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Integrated Product Service Engineering - Factors influencing environmental performance

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Abstract

This paper aims to lead theoretical discussion regarding which IPSE (Integrated Product Service System) factors are expected to increase environmental performance of a life cycle compared to a traditional product sales business. Existing theories such as theory of product development, transaction cost theory and theory for risk management are used and the paper theoretically analyzes and identifies the following crucial characteristics; complexity of the product, uncertainty of offering, control of product operation, asymmetric information and scale of economy.

Keywords: PSS, environmental performance, information asymmetry, economies of scale, risk

1 INTRODUCTION

In society today there is increased awareness about environmental problems and this in combination with concern about future shortages of natural resources has resulted in increased pressure to find innovative strategies that can tackle these problems. During the last two decades, industry and academia have proposed and tried to implement several strategies and solutions. In much of the manufacturing industry today, numerous companies' business offerings are a combination of physical products and services. From academia, these include Functional Economy [1] and the Integrated Product Service Engineering (IPSE) concept, also often called Product/Service Systems (PSS) (e.g.[2]). PSS is defined, for instance, as "a marketable set of products and services capable of jointly fulfilling a user's needs" [3]. The proposal of a "life cycle-oriented design" [4] highlights an important step for the "product and technical service design processes" integration. Additionally, some specific engineering procedures and computer tools have been developed and validated with industrial cases (e.g.[5]).

However, the research in this area is still in its infancy and a number of questions remain unanswered. Specifically, a general weakness in existing literature is that even though a large number of authors have stressed PSS' environmental and economic potential (e.g.[6]), very few studies have proved PSS' potential for changing environmental performance. There are two main questions to consider. One is under which conditions PSS is a suitable offering and in general, PSS approaches seem to work well for e.g. products with high costs to operate or maintain, complex products and long life products [2]. Theoretical investigation has also begun: For instance, property rights have gained attention as a key for PSS to be meaningful [7]. Yet, all these literature are insufficient, especially from scientific viewpoints. The other main question is which PSS factors influence the environmental performance in comparison with traditional product-sales type business. Very few e.g. [8] have attempted to analyze the relation between PSS types and their influence on environmental impact.

2 REDEFINING IPSE

Our research group at Linköping University and KTH (The Royal Institute of Technology) in Sweden has developed what is termed Integrated Product Service Engineering (IPSE) [9]. IPSE looks at combinations of products and services and is a type of engineering, which is different from PSS per se. In addition, it attempts holistic optimization from the environmental and economic perspectives throughout the life cycle. IPSE also consists not only of design as the most influential activity, but possibly other engineering activities such as maintenance, upgrade, remanufacturing, etc. Therefore, IPSE has to deal with the time dimension of the life cycle. Figure 1 depicts different interesting processes for IPSE, obviously showing various disciplines and different aspects to be addressed. An IPSO (Integrated Product Service Offering) is an offering that consists of a combination of products and services that, based on a life cycle perspective, have been integrated to fit targeted customer needs. This often creates close contact between the supplier and customer. Further, IPSO means that products and services have been developed in parallel and are mutually adapted to operate well together in contrast to traditional product sale.In many cases, the service provider retains responsibility for the physical products in the IPSO during the use phase, e.g. the customer only uses the machines and pays for the manufactured volumes; then, when the customer does not need them anymore, the supplier takes back the machines. Such cases increase the provider's interest to ensure that the customer uses machines installed as long as possible and that any disturbances, such as the need for repairs, are reduced. This could lead to a product lifetime extension.

