Integrated Product and Service Engineering *versus* Design for Environment – A Comparison and Evaluation of Advantages and Disadvantages

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The objective with this paper is to, from several perspectives including those found in the traditional Design for Environment (DfE) literature, compare and evaluate advantages and disadvantages between the concepts of DfE and Integrated Product and Service Engineering (IPSE). Lessons learned from the use of DfE have been integrated into the IPSE methodology.

One conclusion is that IPSE is a promising approach to take the environmental related requirements that DfE tries to promote one step further, i.e. to be better integrated with other types of offering-related requirements. In short, IPSE opens up for a more balanced development of offerings.

Keywords

Integrated Product Service Offerings, Integrated Product Service Engineering, Service Engineering, Design for Environment

1 INTRODUCTION

"Competing in time" reflects a growing pressure on firms not just to introduce new products but to do so faster than competitors [1]. The rate of market and technological changes has accelerated in the past decade. Central to competitive success in the present highly turbulent environment is the firm's capability to develop new [2] and to improve and further develop and optimize old products i.e. an increased emphasis has been put on time efficiencies in the product development process. Developers within the company must develop and proceed faster and faster - and at the same time satisfy an increasing number of customer product demands.

In traditional product development a multitude of requirements must be considered. Ullman [3] has categorized some major customer requirements into eight types: functional-performance, human-facto, physical-factor, reliability, life-cycle, resource and manufacturing requirements. The aim in the design process is to optimize the product in relation to those requirements. This can be illustrated with a geometric form, e.g. as a box, where the box represents the product and its sides represent different perspectives/views, e.g. economic and quality, from which the product can be optimized from (see Figure 1). The volume of the box can be seen as the total cost of generating the product or offering. The aim is to out of existing requirements create as good a product as possible. *The focus in the optimization is in general focused on producing products for as low a cost as possible, but at the same time with as high a price as possible. An example of this would be to get a box's total volume, i.e. cost, as low as possible*.

When focusing on only one perspective, there is a risk that one tends to "push" down costs, a push that if done incorrectly implies that one could get higher costs for other issues. It is important to try to reduce the life cycle cost of the entire offering, i.e. avoid costs that give a "net" cost reduction in relation to the functionality.

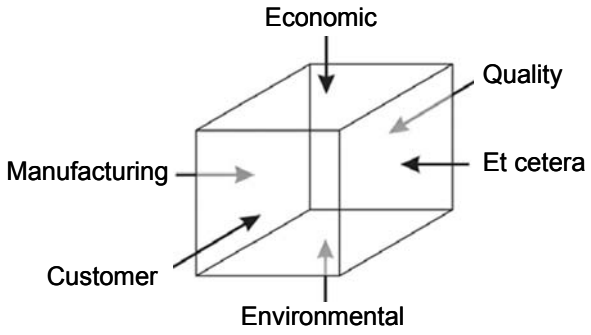

Figure 1: Some different perspectives to use when evaluating and optimizing a product.

As Blessing, Chakrabatri *et al.* [4] have stated "*the aim of engineering design research is to support industry with aids that can improve the chances of producing a successful product"*. In the literature, there are numerous of methodologies to guide and support product developers in this process, e.g. QFD, FMEA, and LCA. The aim of the companies is to produce successful products that enable them to provide benefits.

One problem with many existing support tools is that they tend to be solely focused on one issue, e.g. quality or the environment. Today, a more overarching perspective is seldom found in the literature, e.g. as the notation by Blessing [5], Baumann, Boons *et al.* [6] and Bylund, Grante *et al.* [7] indicate. The restricted perspective of many design method and tool developers has resulted in many stand alone methods and tools - tools that are aimed at solving one problem or issue in the industry and most likely do, but with a result that does not fit in with the rest of the company's modus operandi [7]. The conclusion after a literature review is that design methods and tools are almost always lacking from an over-

arching and holistic perspective - even if some of them claim to have one.

