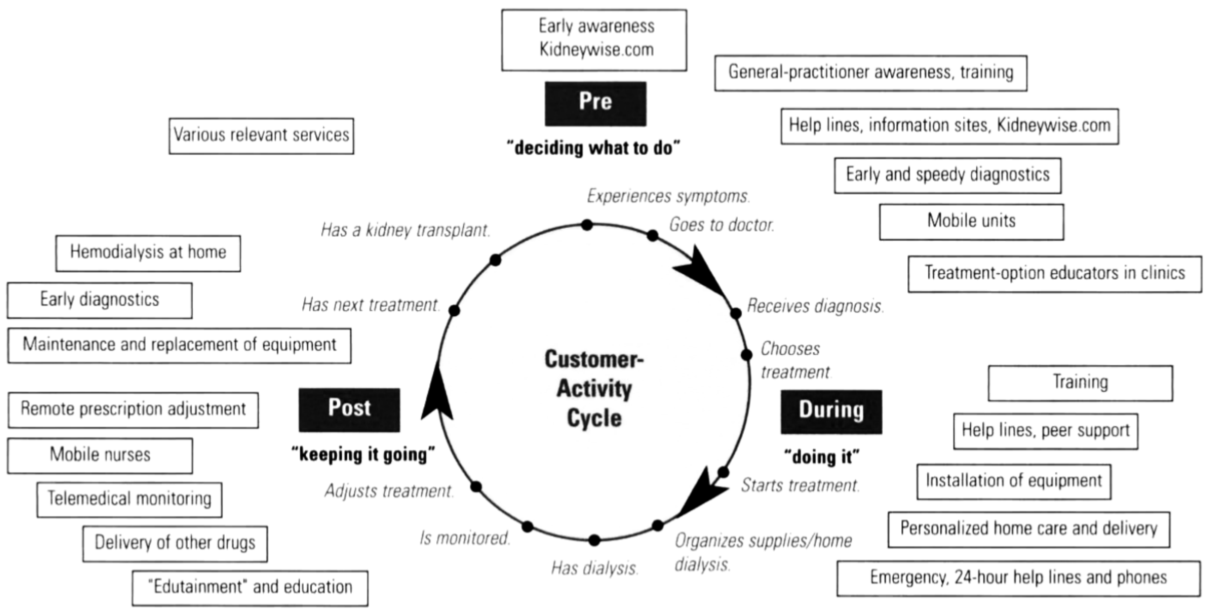

Figure 3. Example of a Customer Activity Cycle for patients with a serious kidney disease [Vandermerwe 2000].

4.3. Network of actors

Services are often not just delivered by one party, but often demand a network of actors to provide the service [Mont 2004]. By mapping the system of actors and the relations between them, an overview is created of how the actors are organised in order to provide the service. Here we can identify how value is generated in the whole network through service provision, financial, material, energy and/or information flows. This view can be used to reveal opportunities to include other actors and stakeholders not considered in the current system, as well as how relations can be established and maintained.

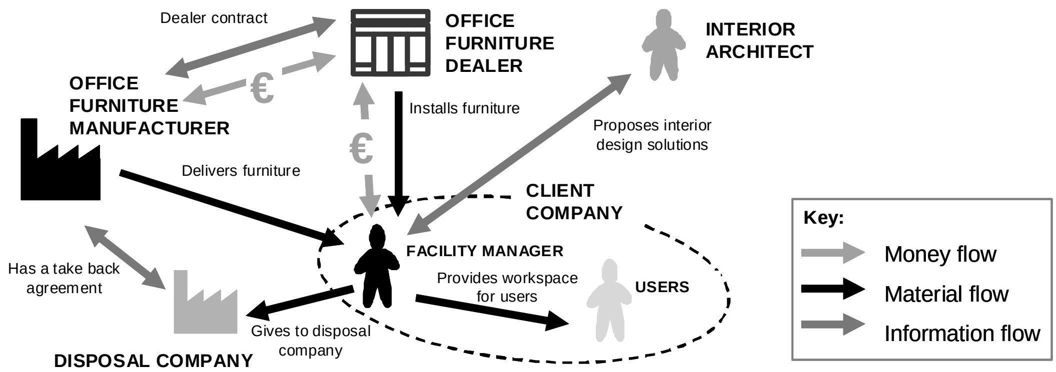

Figure 4. Example of a mapping of an actor network for office furniture with actors and how they relate to each other.

