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DESIGN FOR UTILITY, SUSTAINABILITY AND SOCIETAL VIRTUES: DEVELOPING PRODUCT SERVICE SYSTEMS

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1. Introduction

In the developing discussion about sustainability there are emerging theories about the levels of environmental improvement necessary to achieve a sustainable ecology [Reijnders 1998]. Many of these theories state the need to improve environmental performance by a factor x, where x can be 4, 10 or 20. Regardless of which factor one chooses to subscribe to, there is a clear need to re-address the manner, in which we develop and provide products to users and consumers, in order to be able to make leap-changes to the environmental profile of the products, rather than merely small incremental improvements. Or in other words, we need to move from focusing on the design and development of the simple artefact to the innovation of a whole product service system (PSS), including its socio-technical utility and behaviour problematic, in which the traditional manufacturer-vendor-user relationship is rearranged, in order to deliver environmental and economical benefits for both customer and company alike.

2. Motivation and methodology

One of the main hypotheses supporting our arguments in this paper is that PSS development should result in enhanced consideration of utility, sustainability and societal values. There are existing examples of the enhancement of business and market share by focusing on PSS, but this is often not a result of upfront strategy and ambitious goals, nor is it the result of an attempt to expand the concern to those of users'/buyers' societal behaviour. Our motivation is therefore to provide insight into the development of PSS solutions in order to ensure positive results in these three areas.

Through a review and presentation of state-of-the-art research results and theories in the domains of product development, life cycle costing and the slowly emerging domain of PSS-development [McAloone & Andreasen 2002], we will challenge current models of the product development process. Our aim is to begin to stimulate the consideration of a renewed model of business creation, based upon a broadened definition of product and the relation to the customer.

The field is new and our considerations are preliminary at this point and it is therefore too early to consider an empirical study to support our theory. However, by collecting a series of theories from various existing domains and comparing these to specific examples, our intent with this paper is to develop a set of hypotheses that will inform and guide an empirical study into the development of product service systems.

Our approach to PSS is closely related to the area of Design for Environment, but has a wider scope, to the ecodesign area, and to Life Cycle Engineering (LCE). Feldmann [Feldmann 1994] sees the balance of ecological and economical issues as a necessity, and therefore an optimised cooperation of

technological development, legislation measures and the social way of acting is essential. Within the scope of LCE we intend to identify the core area for innovative efforts; the PSS design.

3. State-of-the-art surrounding PSS methodology

3.1 The enhancement of product development

The area of design research, the content of textbooks on designing, and the industrial practice has undergone an interesting development from the birth of this area in the late ’50ies until today. At the same time we can see a development towards an ever-strengthening focus and ability to master certain competitive aspects of the products.

Engineering design, as identified and described by [Pahl & Beitz 1996], was a professionalism and methodology focusing upon the technical and engineered aspects of products. In the late ’70ies it was realised, that the context or super-system of engineering design in companies was a continuous activity, product planning, for utilising and maintaining the business related to the products, and a row of new product development (PD) projects, leading to new business and products. PD was expanded to integrate market and production development in a procedure called integrated product development (IPD), see for instance [Andreasen & Hein 1987].

IPD is currently supported by the so-called “Design for X”-methods, i.e. methods for redesigning or enhancing products in certain X-dimensions like product life phases: production, assembly, distribution, maintenance or disposal, - or dimensions related to certain product or activity properties: quality, cost, risk, or environmental effects.

DFX is showing very strong results of enhancement of quality, reduction of costs and reduced environmental effects at disposal, but still far from the factor x improvement discussed earlier being much greater than 2. These results are obtained by using insight into the proper link between product characteristics (the product structure) and the characteristics of a product life phase (disposal) and the way effects are caused in this life phase (for instance cost or environmental effects).

The concept of IPD is today also related to an integration of product life aspects and the company’s concern for total life aspects like cost or environment. One may say that the handling of life aspects has undergone a change of approach from an upfront specification approach, through DFX-approaches with analytical investigations into the causes for the realised properties, to today’s pro-active exploration of product life phases and the linking of domain experts or stakeholders to the design team, see below. This development has not ended; further rationalisation is obtained by computer support related to product modelling enriched by product life data.

3.2 Enhancement through life cycle design

It is important, when trying to define the nature and qualities of a PSS, to consider the life-cycle mindset. Referring to a more established field, life cycle costing, Feldmann has stated that there is a need to confront life cycle economic considerations with environmental considerations, in order to achieve significant environmental product improvements: *“the solely economical assessment of products must change into a well balanced valuation of economical and ecological issues. To fulfil these requirements an optimised cooperation of technological development, legislation measures, and the social way of acting is essential”* [Feldmann 1994].

