Environmental and Economic Benefits of Industrial Product/Service Systems

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Abstract

Increased competition and new customer requirements have forced manufacturers to strive towards selling industrial product/service systems. Product/service systems have derived partly from environmental research and development. However, it is still not clear how much can be earned in environmental and economic concerns.

This paper aims to explore the economic and environmental benefits of product/service systems from a life-cycle perspective in comparison to traditional selling approaches. To fulfill this aim, four case studies were performed at four product/service system providers in Sweden. The data was collected through semi-structured interviews, telephone interviews and data provided by the product/service system providers. A comparison Life Cycle Assessment (LCA) was conducted between traditional scenarios and product/service system scenarios. In addition, a Life Cycle Cost (LCC) analysis was conducted. To summarize, in all four cases the product/service system scenarios had environmental and economic advantages in comparison to their traditional selling scenarios.

Keywords

Integrated Product Service Offerings (IPSO), PSS, Life Cycle Assessment (LCA), Life Cycle Cost (LCC)

1 INTRODUCTION

Integrated product and service offerings (IPSO) is a trend, increasing worldwide, which rather than selling the product alone integrates products and services into an offer that meets the customer's needs. This type of offer applies to a variety of concepts such as integrated product and service offerings, Product/Service Systems (PSS), functional sales, integrated solutions, aftermarket services, turnkey products with added value and total solutions. In the following text the IPSO term will be used.

An IPSO 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. IPSO further means that products and services have been developed in parallel and are mutually adapted to operate well together. This contrasts with the traditional sale when the provider transfers responsibility to the customer through the sales phase.

IPSO often create close contact between the supplier and customer, leading e.g. to offers being customized and improved to suit the customer better [1]. In many cases, the service provider retains responsibility for the physical products in the IPSO during the use phase. One example is when a client does not own the machines installed by the supplier, but only uses them and the products they offer and pays for the manufactured volumes. Then the supplier takes back the machines when the customer does not need them anymore. 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. The increased responsibility by the IPSO supplier also potentially facilitates improvements identified and implemented in comparison to traditional sales. This could lead to a product lifetime extension.

This paper is a part of the KIPTES project, which has the purpose of collecting and establishing knowledge concerning the activities of Swedish companies and researchers within the area of integrated product service offerings, and subsequently to spread this knowledge. The study was divided into four steps: a literature review; mapping of Swedish researchers within the area as well as their research projects; mapping Swedish companies and their activities within the area; and finally in-depth case studies using e.g. LCA and LCC. This paper is based on the case studies in the fourth step while the third study is partly presented in Lingegård et al. [2] with focus on organizational changes associated with IPSO.

2 OBJECTIVE

The objective of this paper was to explore the environmental and economic benefits of industrial product/service systems. This exploration includes comparisons to traditional approaches of selling products at four providers of integrated product and service offerings in Sweden.

3 METHOD

Methods used for the research were mainly case study methodology including e.g. data collection through literature and semi-structured interviews with company staff. In addition, in order to conduct the assessments Life Cycle Assessment (LCA) [3] and Life Cycle Costing (LCC) [4] were used. The data collection for the four case studies [5-8] were mainly carried out by Larsson with support from the other two authors of this paper.

3.1 Inventory

When collecting data for the LCA and LCC, several different sources have been used. This is both because individual sources have not been able to supply data for the entire life cycle, and in order to confirm data that has been considered uncertain. It can generally be said that the aim here has been to look for data as close to the source as possible, i.e. suppliers and staff at the case companies.

This research is based on facts obtained by the case companies and where the data not been available, realistic assumptions were made in dialogue with these companies. To increase the performance quality as the assumptions on IPSO scenarios are always underestimated and the traditional sales scenarios overstated. This means that differences in the paper between IPSO and traditional sales scenarios are less than they probably would have been in reality.

All of the scenarios described in the case studies exist today at the companies, except for Scenario D in Case Study C, which is tentative. This means that the comparisons between the scenarios are valid and industrially practicable.

4 CASE STUDIES

The following paragraphs describe the four case studies conducted at the four IPSO providers for this research. In addition to the case study descriptions the results will be shown.

4.1 Case Study A – Cleaning of plaster exteriors [8]

The functional unit in this study is the cleaning of 1 m^2 of plaster exterior.

The company of Servicestaden Sverige AB cleans building exteriors as one of its businesses. The design of the building to be cleaned and painted affects implementation, and there are various options to facilitate work on the building exterior (facade). Extended nozzles for washing equipment, sky lifts, moveable scaffolding or fixed scaffolding are all examples of tools that facilitate the cleaning of facades. When the wall is to be painted after washing, it is advantageous to use a scaffold, which is mounted on the wall, making it easier for the painter.