4.4. Service Engineering approach

In a series of articles [Shimomura et al. 2003] a group of Japanese researchers have proposed a conceptual framework, models and a design approach for what they call ‘*Service Engineering*’, i.e. they adopt an ‘engineering’ viewpoint on PSS design. The core model is shown in Figure 5. A service is an activity that entails a change of state of the *service receiver*. The receiver should probably be thought of as a metaphor, not (only) the person, but also what he/she does, when his/her activities change state. The *service content* is by nature material, energy and/or information, while the *service channel* can transfer, amplify and control the service content, and influence the state of the receiver indirectly.

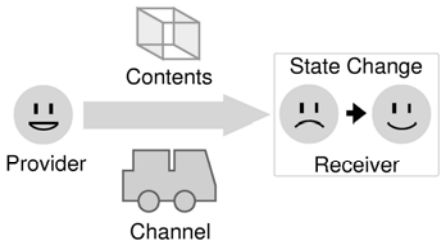

Figure 5. Elements of a service [Tomiyama 2001].

If we take the example of a bicycle rental service; the *service receiver* could be the person renting a bike; the *state change* could be transportation from one part of town to another; the *content* could be the rented bike; the *channel* could be a bike rental station; and the *provider* would be the company or companies offering the rental service. In order to describe the reciever’s state change and the active conditions in the service content and channel in Service Engineering, the wellknown concept from design methodology of function is applied. Besides its name, a function is described by function parameters (target parameters) and function influences, i.e. the function’s effect on the function parameters. Reciever’s state, service content and channel are also described with parameters. Hereby it is possible to tie functions and services together as shown in Figure 6.

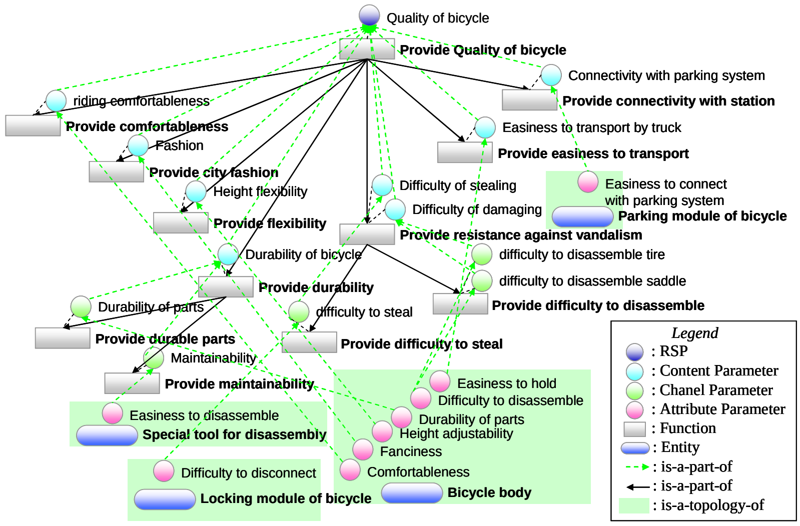

Figure 6. Service Engineering's view model of functions, channels, content and receiver state parameters (RSP) in the case of a bicycle rental service [Sakao 2006].

As it is shown in Figure 6, the quality of the bicycle in this case are described by functions that are achieved through the bicycle body, the parking module, the bicycle lock and the tool used to disassemble the bicycle. These entities have channel and content parameters that in turn determine the receiver state parameter. Three models are used in the SE approach:

- A *view model* as shown in Figure 6, which describes the structure of functions that change the reciever state parameter and shows the service's channels and contents.
- A *scope model*, which express the target range of a service: From whom to whom is the service delivered? What receiver state parameters are influenced? The scope model handles the multiple view models of receivers and providers.
- A *flow model*, showing how service provider, intermediate agents and receivers are related. This is similar to the network of actors presented in 4.3.

As we will see in the next chapter about PSS's behavioural attributes, the scope and flow models play an important role in the determination of value relations and service's behavioural dimensions. The research group behind Service Engineering has created an active, knowledge-based computer system to support the development of PSS (Service Explorer). Besides managing the mentioned models, the system also contains a knowledge management system with knowledge about active function carriers, also known as function prototypes.