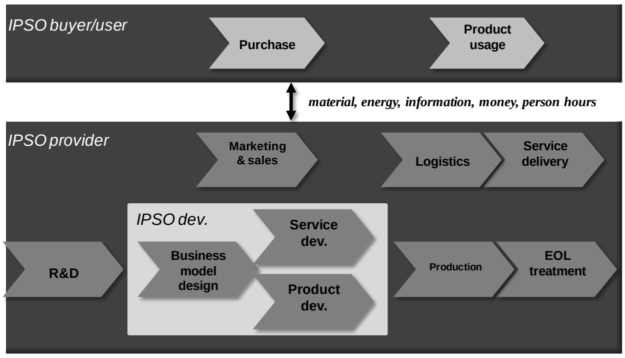
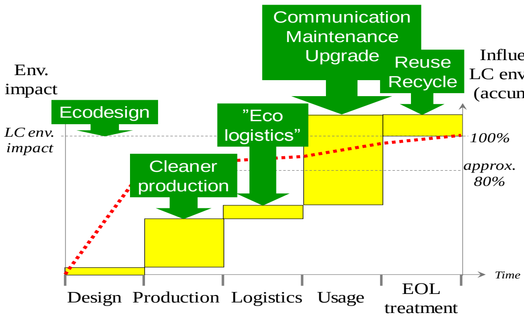


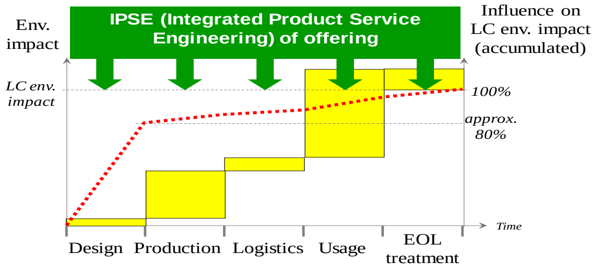
Fig. 1 : Processes of IPSE's interest [10]

Based on [11], IPSE is explained in comparison to Ecodesign (environmentally conscious design) due to some commonality with Figure 2 (a) and (b), where different types of engineering activities are put on the identical graph. The graph depicts the environmental impact of a certain type of product with high impact from its usage phase, which holds true in many cases. The horizontal axis represents the time dimension on the life cycle. Bars represent the environmental impact from each phase such as production and usage (scaled with the left vertical axis). A dotted line represents the accumulated influence of the activity at each phase of the life cycle's environmental impact. It is shown that the design phase has by far the highest ratio, which is generally known. As seen by the dotted line, Ecodesign is obviously crucial, since it is the design activity with the dominant influence. However Ecodesign is not sufficient since it leaves out control after the design phase. This is why IPSE is more effective, including the possible employment of other engineering activities such as maintenance.

In this paper the following characteristics are to be paid particular attention. The first is its length of the usephase which be long, e.g. more than 20years. Therefore IPSE has to address much of this time dimension with design and especially effective design since the earlier a certain action is taken the more effective its outcome is in general.



(a) Various Eco-activities



(b) IPSE

Fig. 2 : Comparison of IPSE and other activities

Note: The environmental impact (shown by bars) is a rough estimation of active products. EOL and LC stand for end-of-life and life cycle, respectively.

Then, what is design? A seminal work by [12] states "design is an engineering activity that … provides the prerequisites for the physical realization of solution ideas" (originally in [13]). This mainly concerns processing information about needs and wants from stakeholders and through the product life cycle, as well as about function and structure of the product. Effective processing of information plays a central role in IPSE – this is the second characteristic.

Then, design of what? This is the next relevant question as discussed in [14], which points out an artefact, i.e. an object to be designed, is today "integrated and systemic product-services linked in a high-level user experience". Also acknowledging co-creation of value by a provider and a customer/user is a strong idea behind the servicizing (see e.g. [15]), a provider cannot get rid of influence from its customer/user to create the intended value. Thus, a provider can design something contributing to its value, but cannot design the value itself. This means that control of risks of the value creation process is crucial. Thus, this risk is the third characteristics.

In sum, IPSE can be defined as an engineering activity controlling risks of value creation through dealing with information originating from a wide window on the time dimension.

