From Ecodesign of Products to Sustainable Systems Design: Delft's Experiences

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Abstract

The paper presents ten years of experience with the integration of environmental aspects in product development from the Design for Sustainability (DfS) program of TU Delft. It describes the lessons learnt from the different phases in the DfS research, starting with project based ecoredesign, followed by the integration of the Ecodesign methodology into a business management perspective and ending with nowadays experiments with the design of sustainable systems.

Particularly, a new model for the development of "sustainable satisfaction delivery systems" is being proposed, that will be tested in further experiments of the Delft University with entrepreneurs, industrial designers and environmental specialists. The model focuses the systems design team's attention on three aspects: the device, the institutional or infrastructural context, and on user practices. These three aspects are displayed in a Sustainable Systems Triangle to facilitate the conceptualization process.

Examples are being given of an ex-post analysis of sustainable systems examples, to show how the triangle model could work as a guiding principle for development teams.

1. Introduction

Since 1990 sustainable development is on the research and education agenda of the Sub Faculty of Industrial Design Engineering of the Delft University of Technology. During **the pioneer phase** (1990-1995) the focus was on the eco(re-)design of existing products. Starting with the basic industrial design methodology taught in the faculty [14], additional tools and methods were developed, to ensure that environmental aspects were taken into account systematically in all steps of the product creation process. Complicated Life Cycle Assessment (LCA) approaches were being adapted and streamlined for use by design consultants and small and medium sized companies, creating tools like the MET (materials, energy and toxics) matrix and the Idemat database on environmental aspects of materials. Life cycle design strategies, illustrated in the LiDS wheel, were tested out in industrial demonstration cases. An international dimension was added to the program by the issue of the so-called PROMISE manual by the Industry and Environmental program of UNEP, the United Nations Environmental Program [19].

Furthermore, during this first phase, the following lessons were learnt:

- For almost all existing products, redesigns are possible that lead to significant de-materialization, de-carbonization and detoxification on the level of individual products;
- For engineers, acquainted with the industrial design methodology, the inclusion of environmental tools and approaches is –technically spoken- relatively simple and self-instructive: "Ecodesign, you can do it yourself";
- Successful Ecodesign pilot projects are no guarantee that the approach is being integrated on a regular basis in the normal business;
- Companies are being considered, by the "green" designers, not as partners but as pupils or even enemies that have to be convinced of the right case.

The next phase in the DfS program (1995-1999) can be described as the **business integration** phase. During this period, the focus is on drivers for companies to take Ecodesign on board, such as (1) the opportunity to create new customer values and higher product quality; (2) legislation and regulation, particularly concerning the end-of-life phase of packaging, electronic equipment and cars; and (3) cost reduction by more efficient designs.

Business wise lessons were learnt, such as:

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- Although the outcomes of official LCA-studies might be achieved closest following a scientific approach, consumers, governments, environmental organizations and industries all have their own interpretation on what is more and what is less "green". It's realistic for ecodesigners in companies to take these different perceptions and opinions into account into the environmental strategy;
- LCA might be an appropriate tool for environmental validation, but in the product creation process other tools, such as "green brainstorming" and benchmarking, are necessary to create the necessary green options and innovations;
- In order to convince companies to adopt Ecodesign as regular part of their business and product development process, it's not only necessary to create new external values (higher profits, larger own market, etc.), but also to take into account the interests of suppliers and end-of-life actors as well as to demonstrate potential added value for the internal company stakeholders involved;
- POEMS (Product Oriented Environmental Management Systems), provided they are designed to support the Ecodesign process in a "natural" way, can be of great support in transforming project wise Ecodesign learning into continuous and normal business;
- The first priority in the product strategy of companies should be to improve the environmental profile of those products that have a good value/costs position on the market, but relatively high eco-costs. For most consumers, the quality and price filter in purchasing a product is first criterion, only after that has been passed the second filter concerning the perceived environmental impact plays a distinctive role.

The research topics of the business integration phase are still high on the agenda of the DfS program. This means that studies on supportive decision-making models and tools for companies are being carried out, particularly aiming at green design rules management, POEMS, end-of-life modeling and tooling, approaches for supply chain management etc. Also the attention has emerged for the environmental potential of certain technologies, such as fuel cells and human powered technology, to be applied into consumer and professional goods. In the DfS eco-lab prototypes are being build and tested, based upon these technologies. While all these important issues are progressively being studied, within the program the need was felt to go beyond the Ecodesign of existing products and the integration of the Ecodesign methodology into existing business. Therefore, the next paragraph will discuss a new part of the DfS program, called -the design of-sustainable product-service systems.