To support this statement, Kimera & Suzuki present an important challenge for the product developer, of first designing the life cycle and secondly designing the product, to fit the life cycle: *“For sustainable product development, it is essential, to first design total product life cycle in order to make reuse/recycling activities, more visible and controllable, and then to design products appropriate, to be embedded in the life cycle”* [Kimura & Suzuki 1996]. We believe that mastering this challenge is key to successful PSS development.

Building upon the challenge presented by Kimera & Suzuki, Tomiyama begins to combine product life thinking, service intensive engineering and knowledge intensive engineering, in order to satisfactorily produce sustainable product service systems: *“Intensification of service and knowledge contents within product life cycles is considered crucial for dematerialisation, in particular, to design*

optimal product-service systems from the viewpoint of environmentally conscious design and manufacturing in advanced post industrial societies" [Tomiyama 2001].

3.3 A subsequent expansion of the product concept

When we assume product life responsibility for a product, the design task changes its nature. A manufactured product's destiny is to be distributed, sold and domesticated, i.e. it is brought into the surroundings and context in which it is to serve for a period. In this situation we may focus upon the product itself, the man/machine interaction (learning, training, job-situation, working conditions etc), the products utilisation process (its productivity, reliability, yield, availability etc, and the occurrence of failure, repair, upgrading etc). Here we also find the question of system fit, i.e. how well the product works together with other system elements and how well it contributes to the overall optimisation.

The product will be able to serve the user for a period, known as the product service period. After this period many different situations may occur with the product, from: returning to the manufacturer, being upgraded, reused by a new owner, and finally subjected either to a planned and controlled disposal – leading to recycling, or a primitive disposal. So the total product life period from raw material allocation to this disposal situation may also be seen as a sequence of activities, all caused or disposed for by the designer.

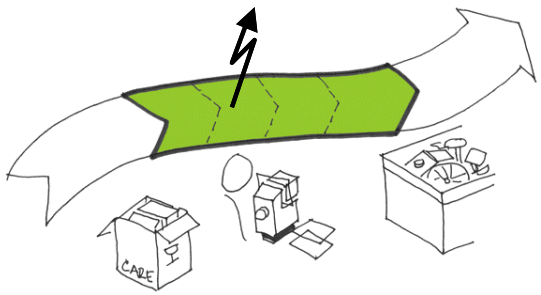

Figure 1. Expansion of the product concept

One of the significant consequences of carrying out PSS design and development is that the time domain is expanded, both by prolonging the period of time that the producing company has an active interest in- and control over the product and also by creating the need to consider multiple product lives, where the product (artefact) can be subject to numerous users over longer periods (the shaded area of Figure 1).

Considering the dimensions we have discussed thus far, we can begin to identify a PSS as having the following characteristics:

- in the time domain it is a sequence of multiple, interrelated life phases and activities throughout the product's service time;
- in the artefact system domain it is a set of multiple, interrelated systems, between which the product life phase system of use is the predominant, but where other systems (the producer's maintenance system, the overall system related to the product, the supply of input to the product, etc.) can also be of importance;
- in the value domain it is a set of multiple stakeholders' values, determining the utilisation and reactions to the artefact systems and activity systems effects and determining how seriously the side effects are regarded [McAloone & Andreasen 2002];
- in the social domain it addresses users' attitudes and responsibility and responds with an environmental "system" arrangement.

It is important to see that the traditional pattern of a manufacturing company's share of the life plans, followed by the owner's share of the product life and finally the undefined ownership period of disposal, shall now be viewed in a new way. The company's business intent, the user's intent in the

product's materialisation and their joint interest together with the society in the total life cycle is a better view for innovative thinking.

4. Challenging existing models of PSS with respect to sustainability

The current models and understanding of PSS development are questioned by [Ehrenfeld 2002], who observes that current work for attaining sustainability (through PSS) is based upon two competing concepts:

- eco-efficiency, which is a relative measure, based upon the hope that societies can continue to behave as they have, except that they will do everything much better
- dematerialisation, which is both a relative and an absolute measure, reflecting some sense of natural limits.

Ehrenfeld's challenge to our current understanding of PSS, then, is that there is no coherent strategy foundation that points towards sustainability. In his discussion of ways in which to ensure a coherent understanding of PSS for sustainability, Ehrenfeld presents three strategies of *naturalism, humanism and moralism* in contrast to Bruntland's *ecology, economy, equity*.

Modelling Ehrenfeld's approach to sustainability, we can derive the following important messages from his philosophy:

- sustainable consumption is as important as sustainable production:
    - the human agency becomes explicit
- the shift from products to services is not automatically more sustainable
- product and service are two different modes of delivering satisfaction, each with its specific set of artefacts, context and consumer behaviour
- the differences are timing and involvement of the actor being satisfied
- products provide satisfaction once the artefact is acquired:
    - one-off occurrence (e.g. home made burger)
    - continuously (e.g. car, art, carpet)
- services provide immediate satisfaction
    - e.g. insurance, museum visit.

