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DEFINING PRODUCT SERVICE SYSTEMS

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1 Abstract

There are a number of theories that describe the necessary improvements in global environmental performance in order to maintain status quo in our ecosystem [1, 2]. These theories are far reaching in their ambitions, and it is not immediately apparent as to how we should be able to achieve, for example, a factor 20 improvement in our environmental performance. One attempt, however, has recently emerged, which combines the product as an artefact with the service that the product provides to the user. Through the combination of these two facets, the company retains ownership of the physical artefact and instead provides what the customer really wants – the actual functionality from the product. This enables a series of potential improvements to the product's performance throughout its lifecycle. The ideal of product service system (PSS) development is that all three stakeholder groups – customer, company and society – benefit from the service systems related to each one of these dimensions, rather than simply one of the above.

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. We attempt to identify the nature of such a multiple definition of PSS, the link to proper understanding of value and utility and innovative approaches for PSS-oriented product development.

This paper will expand on the phenomenon of PSS in the belief that a proper understanding of PSS will give us the design degrees of freedom necessary to create radical innovation. The article draws upon existing product development and PSS theory and models and experiences from projects carried out with both industrialists and students.

2 Introduction

In the developing discussion about sustainability there are emerging theories about the levels of environmental improvement necessary to achieve a sustainable ecology. Many of these theories state the need to improve environmental performance by a factor X, where X can be 4, 10 or 20 [1]. If we take the mildest of these theories and try to consider how to reduce the environmental footprint of our products by a factor 4, this demands for a completely new world-view, affecting the way in which product development, personal behaviour and, in fact, infrastructure are planned and formed. Factor 20 makes this challenge simply five times more demanding!

There is therefore a 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), in which the traditional manufacturer-vendor-user relationship is rearranged, in order to deliver environmental and (for the company) economical benefits.

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 [3] in his foreword to the 2nd International Seminar on LCE, 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 want to identify the core area for innovative efforts, the PSS design.

3 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 a stronger and stronger focus and ability to master certain competitive aspects of the products.

Engineering design, as identified and described by Pahl & Beitz [4], 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 [5].

IPD is currently supported by the so-called "Design for X"-methods, i.e. methods for re-designing 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.

4 Expanding the product concept

When we take a product life responsibility for a product, the design task changes its nature. In the following sections we will bring in new aspects or dimensions, beginning with the designed product. 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, re-used 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.

5 Reviewing the quality concept

Parallel to our gradually enhanced understanding of product development we have also seen an enhancement of the concept of quality, or more precisely "the good product":

- In the seventies we found a manufacturers approach: "The good product can always be sold", and approaches focusing on uniformity of the products.

- In the nineties our focus changed to listening to the voice of the customer, i.e. qualities and (mis)fits experienced by the customer to be used for proper product positioning [6,7].

- Today we have identified the possible discrepancies between the company's quality concepts and customer/user perceived value, which may be articulated in a metaphorical way as: "quality is carried by the bicycle, value is experienced by bicycling".

- Today we know that the product's utility and yield is related to the process or transformation of the product [8] and we need a unit of performance, if we shall compare different products by, for instance, their environmental effects.

So today we focus on a design task, where the designed object both shows an expansion of the concept of products and an expansion of the quality concept. If we want to design for enhanced product service performance, which causes subsequent environmental effects, we must understand in a new and innovative way, how the product is really linked hereto and what will be the user's concept of the product's raison d'être.

6 Multiple life phases and stakeholders

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 consideration of multiple life phases poses a new and challenging set of criteria for the product planning and development activity to pay attention to, including:

- An extended stakeholder gallery:
  meaning that new and varying types of stakeholder must be considered and planned for, in PSS development, so as to avoid unexpected situations in the product's life;

- Increased product liability:
  meaning that the artefact remains in the ownership of the manufacturer for much

longer, giving greater responsibility regarding its usage, usability and quality. There is a challenge here in understanding the interrelationship between, and ownership of the universal virtues of cost, quality, time, flexibility, risk, efficiency and environment [9];

- Closer contact to the end-user:
  and therefore reaping the opportunities to understand better, be influenced by and influence the customer;

- The risk of cannibalisation of existing/future products and markets:
  demanding a new approach, during the PSS planning activity, to flexible product family planning;

- A new opportunity/necessity to consider the meaning of core business:
  which highlights that a re-focus is necessary of the company's main activities, and the possible re-grouping and creation of new support mechanisms inside the company: "do we follow the product or the business, or both?"