2. The design of sustainable product-service systems: a reflective practice approach

As indicated above, the experience with Ecodesign of products at an individual level has been positive in the DfS program with environmental impact reductions varying from 10 to 50% in terms of LCA-indicators when comparing new with old product designs. However, several studies carried out by environmental institutes during the nineties on sustainability at a global scale indicated that at the system level, much higher eco-efficiency targets should be met. With systems we do mean here the total of production and consumption processes, including products, services and the needed infrastructures, within a certain sector of society.

Particularly, some studies like [7,11] showed evidence that by dematerialization strategy, that is substituting physical products by non-physical services large gains in eco-efficiency improvement could be gained.

In order to test this hypothesis a series of long-term societal experiments has been set up in the DfS- program, together with Dutch companies, new entrepreneurs and TNO Industry (Netherlands 'Applied Technology Research Institute) in a special, new organization: Kathalys. These experiments have been designed in such a way that on the one hand the theoretical ideas for eco-efficient product-services systems were being brought into real practice by companies and designers, in a niche market situation. On the other hand, with funding aid from the Dutch government, researchers have been –and still are- assessing the progress of the different longer term projects (1-5 years run time), testing their respective models and hypotheses on service systems design and intervening (for adaptation) in the experiments when the –interim- results indicate this. At the moment, these experiments are being held in the following areas:

- Household
  - The intelligent and energy-efficient kitchen
  - The wash-in service, combining the service of local petrol stations with washing and cleaning services for clothes
- Office/Work environment
  - Eco-efficient workspace design, logistics and equipment service
- Tourism & Leisure
  - Eco-efficient food and drinks chain management
  - Educational services
- Mobility
  - Car sharing
  - Fuel cell assessment for sustainable mobility concepts
  - Mobility communication platforms
  - ICT for chain mobility

- Short distance luxury bicycle concepts

From these projects the following –interim- methodological insights have been gained [3]:

1. For many new, eco-efficient product-services combinations new organizations are required, either business coalitions from existing companies or completely new ones. To create these new organizations is a difficult, but necessary task.
2. The gain in eco-efficiency of the new systems can be accounted in several ways and depends to a large extent on the context defined, the assumptions made and the efficient use of existing infrastructure (see also paragraph 4 for an elaboration). New, transparent procedures are necessary to be able to take into account future scenario's for the designed systems and account for uncertainties in uncertain future use of new artifacts, user behavior etc.
3. Business is the driver for successful product-services combinations, not the factor environment. Therefore, the creation of new user values by the service designers is essential.
4. The availability of ICT is a crucial element in almost all new services, but has both a positive and a negative impact on the eco-efficiency of the system.
5. Almost no governmental policies and instruments do support the transformation of eco-efficient services from niche markets to full growth on the market.
6. The application of new design and service development tools is necessary, such as:
   a. the META (Materials, Energy, Toxics, Added value) matrix, with which a qualitative, quick environmental assessment of a product service system is possible;
   b. the ViP (Vision in Product development) scenario approach: to be used for companies and designers that are fixed on existing products and solutions. The approach offers the development of a new product or product-service vision by envisioning the future context, the interactions with the user and by making the implicit designers' choices explicit;
   c. Backcasting, looking back from future sustainable scenarios to today's system, thereby identifying key factors, actors and technologies for change;
   d. 'Blueprinting', when an existing service is being redesigned or replaced. Blueprinting is a method to describe a service in the same way as a product with the help of a process tree, can be a suitable tool to obtain insight in the visible and invisible elements of a service [13];
   e. the Ecocosts/Value (EVR) approach [17], which makes it possible to judge not only the environmental potential of a new concept, but also it's related ecocosts and market value.

Furthermore, from a more conceptual perspective, the experiments so far have inspired the DfS researchers to come up with a new model for the design of sustainable product-service systems, by means of the Sustainable Systems Triangle, that will be described below.