5. Conceptual PSS

Based upon the models and examples above we arrive at the following insights concerning the nature of a service:

- *The characteristic of a PSS follows the product:* From our scope of industrial change, the character of a PSS is linked to the manufacturing company's products. We do not need to go into details with the structural characteristics of products as we have a developed theory about the fundamental set of characteristics of a product (Theory of Technical Systems), but we have to be mindful with the following characteristics.
- *The service characteristics follow the transformation:* A service is related to one or more steps in the activities, that are arranged by the user him/herself or that he/she gets involved with. The characteristics may belong to any of the product's life phases: the design and specification of the product (delivered by a projecting company), the distribution/installation/domestication, the preparation/execution/finishing of the use of the product, the maintenance, and/or the disposal of the product.

- *Service is characterised by the service channel:* How should we understand the service channel? Services are channelled through the transformation process' operator system. We envision the following types of channels:
    - *Human systems.* We saw in the service blueprint example that the operators were the primary focus of delivering the hotel service. Through direct participation and influence in the customer's activities, services that could belong to other channels, e.g. such as information or management, are provided.
    - *Technical systems.* This channel includes "the sold product" that determines the customer's activity process, e.g. a printing machine used in newspaper printing, but it could also be other technical products, such as auxiliary equipment (e.g. for cleaning, for packing newpapers, etc.)
    - *Information systems* that could provide the data about use, technical know-how, operational experience, layout support, production data, etc.
    - *Management and goal systems* that channel control, management, certification and deliver production plans.
    - *Active environment and conditions*, e.g. in the form of space, work traditions, agreements, social status for operators, etc.

  Besides service that is channelled through the operators in the transformation process, service providers can enhance activities with new or adjusted content that is connected to the customer's activity cycle, as e.g.:
    - *Supplying auxiliary input:* If we were to continue with the newspaper example, a delivery system for glue, printing ink, cleaning agents, etc., could be offered.
    - *Removal of by-products*: This could be air filtering, wastewater purification, waste removal, etc.

  A general model for the service channels could look like what is shown in Figure 7.

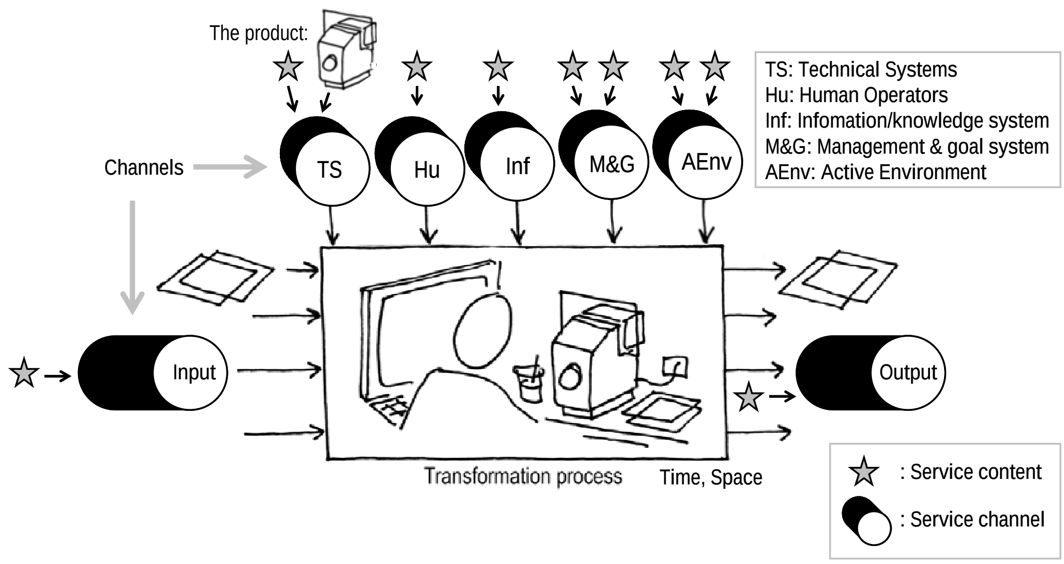

Figure 7. A proposal for categories of service channels in relation to the transformation process in a customer's activity cycle.

- *Service is characterised by the service activity:* The service should interfere with the transformation activity. In most cases, the service is of a dynamic nature: humans are taking action, information is delivered, management is established and operating, etc. In some special cases though, the service can be of a risk dependent nature: only if an accident or fault occurs, will the service be initiated. The pattern of service deliverables may be a single operation, a repeated delivery or a cyclic repeated sequence (as shown in the Customer Activity Cycle model).