The single focus opens up a possibility for sub-optimization. When focusing on e.g. design for production in order to cut down costs, e.g. by using more integrated parts, this may result in increased costs for service and end-of-life treatment, instead of reducing the overall cost for the product, i.e. the total life cycle cost increase. This cost could in this case be both environmental and or monetary in nature.

2 OBJECTIVE AND METHODOLOGY

The objective with this paper is to, from several perspectives including those found in the traditional Design for Environment literature[1], compare and evaluate advantages and disadvantages between the concepts of *Design for Environment (DfE)* and *Integrated Product and Service Engineering (IPSE)*.

To do so, we have analysed existing literature and also reviewed how some companies, mainly in the mechanical industry, are working with issues like DfE and IPSE.

3 DESIGN FOR ENVIRONMENT METHODS

During the past years, there has been a trend towards a rapid development of DfE methods and tools to employ in the area of product development. According to Mathieux *et al.* [8], extensive research on DfE, mainly in the areas of strategy, methodology, and tools, has been carried out by research organizations and industrial companies. The result is a considerable number of DfE methods and tools [9, 10] that fall into a wide range of categories, from relatively simple checklists or general guidelines to more complex software-based decision-making methods [10, 11].

Despite the many existing DfE methods and tools, their use is still limited. When they are used, these methods and tools are often not integrated in the product development process. This is a point highlighted by e.g. Baumann *et al.* [6, 12] and Tukker *et al.* [13].

NUTEK, the Swedish Business Development Agency [14], had a similar conclusion in its final report on a three-year-long DfE project. According to the report, some large multinational companies (particularly in the fields of electrical and electronic goods, motor vehicles and packaging) are addressing the issue in a rather comprehensive way, and the study concludes that DfE plays a small role in many companies (particularly small and medium-sized enterprises).

Some small and medium-sized enterprises (SMEs) have experience with DfE (demonstration) projects, but they rarely lead to the use of DfE in ordinary product development [13, 15]. Further, most companies do not treat DfE as a management issue see e.g. [16]. Finally, it is common that when a company does practice DfE, the focus is on environmental redesign of products instead of the development of new products. Given this, the potential benefits of DfE have not been realized. The general experience and conclusion of Lenox *et al.* [17] is that if a company uses DfE, it is usually carried out by those working in specialist functions (i.e. those not involved in the ordinary product development, but those working at the company's environmental division). The results of the DfE work are often not carried back to the rest of the product development process in an efficient way. In many cases, the methods and work with DfE are executed separately from the rest of the product development. This may be a result of the isolation that many methods and tools have been developed in, as described by both Blessing [5] and Baumann *et al.* [6].

[1] In this paper, the concept Design for Environment is used but the literature review also incorporates literature of similar concepts, e.g. Eco-design and Green Design.

4 INTEGRATED PRODUCT AND SERVICE ENGINEERING

Manufacturing companies, which have traditionally focused mainly on their physical products in the development phase, need to change and widen their working procedures in their offering development. Integrated Product and Service Offerings have been promoted from several perspectives, e.g. economic, social, and environmental, and research in this area has emerged in several disciplines. The methodology is closely related to the area of DfE, but has a wider scope including Life Cycle Engineering (LCE) [18].

IPSE is a methodological approach for creating Integrated Product and Service Offerings. *The aim with IPSE is, from a lifecycle perspective, to generate and optimize offerings with a combination of products and services that satisfies an identified customer need, and at the same time increases the competitiveness of suppliers.* IPSE focuses not only on the production phase, but also incorporates the use and the end-of-life treatment phases, enabling great potential for environmental improvements. In addition, it creates new ways for the supplying company to profit from environmental improvement during the use and end-of-life phases, especially if the offering's products are still owned and controlled by the supplier. Example improvements include a reduced need for spare parts, energy and other products during use, which translates into savings from an environmental perspective as well.

The IPSE-model, illustrated in Figure 2, highlights and illustrates vital and crucial activities in the generation of the offering (see also Lindahl *et al.* [19]). The two-way arrows in the method symbolize the important communication needed between the different stakeholders within the lifecycle activities.