3. The Sustainable Systems Triangle (SST)

Ehrenfeld & Brezet [4] make several observations, to take into account in further experiments with eco-efficient product-service systems. Points for discussion are:

I. eco-efficient services vs. products as discriminating notions;
II. eco-innovation as a process with a natural progression;
III. the humanistic side of eco-innovation.

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3.1. Rethinking the notions of products and services.

Much current literature and emerging policy discussion has the general theme of a shift from products to services. [8, 11, 15, 18]. The impression that a reader gets from this literature is that products are substantially different from services. We argue below that these two categories are merely different modes of delivering satisfaction and that the dichotomy established in much of the current literature clouds the basic design issues involved in the more important goal of finding more sustainable ways to satisfy demand. It is not the difference between product and service, but the design of the artefact, its institutional (or infrastructural) context, and the consumers' practices-in-use that are the critical factors determining its effectiveness in promoting sustainability. Manufacturing processes produce artefacts that are then purchased and used ultimately to satisfy consumers. These goods are artefactual or material in nature and we shall refer to them as products which term is more familiar in the design community [12]. Products are artefacts purchased by actors in anticipation of future service, even if they are used soon after the acquisition. Services, an alternate mode of satisfying demand, are immaterial in nature [11,12,15]. Services are consumed right away.

The apparent category difference of products and services has its roots in economic conventions where market transactions have been divided, for convenience in

keeping accounts straight, into goods (products) and services. For goods, satisfaction follows after the market transaction and may be a single event, for example eating the food brought home from the supermarket, or continuing events, like commuting every day in the automobile purchased or leased from the dealer, or continuously enjoying the comfort of a carpet on the floor. Services have a different temporality that we argue is the primary and constitutive aspect differentiating products and services. Services are consumed at or very near the time of the market transaction. Both forms of satisfaction involve both actors and artefacts and both involve some sort of infrastructure (or institutional arrangement) in which the products and services are provided and subsequently consumed. Consumption is equivalent to the actions that produce satisfaction. Thus we argue that the very notion of product-service systems, as different from either products or services is misleading as both products and services, as conventionally denoted, produce satisfaction within a system of actors and other artefacts.

The number of terms in use is large and confusing as shown in the following list [8, 11]:

- Non-material services
- Dematerialized services
- Eco-efficient services
- Product-life-extension (services)
- Product use services
- Product oriented services
- Need-oriented services
- Demand services
- Results-oriented services
- Product-based services

Confusion between products and services is further complicated by the terminology of the Wuppertal Institute where products are defined as "service-producing machines" [20] We prefer to use a different distinction, satisfying, that avoids the confusion of terms in much of the emergent literature on products, services, and sustainability. Human beings are actors spending most of the time seeking satisfaction (completion or perfection) by pursuing intentional goals. Our days are spent in practices that are so familiar that we do not think about them as we practice them [5,6]. As we satisfy our intentions in one domain of our concerns about living, we move to another and so and on. In order to achieve satisfaction, we either pick up an artefact we 'own' and use it or ask some other human being or artefact to do something that is satisfying. The only difference in these two modes is whether we do the work involved or it is done by another person or machine we do not "own." There are no "products" or "services" involved, only action in which artefacts or other people are involved. There is a clear instrumental character to the artefacts-in-use. Both modes of satisfying are encountered in everyday life, as illustrated in the next examples.

Example 1
The most common way of commuting to work in the United States is via one's own car (the product). The actor drives the car to work. He or she is active in this role and the artefact's meaning as a "car" is constituted by and within the action in which it is being used. It is nothing but a pile of stuff otherwise. On the other hand, should the commuter's car be unavailable, he or she can call a taxi and ride in it to work (service). The actor in the second scenario is passive in this mode of satisfaction and during the passage from home to work could be said to be inactive. Technologically, little, if anything, is different. Identical models of vehicles

If we look at other examples of what are conventionally considered to be services, we often, maybe always, find that the transaction between actor and service provider is aimed at providing immediate satisfaction. On the other hand, when we look at market transactions involving goods (artefacts), most of the time the artefacts are acquired for future use:

Example 2
When one buys food in a supermarket, she is obtaining an artefact (product) she will use in the future to satisfy her hunger. But when one goes to a restaurant (service), he seeks immediate satisfaction for the same concern. There may also be other intentions present that lead to the choice of one mode of satisfaction over the other, for example, wanting to be seen in the latest high-fashion bistro. When we act, we aim to be satisfied in some domain of concern, and we will choose the means according to other criteria depending on the moment. Artefacts are always involved, whether we own them or acquire their services through other arrangements. In the back of the restaurant, the chef is using a stove, food processor and other tools just as we might at home.