Traditional exterior cleaning – In the traditional sale of facade cleaning, the customer first turns to a paint company to order facade painting. The painters then estimate the time based on the drying time of a traditional facade washing with high pressure water, which is equivalent to between six to ten working days. In the next step, the customer contacts a company that provides facade cleaning. The customer must schedule when the cleaning of the facade should be performed in order to permit enough time for drying in time for painting.

Exterior cleaning with high pressure water – Exterior cleaning traditionally consists of spraying the surface to be cleaned with a detergent, which may be allowed to sit for a short time. Then the dirt is rinsed and the facade is cleaned using high pressure water. A professional pressure washer is often small enough to fit in a smaller truck. When the pressure washer is used, the liquid may penetrate well into the wall, depending on water and water pressure. Because of this, painting cannot begin until the walls are dry.

Exterior cleaning with Qlean method – The Qlean method consists of cleaning done with ultra-clean water. Ultra-clean water is tap water that is completely free of bi-products such as salt, lime, minerals and metals. When ultra-clean water comes into contact with dirt, it not only loosens algae and exhaust fumes, but also functions equally well on grease and oil. Application of the ultra-clean water on the facade is done by piping with nozzles (see Figure 1).

To get the maximum power of the ultra-clean water, the Qlean method is always implemented from top to bottom on the facade. This means that the consumption of ultra-clean water and the time for washing is highest at the beginning of exterior cleaning. Hence, the ultra-clean water flows down the facade to loosen up the dirt even on surfaces that do not have nozzles directed towards them. The Qlean method does not allow moisture to penetrate deep into the exterior wall, so painting can take place as soon as a day after cleaning.

Figure 1. Application of ultra-clean water on the facade by a piping system with nozzles [9].

Scenarios – To identify the costs and impacts of facade cleaning, three scenarios were created. Scenarios and assumptions for each were determined based on consultation between the authors and Servicestaden. Common to all scenarios is that the facade cleaning requires the use of scaffolding and a staffing of two persons during the entire cleaning operation. After drying, scaffolding used in the facade cleaning remains until it is painted. Table 1 shows the differences between the scenarios.

Table 1. Summary of scenarios.

Scenario	T/I*	Washing Method	Capacity [m^2/day]	Drying Time [days]
A	T	Detergent – Pressure washer	300	6
B	T	Qlean-method	250	6
C	I	Qlean-method	300	0

*T/I stands for (T)raditional sales and (I)PSO

Scenario A: This scenario means the sale of traditional facade cleaning when using detergents and high pressure water. A day's cleaning corresponds to a cleaned surface of 300 m^2 with a drying time of six days.

Scenario B: This scenario means that the facade is cleaned by staff that rent ultra-clean water equipment from Servicestaden and thus applies the Qlean method, but that the facade cleaning is sold through a traditional sales model. This means that the client is still based on the painter's understanding concerning drying time of six days. This scenario also means that the company which rented the ultra-clean water equipment does not have time to clean as many square meters as the Servicestaden staff would have covered. A day's cleaning corresponds to a cleaned surface of 250 m^2.

Scenario C: This scenario means that Servicestaden offers the customer a clean and dry exterior wall one day after cleaning. This is conducted using the Qlean method. A day's cleaning corresponds to a cleaned surface of 300 m^2.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 2.

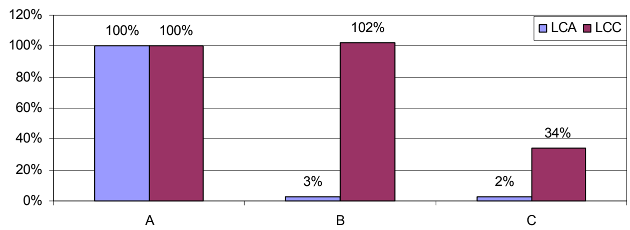

Figure 2. Summary of LCA and LCC in Case Study A.

Scenario A is set to be the reference value and thus become the scenario that all scenarios are compared with.

The results clearly show that it is environmentally preferable to use the Qlean method compared to the high pressure water method. To make it cost-rate motivational to switch methods, the drying time needs to be included, as in Scenario C. By applying IPSO which include short drying times for a customer, the customer can schedule an earlier painting. It is therefore in their best interest to choose IPSO over traditional marketing facade cleaning.

Discussion about the LCA – The inventory of life cycle analysis brought up several uncertainties surrounding the calculation, as discussed below.

It was hard to find data about the exterior detergent; instead, data based on assumptions and the detergents content was collected and aggregated from several databases. However, some detergent data was not found and was left out from the study. Therefore, it is likely that the exterior detergents' environmental impact is higher. This would imply that the high pressure water wash is even worse in comparison with the Qlean method.

It is uncertain to what extent the estimated supply pump is in line with reality. For example, it was calculated to be used on maximum load. The calculations still show that the supply pump's environmental impact is minimal in comparison with the production of high pressure water and ultra-clean water.