- *Service is characterised by the stakeholder's network pattern and value enhancement:* Delivering a service does not become a business relation unless the stakeholders experience benefits, here in particular the user and his/her activities. The enhancement of value can be based upon many types of quality enhancements related to the purchasing, installing, operating, maintenance, and disposal of a product. We will propose a preliminary model of PSS properties in the next section.

These five PSS characteristics cannot be captured by one model or a set of interrelated models. We foresee that we at present may rely on a set of only partially related models of transformations, technologies, activities, channels and their operation, service activities, service stakeholders, and value enhancements. It is surprising that most of the insight to be established during conceptualisation of PSS should actually also be present when conceptualising products. The reason that this is not usually the case is that market and customer relations are managed by the sales/marketing organisation, and generally not considered a major influence on the design of the product. Companies follow the main stream or make risky guesswork. The conceptualisation of a PSS may take its starting point in any of the mentioned five charactistic groups or their sub topics. We believe that close insight into the user's operation and problems, and his/her value perception is a basic condition for being able to design successful PSS. To sum up, we might say that a service's characteristics are a set of characteristics relating to the:

- product characteristics;
- transformation characteristics;
  - characteristics of the technology related to the application of the product;
  - characteristics of operators belonging to the product's use;
- service characteristics;
  - characteristics related to the technology related to the service;
  - characteristics of operators belonging to the service's channel and execution.

6. Behavioural properties of PSS

A general trait of a man made system is that structural design leads to certain behavioural properties when the product is established and in use, such as function, functional properties (performance dimensions), production properties etc. However, the user determines by his perception, preferences, experiences and value references, what he percieves as important properties of the system. Therefore, the designer is only partially able to create the value pattern and often the launch of a product on the market becomes a flaw because of a wrong interpretation of the users' wishes.

Based upon the identification above of the structural characteristics and the composition of a PSS, we will give a short and preliminary proposal for PSS property classes, which can serve as an inspiration for identifying the important value relations between stakeholders as pointed out by Tomiyama [2001]:

- *Activities' performance follow the 7 Universal Virtues:* In his thesis Olesen [1992] proposes seven classes of properties of an activity seen from the perspective of the stakeholder that is interested in the operation and the result of the activity: *cost, quality, time, efficiency, risk, flexibility,* and *environmental effects*. Take note that this set of classes differs from the traditional property classes related to products, as proposed for instance by Hubka [Hubka & Eder 1998] or Pahl & Beitz [1996]. The activities related to a PSS may be both the product life activities and the activities related to the channels (the vertical patterns in Figure 7). If we change the stakeholder perspective from the owner or buyer to the actor in the service or product life activity, we will expect another set of values.

- *Operators experience PSS usability:* Figure 8 shows a general breakdown of a system's acceptability [Nielsen, 1993], in which the owner's and the operator's interests intervene. In the operator's experience of usability we find important aspects, but dimensions of ergonomic properties are missing in the quoted source.

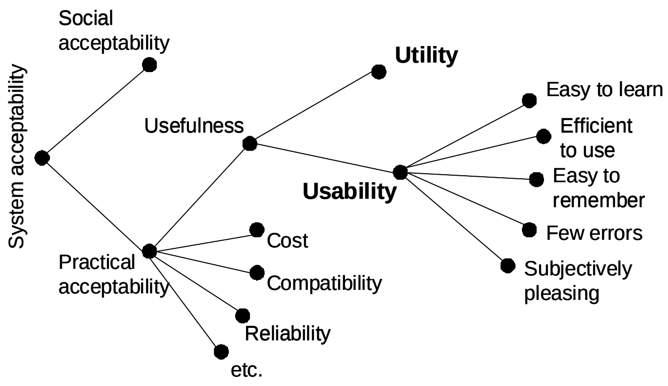

Figure 8. A proposal for categories of service channels in relation to the transformation process in a customer's activity cycle [Nielsen 1993].

- *PSS availability and risk are the responsibilities of the provider:* In the performance and usability dimensions, interwoven dimensions determine the availability and, in exceptional situations, breakdown and failures or absent deliveries. Seen from the provider's perspective the risk dimension is important, and several types of services are based upon risk minimising: systematic maintenance, operator training, insurances, etc.
- *The PSS is also a matter of soft qualities:* Like consumer products, clothes and cars, PSS may also be related to soft qualities, which the buyer/user balances against the price, brand reputation, esteem qualities, product history, promotion, etc.