3 PRODUCT DEVELOPMENT

According to ENDREA [16], product development is defined as: "all activities in a company aiming at bringing a new product to the market. It normally involves design, marketing and manufacturing functions in the company". The current business model for many products the focus is normally on cutting down the cost for manufacturing and delivering and little focus is placed on later phases of the product's life cycle. At the same time, life cycle cost studies and life cycle assessments have shown that for many products, it is during the use-phase where the major costs and environmental impact for the product occur. Figure 2 shows, in a basic way the environmental impact accumulation over the product's life cycle.

When developing IPSO, the basic principal is to consider all life cycle phases in order to optimize the offering from a life cycle perspective. The idea is to get the lowest total cost for the offering possible, not only to get the lowest cost for product. Costs are often associated with the use of materials and energy, which in turn provides a negative environmental impact, implying that more cost-optimized products usually have less environmental impact. Figure 2 also illustrates the different phase's impact on the total environmental impact and how important the design phase is, especially the early part of it where the product specification is defined.

At the same time, the initial product specification sets up boundaries for potential actions in the later phases which is often referred to as the "design paradox". The paradox, Fig 3., is that when the general design information is needed, it is not accessible, and when it is accessible, the information is usually not needed. Costs for later changes increase rapidly, since earlier work must be redone [17]. Figures 2 and 3 illustrate the importance of the design phase as well as getting in relevant requirements as early as possible in the development process. It also shows the problem with traditional product development where often little care is taken in product development (and in its specification) for future services, maintenance, and end-of-life-treatment. Traditionally, the initial focus is on developing the physical product and subsequently a possible service (intangible product) is developed, but this is hindered by the limitations set up from the physical product. When developing IPSO, the development is accomplished in an integrated and parallel approach.

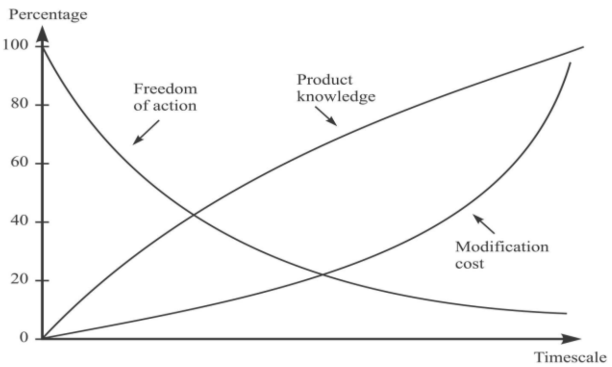


Fig. 3. The relation between "Freedom of action", "Product knowledge" and "Modification cost" is shown [18].

The rate of market and technological changes has accelerated in the past decade implying that companies must be pro-active and rapidly respond to fluctuations in demand [19]. A way to handle these challenges is to do more of the product development in a more parallel and concurrent way in order to e.g. shorten the calendar time (from start to stop) and increase the collaboration over competence disciplines. One concept in line with this is Integrated Product Development (IPD), whose basic idea is to increase the efficiency in product development by more parallel activities and a higher degree of co-operation between functions, levels and individuals in an enterprise [20].

However, if a business model is changed from selling products to providing a function via IPSO, this also changes the conditions for development. When selling products, there is a need to constantly sell new ones or new models in order to survive. This implies that a company should want to split technical improvements between several versions in order to be able to sell more products over time. However, if a company sells IPSO, this is changed since the company wants the customer to use it for as long a time as it is economically interesting. The company will implement the best technique at once instead of taking it in steps leaving more time for developing more optimized offerings - offerings that are more cost-efficient and effective, and therefore in general give a lower negative environmental impact. Nevertheless, it will still be relevant for shortening the calendar time (from start to stop).

4 INFORMATION ASYMMETRIC BETWEEN A PROVIDER AND A USER

In general, environmental impact of a product life cycle is determined by product characteristics themselves and processes on the product. The former includes the type and amount of materials in a product, while the latter includes how to treat the product at EOL (end of life). Thus, the environmental impact of a product can be decreased by changing either its characteristics or its processes. However, one has to own and apply appropriate information to do so. There are different types of such information about a product itself or processes along the life cycle phases such as design, manufacturing, usage, and EOL. In addition, the information may not be documented in such a way that it is easily transferrable to another actor.