Christensen and Tan [10] provide a challenge for PSS developers to consider that products can only be classified as innovative if they:

"contain a difference (in relation to existing products) that induces appropriate, valuable and desirable effects on the company, consumer and society".

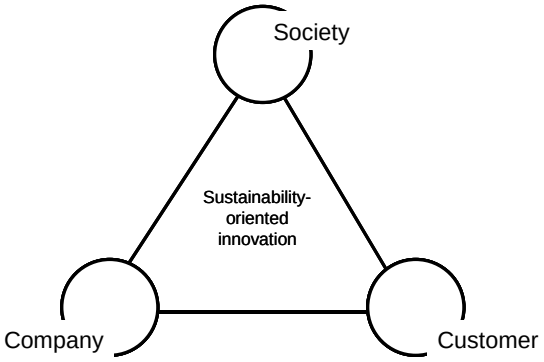

Figure 1 - Three-forces model (Christensen and Tan [10])

The challenge of creating positive effects – appropriate, valuable and desirable – relates to logical, physical and psychological aspects that should be built-into products. The classification of stakeholders into three main groups – company, consumer and society – coupled together with the positive effects, makes this definition of innovation strong in a sustainability concept, as this forces a mindset of continuous product improvement in both a physical and a societal manner.

7 A product service system

In our efforts to identify the proper nature of a product service system we have now made the necessary expansion of the concepts (product, quality, life phases, stakeholders) and we are ready to try and formulate a system of characteristics or ontology of the product service system. Our goal is to understand and thus design a product service system in order to be able to enhance its properties; especially those related to environmental effects.

A PSS has the following characteristics:

- In the time domain it is a sequence of multiple, interrelated life phases and activities throughout the product's service time, i.e. the period where it is utilised in accordance with its planned purpose (the product seen as Sachsystem – Ropohl [11])

- In the artefact system domain (Handlungssystem – Ropohl [11]), 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 (Wertsystem – Ropohl [11]) 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 (according to Eekels [12]).

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.

8 Designing a PSS

- As we mentioned earlier, we see a necessity – and indeed opportunity – to adopt innovative approaches, in order to make substantial changes to the ways in which the products we produce affect the environment. We have also mentioned that we view PSS design and development as an enabler for innovation and substantial environmental improvement.

- But what can PSS development deliver that traditional product development cannot? There are many areas where see significant benefits to be reaped from PSS development.

- PSS development can deliver more than merely new products:

- For the *end-user* it can also deliver new patterns of usage, lifestyle, purchasing and flexibility.

- For the *producing company* it can deliver closer contact to the end-user and therefore:

    - maintain contact, supply maintenance, upgrading and disposal of the product;

    - see the end-users' utilisation of the product as the delivered service and strive to accentuate this service;

    - realise new ownership patterns such as renting, leasing, service-contrats, and so on.

- Also for the *producing company*, new markets, greater market share and a redefinition of core-activities can be achieved.

- For *society*, the overall effect should be an increase in the sustainable dimensions, towards the factor x improvements we mentioned at the beginning of the paper. Here we are talking about:

  - increased product efficiency (due to the producing company having increased liability for-, insight into- and ownership over the product);

  - a closer relationship between societal needs (from Christensen and Tan's definition [10]) and the products that industry supplies (due to the voice of the customer (and other stakeholders) being louder and clearer than before.

In the following we would like to illustrate two examples of PSS design in an attempt to explain their role and their differing nature with respect to traditionally developed products.

8.1 Xerox

American photocopier manufacturer, Xerox, have spent the past decade re-organising their business, their product development and their relationship to their products. They have done this in order to be able to reap the benefits from what they call *asset management* – or in other words, the establishment and utilisation of a much closer relationship to both the physical artefact and to the customer. With these newly defined relationships, Xerox has been able to make environmental improvements of a magnitude that simply would not have been possible had their mindset been that of a traditional product manufacturer, with minimal further involvement in the product's life after sales.