Ehrenfeld concludes that the current distinction between product and service is not currently meaningful in relation to sustainability, because:

- users exhibit different ways of acting with products than with services
- the user is directly, actively involved in the utilisation of the artefact in product mode, but not in service mode
- the institutional context is different: in the product mode the actors have complete rights to the artefact (property rights), in the service mode the rights are limited
- the timing of the satisfaction is different: artefacts may provide immediate satisfaction or acquired for later and/or continuous satisfaction.

We therefore have a challenge, when defining PSS, to carefully consider the user, the context and the timing aspects of the PSS under development.

5. Arguments for PSS development

5.1 Creating a meaningful distinction

One step in the direction of understanding types of PSS (and subsequently the level of ambition of a PSS) can be found by expanding the classification of ecodesign types by [Brezet et. al. 1999], where Ehrenfeld creates a graduating definition, using three criteria:

- alterations to the actual product (the physical artefact);
- the context in which the product is used (defining the service); and
- the user's interaction (and thus learning) connected to the product.

	Change in device concept	Change in infrastructure	Change in user learning
1. Process and "product" redesign	None to minor	None	None
2. Functional innovation	Significant	None to minor	Minor
3. Institutional innovation	None to minor	Significant	Significant
4. System innovation	Significant	Significant	Significant

Figure 2. Innovation PSS – categories [Ehrenfeld after Brezet et. al. 2001]

It is clear in Figure 2 that the ambition is towards developing a PSS that can achieve level 4, system innovation. We have therefore chosen to present two examples to illustrate successful PSS attempts, in terms of sustainability

5.1.1 Example: Pay-per-wash service from Electrolux

In Gotland, Sweden, domestic appliance manufacturer, Electrolux carried out a pilot project in 50 households, where an ordinary product (the washing machine) was replaced by a product service system (a pay-per-wash service).
The philosophy here was to discretely alter the consumer's relationship to the product towards the acceptance of a service. Electrolux's approach was to provide a pay-per-use system, combined with an automatic replacement programme and a central data logging facility (to gather data and automate the service). The result of this pilot study can be described as follows:

- pay-per-use system implemented
- energy efficient digital washing machine provided
- central database and 'smart energy meters' installed
- automatic replacement of washing machine after 1000 washes (4-5 years)

Due to the fact that a standard washing machine was chosen for this pilot study, but significant changes were made to both the infrastructure between the company an the customer, and also the user's interaction with the product, this product service system can be argued to be an institutional innovation (row 3 in Figure 2).
We believe that by classifying PSS in the manner described in Figure 2 can give good guidance to the level of sustainability ambition of the PSS. We have chosen to present just one example in this paper, but are collecting examples in order to test and develop this model.

5.2 Rearranging the stakeholder gallery

Another important aspect of PSS development is that we have the opportunity to rearrange (and sometimes redefine) the stakeholder gallery connected to the product. This redefinition of stakeholders' roles and responsibilities should be carried out in order to provide benefits to all stakeholders and to the goal of sustainability improvements.

5.2.1 Example: In-house painting of automobiles in a manufacturing plant

In this example, we compare two situations: the first where a paint manufacturer (in this example DuPont) supplies paint to a car manufacturer (Ford) for painting their cars; and secondly where the paint manufacturer is invited into the car manufacturer's plant, to overtake the job of painting the cars.