Who owns the information on how to improve the environmental aspect of the product and processes at different stages of the life cycle? Information asymmetry exists in many cases between the OEM, who in many cases designs a product, and the user. For instance how to attain the best energy performance for the product in practice may be more hidden to a user than to a designer – the user simply does not know how to operate the given product for the best performance, or the provider has more knowledge of the best available technologies at the moment. There can be various reasons for this, such as a lack of user education in spite of the existence of the necessary information, or the strategy of a user as a company not to get the competence.

Note that information asymmetry in the "market for lemons" addressed by [21] is not the main issue of this paper. In that case, the information possessed by a provider is about a product at a point of sale and is unchanged after the sale of the product, as it is based on a product-sales type business and the provider has no access to the product afterwards. This is shown with gray lines in Figure 5: the information of a user about the product increases along time and can surpass that of a provider. Note that variation of speed of the increase along time is not considered in this graph. In IPSE, on the other hand, a provider can obtain more information with access to the product during usage, and could maintain superiority regarding product information over the user. This is drawn as Cases 1 and 2 in Figure 5, to refer to the same and a higher speed as compared to the user, respectively. In Case 3, due to the lower speed than the user, the provider is surpassed by the user.

Information asymmetry can be a weapon for a provider to obtain payment in IPSE and makes IPSE meaningful as a business. For example, in the case where an OEM owns more information about usage or EOL of a product, there is potential for the OEM to provide IPSO so that the environmental impact is less than would be for product sales. It is also often reasonable for an OEM to be able to provide maintenance or upgrade service of its product. From the viewpoint of environmental performance, on the other hand, information asymmetry is a hindrance to improvement, since it is costly to transfer information to an actor who needs it.

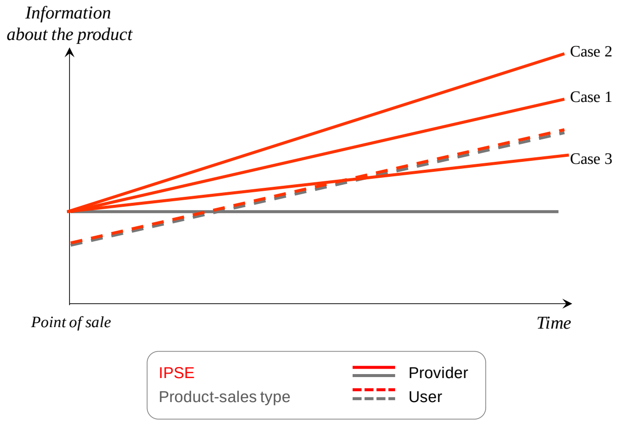


Fig. 4. Transitions of amount of information about a product after sales

5 ECONOMIES OF SCALE

Economies of scale are the result of an increased number of units produced or distributed, making it possible for the unit price to decrease [22]. An IPSE provider has the possibility to attain economies of scale through several different aspects. To provide IPSE is, in some cases, equal to being responsible for all the life cycle costs of the offering, which provide incentives to optimize the total cost as well as to realize economic development, and potentially environmental development [2, 9]. The provider would be able to gain economies of scale for both the products and the services. Leverage in production and administration could be created by offering the same services to different customers [23]. Another way of decreasing costs and achieving economies of scale could be realized when answering customers' demands by constantly configuring the same technology and skills in different ways [24]. For a certain industry the market capacity is limited, which means that a single company may not reach its scale of economy since its market share is relatively fixed for a certain period of time. It is not possible to realize large-scale effects with only a few customers, since much information is needed before, during and after the delivery which results in high transaction costs [25]. If a number of companies outsourced their processes to one organization, this would aggregate the volume and the production efficiency would increase [26]. This would also bring down the transaction costs, since they were created when transferring goods and services [22]. If the transactions occur frequently they are better handled within one single organization, since hierarchical governance facilitates administrative control and coordinated adaptability [27]. Furthermore, customers want to benefit from the knowledge of the supplier, and are reluctant to do business with several suppliers if they want an integrated and global offering [28]. However, the number of actors should be enough to make sure all the components of the offer are delivered by experts [29].