These four property classes are overlapping and not a complete set of properties recognised by owners/buyers/users. However, the list can serve as an inspiration when we have to judge the content of a value relation between a supplier and a customer: Are the new properties attractive enough in the relationship to activate a payment? Figure 9 shows a simplified example of a PSS with focus on the representation of main properties influencing the stakeholder's value perception.

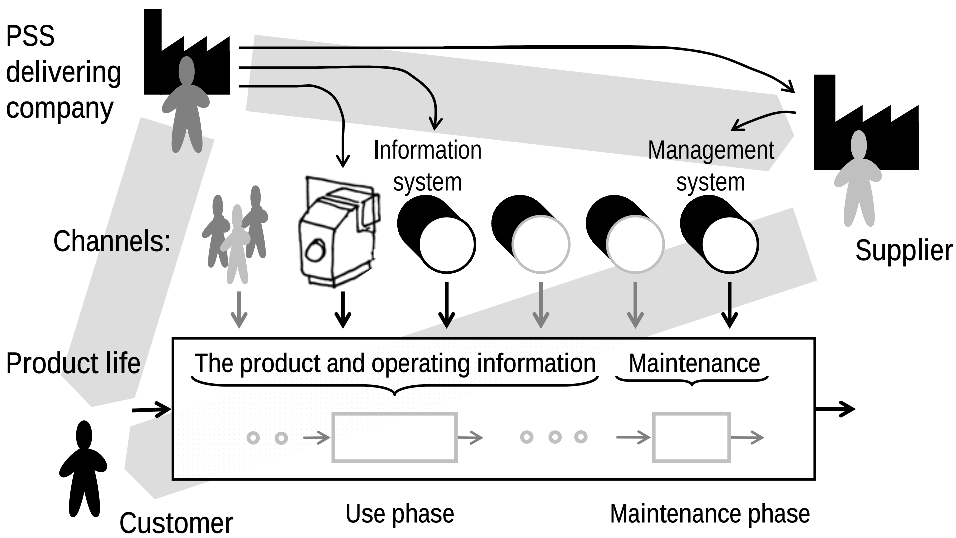

Figure 9. A simplified pattern of product(s), services, channels and transformation activities in which suppliers operate to deliver PSS.

So in order to conceptualise a PSS, not only does the product and its functionality has to be defined, but we must also describe the transformation and service activities, how these are influenced by various kinds of service channels, and finally how these channels are in turn provided by a supplier network. In Figure 9, a printing machine (product) is manufactured by a company and installed at a publisher (customer). The machine has built-in sensors that gather operating data (information system). This data is sent back to the company, which then analyses and diagnoses the machine and monitors it whilst in operation. The company collaborates locally with a service provider (supplier) that manages and maintains all of the publisher's printing equipment (management system). Recommendations of predictive maintenance are given by the company to the service provider that then executes these instructions at the publisher's facility. The service provider works together with the publisher in planning printing production and ensuring that the equipment is fully operational when needed. The manufacturing company collects operation information of the printing machines and can regularly update the printing machine, or if the publisher's printing needs have changed, take back the printing machine and instead offer a different machine that is more suited for the task.

7. Discussion and Conclusion

Conceptualisation of PSS may take its starting point in nearly any of a PSS's attributes and elements. Based on other researcher's work in different dimensions of service design, we have in this paper presented five dimensions of characteristics of PSS:

- the initial product the PSS is based on;
- the activities the user and product is part of;
- the service channel in which services are delivered;
- the conditions in which a service is active in a transformation activity;
- and the network of actors and stakeholders that mutually benefit from providing and receiving products and services.

It has not been possible to capture all these different characteristics in one model, but have to use multiple perspectives to grasp PSS concepts. Although PSS approaches represent an expansion in the degrees of freedom in design, it is notable that these aspects should also be present in the conceptualisation of traditional products. Due to the way companies currently design and develop, manufacture, market and sell industry products, these "new" aspects of conceptualisation are often not considered systematically. The behavioural properties in design cannot be determined directly, but emerge when the the structural characteristics are confronted by different actors and their activities. In this sense a designer will never be able to fully control the use of products and services. Only by insight into the user's or actor's activities, problems and value perception can the designer hope to achieve the desired properties of a product or service. The properties that are essential in the design of PSS were briefly considered in this paper. Here the performance of activities, the usability of PSS, risk and availability, as well as soft qualities were suggested, but this is not comprehensive. The structural characteristics and behavioural properties presented in this paper still need to be verified by applying them to empirical PSS case studies to see if they are able to identify and articulate the conceptual aspects of a PSS appropriately.