4.1 Step 1 – Need and requirement analysis

The main issue is to start from the customer's needs and requirements in order to generate efficient and effective business offerings in conformance with the value constellation concept by Normann and Ramírez [20]. *The identified requirements should primarily be seen as requirements on the requested function and not as product or service-related.* In this activity, it is important to have in mind that it is also critical to determine needs and requirements for other stakeholders, e.g. the managing board, authorities and suppliers. The environment is, in this view, not a stakeholder, but environmental-related requirements are stated by different stakeholders, e.g. legislation.

4.2 Step 2 – Concept generation

The concept generation differs from traditional concept generation since it better highlights the need to generate concepts in an integrated way, concepts that from the beginning and in a parallel processes comprise both the offerings for service and product content. The focus is on finding the best combination of products and services based on the validation of the different requirements stated for the requested function.

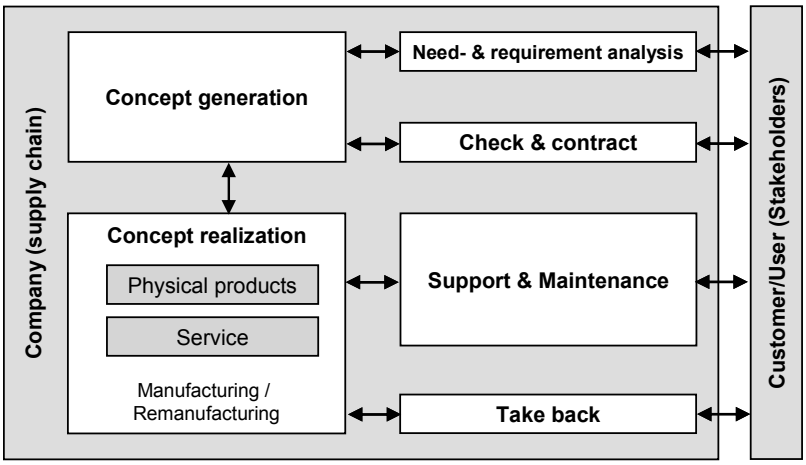

Figure 2: An Interactive design model for IPSE.

The combination can be based on standard products and services, but also on customized ones. The previously developed IPSE methodology provides good support for this activity [21].

4.3 Step 3 – Check and contract

In this activity, it is not only important to verify that customers understand what they will gain from the offering; it is also important to verify that the customer is satisfied with the offering. To do so, the determining factor is that the offering can be transcribed for the customer in an understandable format, e.g. with parameters and description that the customer is familiar with and can interpret. One way to convince the customer of the gain is to use the “need and requirement analysis” activity-identified parameters, and compare the values from the use of the offerings with the original values.

4.4 Step 4 – Concept realization

When there is an agreement/contract of the offerings, e.g. the function, the next step is to go from concept to realization of the offering, i.e. produce the different services and products needed for the offering. The existing IPSE methodologies support an improved dialogue between different stakeholders in this realization process.

4.5 Step 5 – Support and Maintenance

During this activity the offerings function is used and during this phase that the service and maintenance is delivered. Active communication with the customer during this activity is a good opportunity for companies to learn more about their customers’ needs for service and how to better identify and fulfil customer requirements. Since the customer focuses on utilizing the offering and therefore has direct experience with the combination of products and services, it becomes easier to obtain an understanding of his/her experience with the offering.

4.6 Step 6 – Take-back

It is quite common for Integrated Product Service Offerings that the products’ ownership is not transferred to the user, and that the products are therefore taken back when the user no longer needs the offering. The IPSE approach can successfully be integrated with a remanufacturing system [22].

5 DISCUSSION

This section compares and evaluates IPSE and DfE from different perspectives. Other perspectives exist, but the number of pages has limited us to only discuss a selected few. Note that the listed perspectives are not presented in any sort of ranking, and they are all more or less related to each other.

DfE methods and tools like e.g. LCA, which emphasise a holistic view from a life cycle perspective, are often promoted as holistic to enlarge their focus from not only regarding the production phase but also incorporating the use and end-of-life treatment phases. However, according to Lindahl [23] and Lenox and Ehrenfeld [24], one of the problems with several DfE methods and tools is that they tend to focus on the single objective of minimizing environmental impact. It is therefore a bit paradoxical that DfE methods and tools in fact are in general very ”unholistic” in the fact that they only focus on environmental issues.