Apart from reduced transaction costs new costs for complementary products may also appear for the provider in the beginning, but will benefit from economies of scale after the transition [30]. Even though IPSE offerings imply customized solutions to achieve economies of scale, they have to be combined with well-defined modular structures at the component level [31-32]. This could also be useful when considering remanufacturing, since parts that are worn out quickly or require frequent upgrading should be placed in an accessible way [33]. Additionally, the IPSE approach would provide the manufacturer with the knowledge of how many products that are entering the process, as well as when they would do so, which would provide the IPSE provider with a remanufacturing plan that is easier to manage [33].

Furthermore, the IPSE provider can economically afford a high level of specialization and technological features due to economies of scale, and can thereby optimize resource consumption and waste production, leading to better eco-efficiency for the company [34]. The provider also often gains a competitive advantage over the customer when it comes to experience and knowledge concerning the product. With information, such as knowledge of how the equipment is repaired across their whole customer base, the provider can optimize maintenance routines and thereby minimize the cost as well as to increase availability and reduce product failures [30, 35]. Economies of scale can also emerge when the provider is in charge of the operations at the site of the customer, when the expertise of the provider in running the equipment can provide reduction in lead time and scale affects [36].

6 RISK

There are various types of risk, namely possible negative consequences from the environmental viewpoint. Reasons for this include an actor's lack of necessary information due to another actor's possession of the information, which was already discussed in the section on information asymmetry. There is another reason as well – non-existence of information.

Whether a product is better from an environmental standpoint for a given need is not necessarily certain at the time the product is first used. Different factors for this originate from the environment (not in the meaning of sustainability) and users. The former includes the speed of progress of the technology used in the product (or product generations) (see e.g. [37]). If a new product is more energy efficient than the original one, and it becomes available before the end of usage, it may be better environmentally to switch to the new product. The user factor includes his/her discontinuity with the need for the chosen product. For instance, a change in demand causing a user to stop using a product after a short time, and owning another product in addition, generates additional environmental impact.

How can these different types of uncertainty be better handled? A provider could do this. If a provider promises a user in a contract that the "best" available technology is provided within the contract period, the user can avoid the uncertainty of the technology progress. For the user's discontinuity of the need, a provider could give an option to a user so that the user can return the product to the provider after a certain period of time. By doing so, a user can shorten the time of holding that risk. The "trick" behind this is scale of economy that enables a provider to cancel different types of risks arising from its users. Thus, variety of the needs by a group of many customers is cancelled.

7 CONCLUDING DISCUSSION

This paper endeavoured to lead theoretical discussion regarding which IPSE factors are expected to increase environmental performance of a life cycle compared to a traditional product sales business. Four aspects from theory were discussed and their relevance was pointed out. In the theory of product development, information about a product is pointed out to be a crucial parameter, although the theory is to be adapted according to the nature of the offering – IPSO as opposed to a physical, traditional product. Then, asymmetry of the information about a product between a provider and a user was identified as a key for IPSE to be meaningful also through comparison with the product sales type business. Economies of scale were brought into the discussion and this remains to be an important issue for IPSE but with different characteristics from the product sales type business. Finally, risk was discussed and pointed out to be a crucial parameter to be controlled after sale and economies of scale were shown to be an enabler to control the risk in a better way. As shown in these four sections, these aspects are interlinked with each other and need to be further investigated. Nevertheless, the paper has provided a first theoretical cornerstone regarding conditions for IPSE to be a meaningful business style and IPSE's influential factors on environmental performance.

Further research is needed and the authors aim to continue to clarify and model the aspects discussed in this paper to more thoroughly explain the environmental advantages with IPSO in comparison to traditional sales.

8 ACKNOWLEDGMENT

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