Although the product/service distinction is important to economists, it may not be as important to designers of artefacts and the satisfaction-delivery system in which they are embedded. At the risk of introducing yet another terminology, we will speak of **sustainable satisfaction-delivery systems** at the target of our analysis. And although we claim that 'products' are always used in some system, **we will refer to products conventionally as artefacts** that show up at the end of some manufacturing process and have been brought to the market.

The key distinctions that emerge from this abbreviated discussion of human behavior are issues of ownership

and the temporality of acquisition. Satisfaction can be obtained either by using a product previously acquired (self-satisfaction) or via a transaction in which satisfaction is obtained contemporaneously from other actors and the equipment they own. Preferences for the choice of one or the other of these modes of satisfaction are buried in the consumer's cognitive system and are influenced by many factors outside of the immediate acts of satisfaction. **This basic preference between self-satisfaction and conventional market-based services is important in designing sustainable satisfaction delivery systems.** It is not the case that consumers naturally prefer one mode over another.

3.2. Eco-innovation as a process with a natural progression;

Similarly, designers should be critical of claims that there is a natural progressive hierarchy to innovations in satisfaction delivery systems. Some have suggested that there are successive stages in design that offer qualitatively improved levels of environmental performance.

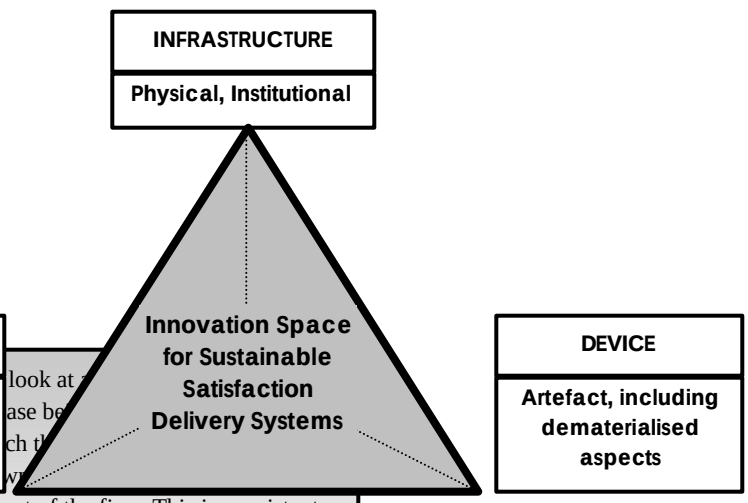
However, based upon the DES and similar projects, this progression could not be confirmed. Our analysis leads to the following vision.

Process product redesign involves little or no change in the design concept or in the quality of the design as seen by the user and virtually no change in the infrastructure. The new items can be used as transparently as the old without the requirement of new practices or learning.

Functional innovation involves changes in the design concept, but like the prior changes, the user sees little or no changes. Some change in the infrastructure is likely. System innovation involves changes in all categories. The design concept is new; the user will need to learn new practices, and new infrastructure will be necessary.

We will add another category, institutional innovations, to represent the last type of innovations that involve only or primarily institutional or infrastructural change. What many call services fall into the institutional category since in the general case, services involve the same artefacts as those a consumer uses in self-satisfaction activities.

These categories are summarized in Figure 2**:** the Sustainable Systems Triangle. We have dropped the notion of stages, as we noted that any orderly progression from the top to the bottom in terms of sustainability performance has yet to be firmly established. Product and process redesign is lumped into a single category: device. The different categories are constituted by three factors of change: in the artefact, the institutional arrangement in which the artefact is used, and in the user's practices, respectively.