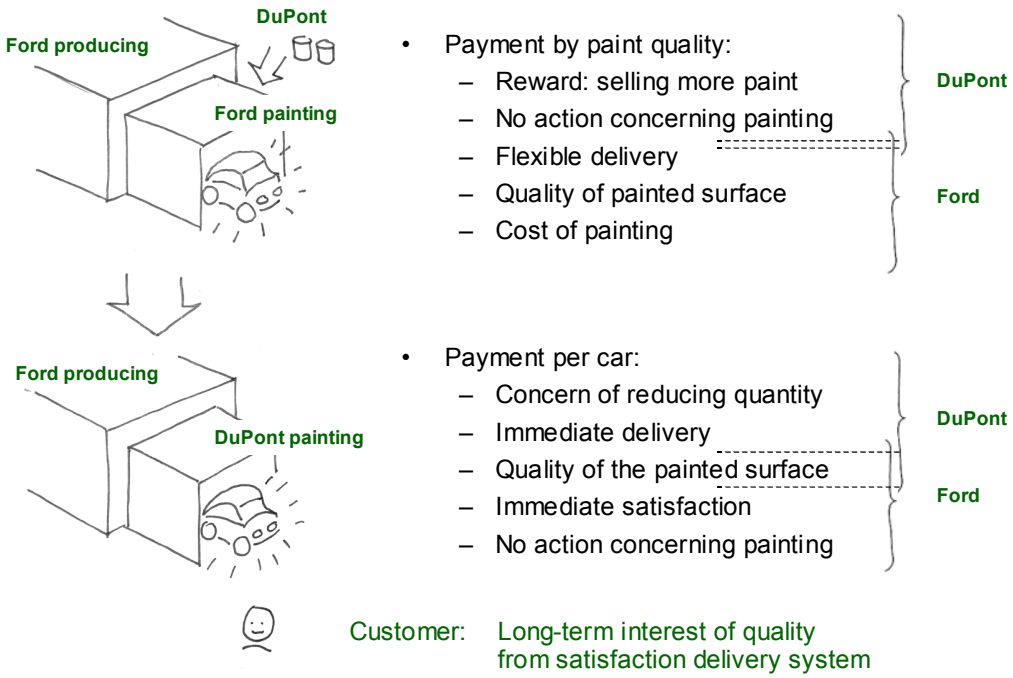

Figure 3. Redefining the stakeholder gallery (after [Ehrenfeld 2001])

It is clear to see, in this example, that the shift from paying for tins of paint to paying for painted cars creates important synergy for both supplier, customer and environment. The supplier establishes a closer (longer term) relationship to the customer, delivering a product that is highly based on their core competencies and at a higher price than if they were merely to sell paint. The customer is freed of the responsibility of providing good surface and finding the right paint manufacturer to fit their plant and own competencies, and instead can focus on their own core competence – producing cars. The environment gains from an increased focus on surface quality (and therefore less waste) and optimisation of raw materials usage.
Again we have chosen a simple example, to emphasise the importance of consideration of all stakeholders and their roles, for successful PSS design.

6. Reflections

We believe that by expanding on the phenomenon of PSS we can begin to demonstrate that PSS will give us the design degrees of freedom and the proper socio-technical scope necessary to create radical innovation. The article draws upon existing product development and PSS theory and models and experiences. We believe that through our approach to the phenomena, we have demonstrated a series of important arguments for the consideration of PSS development in industry:

- existing product development procedures will need to be adjusted, because the designed object in the product development process is no longer the simple artefact
- the shift in focus in product development from the simple artefact to the PSS will result in the need for much earlier determination of both business definition and service definition
- there is a need to identify the key parameters in considering central aspects in business creation, such as: the definition of an innovative product for the organisation; provision of a unique service for the customer; the degree of environmental improvement due to a broadened focus in product development
- the development of product service systems will give rise to the need for a new definition of product concept generation. This important phase of the product development process will have to be altered to accommodate and stimulate concepts that involve not only the product as an artefact but also the whole service situation that will arise from the product.

In this paper we have argued for the main reasons for a product developing organisation to consider PSS development, seen from a largely product development biased viewpoint. Of course, for a PSS to be successful – both in terms of general acceptance/adoption and in terms of making sustainability-oriented improvements – there are a number of socio-economical factors that must be considered. The economics of a PSS in relation to a traditional product solution must be studied in detail, before one can claim that the PSS is a better option for both company and customer. Furthermore the social behaviour of users/customers is potentially the largest barrier for PSS-realisation, as it is often difficult to make the user compromise the freedom gained from total ownership of the product, as opposed to partial ownership of the artefact that is encountered in a product service system.

7. Conclusions

We believe that the shift in focus from product development to PSS development is an opportunity to create radical innovations for the organisation. We believe that PSS development is a realistic opportunity to achieve the factor x improvements in the environmental performance of products. Furthermore we argue that PSS development will give other radical improvements over and above environmental improvements: by focusing on the service (and therefore) usage phase of the product's life should give enhanced utility of the resulting products and generally societal improvements should occur, due to a shift in focus from material possession to functional fulfilment. Finally, we can conclude that the change from a product to a PSS approach gives great challenges to both the product developer and the company, leading to a new set of opportunities:

- greater control over the product throughout its lifetime
- increased insight into the nature of the product and the situations to which it is subjected
- the introduction of new degrees of freedom during the product planning and development activities, based on the new set of game rules that apply to PSS
- the opportunity to redefine core business and to create new business opportunities
- to create a new type of design; one which is sustainable across multiple product platforms, product lives and acceptable to the end-user in a more enriched manner than the delivery of a simple artefact.

We believe that PSS development opens up for a greater arena of possibilities and therefore innovation practices than we have seen before. The product developer must become more aware of complex life cycle issues, multiple (and increased variance of) stakeholders, multiple product lives, societal issues, liability issues, and so forth.

We have a clear feeling that there are certain types of PSS that are capable of delivering higher degrees of sustainability-oriented improvements than others. We also feel that there are certain products that lend themselves better to inclusion in (or development into) a PSS than others. This has not been the main focus of this paper, but is an important consideration for further study.

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