The advantage with IPSE is that the method does not focus on a single issue but instead incorporates a wide range of issues, e.g. environmental, quality and economic [18]. Of course, this is also the case for many traditional product development methods such as QFD. The IPSE method has a structured approach, e.g. including scope and flow models to cover the entire offering’s life cycle and different stakeholders’ requirements (see Figure 3).

5.1 Product perspective

DfE methods and tools, like many other traditional design methods and tools such as e.g. various CAD tools, are in general not designed to deal with offerings, i.e. combinations of products and service that require a simultaneous focus on the product and service as a whole.

Existing DfE methods and tools are primarily focused on dealing with physical artefacts and their evaluation. One reason for this is that many of them are based on quantitative data from the entire life cycle, e.g. that concerning material content, emissions and energy consumption. This data are in general quite tricky to gather for physical products, not to mention for services. For practical reasons, there has therefore been a focus on DfE on products.

Another reason for this distorted focus has been that the offerings' service content has often been added on after the products have been designed [25]. One major obstacle with this is that it implies a need to develop the service based on an existing product, since it is very expensive an often unrealistic to change the existing product. This implies less cost-efficient offerings than could be the case if one could design them simultaneously, e.g. a small change in the product that could make the service much easier and increase the customer's satisfaction.

The difference with the IPSE methodology is that the basic idea is to develop the offering's service and product content simultaneously and in an integrated way.

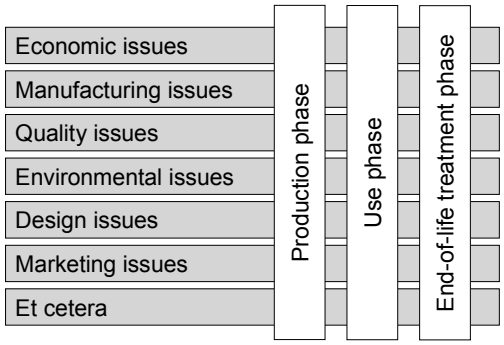

Figure 3: How different issues relate to different product phases. DfE methods tend to focus only on environmental issues, implying a risk for sub-optimization. The advantage with IPSE is that that method does not focus on a single issue, but instead incorporates a wide range of issues/perspectives in its view. Scope and flow models cover the entire product life cycle as well as different stakeholders' requirements.

5.2 Use-phase perspective

The IPSE methodology has taken DfE methodologies' focus on a life cycle perspective one step further. Instead of only analysing and optimizing the product from a life cycle perspective, the IPSE methodology aims to cover and support the offering company in all steps in an offering's life cycle, and especially during the use-phase. The IPSE methodology focus on the use-phase is related to the fact that it is during this phase the offering generates its customer value. It is also during this phase that the service is generated, and at the same time consumed. In many cases, it is also during this phase that most costs related to the offering occurs, e.g. from energy consumption and service. To help customers to reduce this cost and to get paid for this is not only good for the company and customer, but also in general from an environmental point-of-view. Studies show that a major part of an offering's environmental impact occurs during this phase [26].

In addition, DfE tends to place great focus on this phase, but the problem is that stakeholders in general tend to have difficulties in judging and understanding the environmental data output from DfE methods and tools, e.g. those expressed in CO_2 equivalents.

As McAloone and Andreasen [18] state, IPSO has a wider scope than DfE. One example of IPSO's sharp focus on the use-phase is e.g. its focus on making the use-phase more efficient and effective. These types of improvements tend to reduce the environmental impact, e.g. by reducing energy consumption.

5.3 Customer / Stakeholder perspective

In most DfE methods, environmentally-related requirements tend to be treated as the most important or other types of requirements are not even handled, e.g. LCA. The important issue - whether the customer will and can accept the offering after changes based on environmental considerations - are not in focus. There is a risk that the product for example: a) is very good from an environmental point of view, but b) that the changes made may imply that no customer wants to buy the product, since their requirements are neglected.