To see how the look at how it fits, for e ase be manufacturer of ch t for fashion or fu being carried out in the 'service' department of the firm. This is consistent with the general notion of product-life-extension as a 'service' (Stahel, 2000) But if we look to see where it fits in the SST scheme, it would be in all three corners of the triangle. The device has technically been changed for upgradability. A new marketing and care infrastructure is needed. The user will have to learn some new practices. By categorizing it as services only, the design process may end up in the 'wrong' part of the firm, out of sight from the 'product' designers and the competence of the marketing department, that takes care of the contacts with clients and distribution channels. The other way around: by looking consciously at the oven redesign from a SST perspective, unexpected new options for a sustainable system design have been generated with an interesting eco-efficiency potential. As depicted in Figure 2 and 3, new designs should take into account the sustainable potential of not only technical redesign of the

ggests designers to holistically look for the nd institutional context/ infrastructure; and (3)

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Figure 3: The Upgradable Oven in the SST Scheme
Explanation: To reach the envisaged sustainability improvement changes are considered in (1) the technical device;(2) the marketing and service infrastructure; and (3) the user behaviour (do-it-yourself-service for the new design). Because the envisaged changes are radical compared to the existing oven system D', I and U' are depicted relatively far from their origins (the corners of the triangle).

This characterization of innovative categories and the above discussion suggest that the key to designing more sustainable satisfaction-delivery systems may be in looking with an integrative perspective into the innovative potential of device change, infrastructural factors change and user behaviour change at the same time.

3.3. The humanistic side of eco-innovation

In the move towards services, something very central to sustainability may have become lost. Services, as opposed to products, produce relatively instant satisfaction and require little from the consumer other than sufficient funds to purchase the services. This mode of satisfaction has the distinct character of a commodity [2].

There is no learning involved. Instead the opposite process occurs. Consumers gradually unlearn competent skills they might have once possessed relative to producing self-satisfaction, using tools (products) that they have previously purchased. The consequences of this unlearning or de-skilling process are loss of autonomy and increased dependence on the purveyors of the services. The experiential context of such other-satisfaction modes is narrow and probably fails to spill over into other domains of satisfaction, as do practices in more 'home-like' places. If this occurs, the consumer may (and does according to many surveys) feel unsatisfied and seek more consumption to fill the hole.

Looking positively, the humanistic domain offers a set of design criteria attached to sustainability that can potentially radically extend the idea of product/service systems. One possibility, for example, is to ask whether the technological offerings to be found in the market place of affluent communities satisfy the human striving for authenticity, that is the discovery of one's 'true' self. Or in less affluent areas of the world, the relevant question is whether these offerings satisfy more basic needs according to some Maslovian-like hierarchy. The recent SusHouse project at the Technical University of Delft suggests that it is possible to produce gains in the naturalistic dimension (dematerialization) simultaneously with positive results in the humanistic [16]. This report described gains in the strength of relationships among families, an attribute closely related to flourishing.

New theories of design delve into the domain of behavior-steering attributes of artefactual systems that may be incorporated in the design [9]. In the self-satisfaction mode, consumers develop routines through which they produce satisfaction. These routines represent practical learning acquired through use. The designer, consciously or unconsciously, builds in such routines in the artefact. But the user may depart from the intended practical routine with unexpected and unpredicted outcomes. In the language of post-modernism these routines are mediated by 'scripts', a linguistic equivalent of the message the user gets from the object when it is being used [10]. Reflecting the asymmetry of the designer's intentions and users realization, Akrich and Latour refer to 'scripts" as the routines <u>inscribed</u> by the designers in the artefact and <u>described</u> by the users in actual practice [1].

This theory of practice, which suggests that users create meaning through use, raises the possibility that designers can inscribe scripts with more than mere utilitarian ends. As Jelsma writes [9]:

…In the context of a policy aiming at fostering sustainability, designs of artefacts must seek to mediate between the wants of users and the (represented) needs of nature, instead of just serving consumers. To develop such mediating designs, we need a new design paradigm (concepts, strategies, tools) bridging the gap between technical functionality, user needs and sustainable development….

Based upon it's experiences with the design of Eco-efficient Services, or preferably, the design of Sustainable Systems, the DfS program of TU Delft will focus on:

- The integration of the Sustainable Systems Triangle as building block for the Exploration and Policy Fomulation phases, into the ES methodology, as well as the analysis of it's consequences for the subsequent phases of the ES development;
- Refining and expanding the ES-methodology and tools, regarding among others ES-benchmarking, the LCA scenario approach, generation of green

options, EVR method, Purchase and Rules of Thumb for ES;

- Applying the Sustainable Systems Triangle as a tool for analyzing emerging new product-service systems with respect to their sustainability potential.

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