At the Technical University of Denmark (DTU), models and approaches for PSS design and enhancement are presented to students in courses on Product Life Thinking and PSS design. These courses have been given to about 50 students each year for the past four years. In their PSS projects, students are encouraged through the models presented in this paper to consider the multiple dimensions of PSS characteristics and properties, achieve insight into the actors and stakeholders, as well as the activities related to the product. The students are asked to improve the system and conceptualise the PSS's value propostion and activities; sketch the actor-network; explain the relationship between the actors and the PSS; as well as model the physical artefacts in the service system. They are also asked to determine the anticipated economic, social and environmental advantages of this new concept. In this context the characteristics presented in this paper seem to adequately capture and describe the essence of new PSS concepts. However, following the efforts in the product design area for creating a systematical and creative supporting methodology and creating computer support for designing, the area of PSS conceptualisation needs further steps.

Research in the design and development of PSS is still premature, but increasing interest from both industry and academia should develop this field immensely in the next few years. The research presented here is part of a joint effort of a research community in PSS design. Since May 2006 researchers in engineering design and product development from Japan, Sweden, Denmark, Germany and France have met at least twice a year to exchange and discuss ideas and research results from academia and industry. Research in PSS design has for the most part been conceptual and rarely studied in the context of manufacturing companies. The researchers of this paper intend to further develop models and theories of PSS design and confront them with empirical observations of companies actually involved in the development of PSS. For now the research stands untested and indeterminate, but currently research is being done in industrial projects for manufacturing companies in various branches such as ship building, office furniture and refrigeration control.

References

Andreasen, M.M., "The Theory of Domains", Working paper, Institute for Engineering Design, Technical University of Denmark, 1992.

Hubka,V., Eder W.E., "Theory of Technical Systems", Springer-Verlag, Berlin, Germany, 1988.

McAloone T.C, "Confronting product life thinking with product life cycle analysis", Proceedings of 2nd International Symposium On Environmentally Conscious Design And Inverse Manufacturing - EcoDesign 2001, Tokyo, Japan, 2001.

Mont O., "Product-service systems: Panacea or myth?", PhD dissertation, The International Institute for Industrial Environmental Economics, Lund University, Lund, Sweden, 2004.

Mortensen, N.H., Andreasen, M.M., "On the Identification of design Feature Characteristics", Proceedings of Produktmodeller '96, Linköping University, Linköping, Sweden, 1996.

Nielsen, J., "Usability Engineering", Academic Press, Inc, Boston, USA , 1993.

Olesen, J., "Concurrent Development in Manufacturing – based on dispositional mechanisms", PhD thesis, Institute for Engineering Design, Technical University of Denmark, 1992.

Pahl, G., Beitz, W., "Engineering Design: A Systematic Approach", 2nd edition, Springer-Verlag, London, 1996.

Shimomura, Y., Watanabe, K., Arai, T., Sakao, T., Tomiyama, T., "A proposal for service modeling", Proceedings of the 3rd International Symposium on Environmentally Conscious Design and Inverse Manufacturing - EcoDesign'03, Tokyo, Japan, 2003.

Sakao, T., "Example: Bicycle rental service in Lyon - Vélo'v", Presentation slides, PSS Workshop at the Technical University of Denmark, November 2006.

Shostack, G.L., "How to Design a Service", European Journal of Marketing, 16(1), 1982.

Tomiyama, T., "Service engineering to intensify service contents in product life cycles", Proceedings of EcoDesign 2001: 2nd International Symposium On Environmental Conscious Design And Inverse Manufacturing, Tokyo International Exhibition Center, Tokyo, Japan, 2001.

Vandermerwe, S., "How Increasing Value to Customers Improves Business Results", Sloan Management Review, 42(1), 2000.

Weber, C., Steinbach, M., Botta, C. Deubel, T., "Modeling of product-service systems (PSS) based on the PDD approach", Proceedings of International Design Conference – DESIGN 2004, Dubrovnik, Croatia, 2004.

Corresponding author:
Adrian R. Tan, PhD student
Technical University of Denmark (DTU)
Department of Management Engineering | Engineering & Product Development
Building 404, Nils Koppels Allé
2800 Kgs. Lyngby, Denmark

Tel.: +45 4525 5564 | Fax: +45 4593 1577
Email : at@mek.dtu.dk | http://www.kp.mek.dtu.dk/