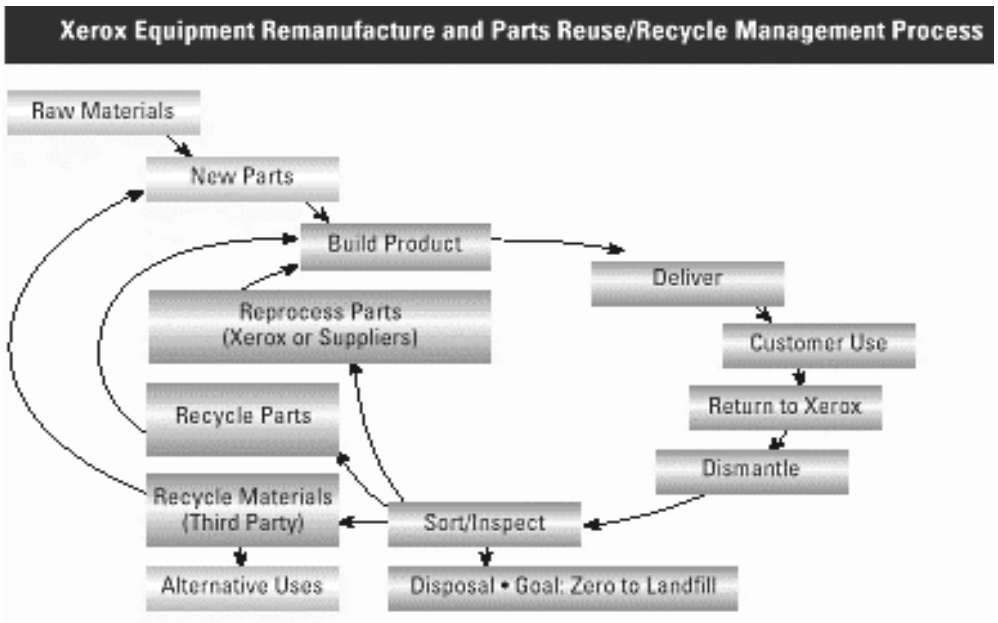

Figure 2 - Closing the loop - one of the by-products of PSS development at Xerox

The company no longer regards itself as merely a photocopier manufacturer, but as a document management company, who provides a service of managing documents from the moment they are created (whether by hand or by machine) through to the copying, distribution and archiving activities. There are also obvious benefits for Xerox in an economic sense, as their closer positioning to the customer makes for a stronger relationship and as Figure 2 illustrates, they save money in materials and components. The customer no longer cares whether the physical components in their product are completely new, just as long as they function correctly – and this is what Xerox is now selling: functionality.

8.2 Interface

The world's largest commercial carpet manufacturer, Interface, offers a selection of floor-covering products and services to its customers. Similar to Xerox, Interface has moved away from the traditional model of product manufacturer to PSS provider. This means that the company offers a series of services, based on their range of products.

For example, Interface provide an office floor-covering service to its customers that is arranged on a leasing basis. This means that during the leasing contract, the carpet is maintained (and even cleaned) by the company. It is therefore suddenly in Interface's interest to develop and manufacture robust carpets with the capability of being easily installed and repaired. Using the concept of biomimicry (the concept that natural systems can guide the design of man-made products), the company have managed to reduce the oil-content in their products to an absolute minimum, and now base their carpets on a newly developed maize content. The random pattern and weave of their carpets provides a low level of installation waste and allows for small areas of damaged carpet to be cut out and replaced, with an invisible result, thus extending the lifecycle of an installation.

Interface has a vision of becoming a restorative company by 2020, meaning that the company's activities will give something back to the environment and society. This affects the company's management and manufacturing processes and its relationship with the entire supply chain.

9 Explaining the approach and effects

As can be seen from the above two examples, the adoption of a PSS programme has led to a clearly new situation in both cases, leading to:

- 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 can also see that the examples demonstrate well Christensen and Tan's model of innovation; delivering benefits to customer, company and society.

10 Our current experiments

The question remains as to how (and whether) PSS development differs from traditional product development. 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 started to experiment and to attempt to develop our own mindset for PSS development in a number of ways, in our research and our teaching. For example, in summer 2001 we held a two-week intensive summer course for 27 international students, from 19 different countries under the “BEST” (Board of European Students of Technology) banner. The aim of the course was to develop sustainable PSS concepts for a future domestic situation, in order to train a mindset for PSS design and development, when guided by the challenges of sustainability [13]. In a similar manner, we plan to continue to develop our ideas and mindsets in a new five-year masters engineering programme, called Design & Innovation, which opened its doors for the first students in September 2002 [14].

11 Conclusion

In this paper we have begun to discuss the many challenges and opportunities in PSS development. We can conclude that for PSS development to become successful and sustainable as a practice, a changed mindset is necessary about the roles and practices of product development. The broadening of scope of both the development task, the relationship to the physical artefact and to the business, increases the complexity of the product development process immensely and calls for new competencies in product development.

The creation of product service systems should give benefits to the customer, the company and to society in general; in this way the challenges of business success and of sustainability can be harmonised. The progression from traditional product development to PSS development should hopefully deliver the difference that is necessary to lift the environmental and sustainability performance of products up to a greater level of effect.

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