The lesson learned and implemented in the IPSE methodology is that *it does not matter that the product is excellent from one perspective, e.g. an environmental one, if the customer does not buy it*. There must be a sensitive and balanced handling and prioritization of different stakeholders' requirements. In the IPSE methodology, this is done in a structured way in the concept generation phase.

Finally, the IPSE methodology advocates a close dialogue with customers / stakeholders. This is especially important in the use phase, since it is here a great part of an offering's environmental impact occurs. By being proactive and having well-developed systems of e.g. education and maintenance, the environmental impact in relation to customer-perceived value can be controlled and reduced.

5.4 Design perspective

When integrating products and services into combined offerings, the identification and handling of requirements becomes more complicated and requires a more holistic view also incorporating the use phase, since the service is produced and used during the use phase. In many cases, the end-of-life treatment also becomes very important since the products might be used several times. If the company maintains control over the offering's products, this is even more important.

IPSE focuses on this part of the design process. This is natural in order to implement changes in a cost-effective and efficient manner. It is also important to make such changes as early as possible in the design process.

Even though the name Design for Environment indicates a great focus on design, many DfE methods and tools have little support for designers. When it comes to dealing with the outcome from many DfE methods and tools, there is a lack of practical support concerning what to do and how to make the improvements. Existing DfE methods and tools are mainly focused on pointing out environmental problems with an existing product, not on how to manage and reduce such problems. Of course, there are some exceptions, but of these, some are tricky to use since they tend not to support the identification of what to focus on first.

The background to this may be that these methods and tools have, in general, been developed with a scientific and theoretical background, sometimes with little regard for their application in practice [27]. The lesson learned when developing IPSE methodology is to have a continuously and parallel interaction with industry in order to get immediate feedback [28].

5.5 Improvement perspective

The improvement issue is important in order to find new solutions that are more e.g. environmentally friendly. It is important that methods and tools stimulate a focus on improvement rather than conservative thinking. One way to generate new ideas is to view a product from a different perspective, and DfE methods and tools with their environmental perspective have such a point-of-view, and have in many cases been an efficient and effective way for companies to find new improvements. Also, the life cycle thinking in these methods and tools has stimulated new improvements, since those working in different parts of the product life cycle have begun to talk to each other.

In addition, the IPSE methodology aims to support improvement-focused thinking, and to help the user to step out of their traditional thinking/focus, e.g. not just focus on the product but instead focus on the context the product or service is used in order to make it as good as possible.

The more perspectives a developer is aware of, the more options he or she will have, and the more likely he or she will be able to produce a successful product. However, the more perspectives there are the more complex the evaluation process becomes. Crucial for success is that the optimization is done with as many different perspectives in mind as possible, e.g. economic, quality and environment. The ISPE tool, Service Explorer [29] is a powerful tool to support such management of different perspectives, as it supports the judgement of different requirements and the innovation process.

Finally, our research and that of others has shown that the supplier's focus on offering integrated products and services can be a driving force for developing new and innovative technical solutions, and has proven to be a successful marketing channel for companies aiming to spread new technology to their customers.

6 CONCLUSIONS AND FURTHER RESEARCH

The conclusion so far is that IPSE is a promising approach, not to take DfE one step further, but to take the environmentally-related requirements that DfE tries to promote one step further, i.e. to be better integrated with other offering-related requirements. Valuable lessons learned from the use of DfE have been integrated into the IPSE methodology.

Since the scope of IPSE is wider and not solely focused on environmental issues, it clears the way for a more balanced and objective development of offerings. IPSE has a strong advantage in that the method includes the analysis of both the mix of products and services within the offering, but is also related to the life cycle of the offering. At the same time, there is a focus on balancing various types of requirements, where environmentally-related requirements are just one of many that a developer needs to pay attention to.

Related to this, there are indications that it is preferable to analyse a product, service or an integrated product and service offering from several perspectives, and to put different perspectives in relation to other perspectives in order to see what consequences might occur.

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