Discussions about the LCC – The inventory of life cycle cost brought to light several uncertainties. During the study, different assumptions and uncertainties were tested, but since the results were not significantly affected, it was decided to only discuss them here.

When a wall is flushed with high pressure water, there is a risk of delicate parts breaking and loosening. It is a question of who is liable, how big the damage is and the cost of repairing the damage. However, because of low pressure technology, the risk of facade breaks does not exist for the Qlean method.

As in the life cycle assessment discussion, there are uncertainties about the supply pump's actual cost. However, since the energy use results in a low cost compared to the whole, it is considered that the result still is valid. Labor costs are based on an estimate of the wages at Servicestaden. When wage variations occur, the result may change.

4.2 Case Study B – Clean floor [5]

The functional unit in this study is to hold a corridor's floor surface of 1 m^2 clean for a year.

The current situation is floor care at both the Valla Campus and the Cleaning Unit at departments at Linköping University, the latter abbreviated LV. LV has taken forward proposals for the departments' current needs and performance. Questions of interest have been e.g. what is needed to achieve the result of a clean floor?. They then make the departments' decisions on the basis of the actions needed to achieve the agreed upon outcomes. LV is interested in using the most effective and efficient method of floor care in relation to the defined customer need. This means methods that provide a clean floor at a low price, which is both environmentally and user friendly.

Definitions of floor care – Floor Care includes several elements that all have the aim of maintaining the floor function. After a floor is installed, a basic, so-called "construction cleaning", is performed. Following this, regular maintenance is conducted until the floor is replaced. In this study, the floor is assigned to "regular maintenance", the collective name for floor care i.e. frequent and periodic maintenance.

Frequent Maintenance – Frequent maintenance means the daily or weekly cleaning regularly occurs. Depending on factors such as congestion, filth, type of room, flooring and age structure, as well as customer demands for cleanliness and luster, the frequency and thoroughness of cleaning vary greatly [10-12].

Periodic Maintenance – The periodic maintenance is designed to facilitate the frequent maintenance and to ensure the floor is better protected [12, 13]. Periodic maintenance means that floor care resources are applied to create a protective layer on the floor. The layer also contributes to make the frequent maintenance easier. The frequency of required periodic maintenance varies due to e.g. if the frequency maintenance has not been performed sufficiently well or whether the burden has been higher than normal which led to increased wear. During periodic maintenance, the old floor care product is removed after which new products are applied. In this case, the periodic maintenance occurs during the times when the premises are used to a lesser extent, e.g. holidays.

Machine use in floor care – In larger premises and in the corridors, it is worthwhile to clean by hand instead of using scrubbing machines. Frequent maintenance with scrubbing machines may require that the floor first be dry mopped to remove any additional dirt particles or other volatile dirt. With both frequent and periodic maintenance, LV uses the same riding scrubbing machine, a "Taski Duospeed". The ride-scrubbing machines are mainly used in the corridors.

Chemicals – Both frequent maintenance and periodic maintenance may require various chemicals and chemical products. Regarding chemical use, it is difficult to generalize, especially when the concentration and volume are different and given that the wide range of different chemical products provides a wide distribution of environmental impact. In Larsson *et al.* [12], the problem of what effect chemicals can have is further developed.

Twister™ method – Instead of using chemicals in the performance of floor care, it is possible to achieve equivalent results with a mechanized solution. The Twister ™ method consists of a cleaning pad, prepared with millions of microscopic diamonds (attached to the Twister™ pads surface), which polishes and cleans the floor with only water as an additive [12]. As the floor care element is implemented, the Twister™ pad is worn down without affecting the lifetime of the floor. The binder holding the diamond anvil to the roundabout also contains a pigment, making it easy to see when it's time to switch to a new Twister™ pad.

Scenarios – In order to compare traditional sales and IPSO on floor care, two scenarios have been created. To facilitate the comparison based on two scenarios from a customer perspective, the LV is the executer of the floor care. The customer buys through a contract in floor care. The contract specifications help the customer determine what requirements LV must live up to. Depending on how the specification is designed, the conditions for introducing new approaches diverge. This is where the specifications are often based on the customer experience. The scenarios that were created to include floor care should be performed on plastics, linoleum and rubber flooring.

Scenario A: Scenario A refers to traditional sales of floor care and is based on the customer specifications that include a clear description of the floor care methods to be used (normally the previously used floor care method). LV earlier used a floor treatment method including polish, and therefore it is included in this scenario. It is assumed that LV uses this as the requested floor care method. The frequent maintenance should be performed every third day, with periodical maintenance once a year.

Scenario B: In this scenario, an offer of floor care, the customer's specifications made demands on the LV providing clean floors. The offer has meant that LV can use its experience of various floor care methods. LV has therefore chosen to apply the Twister™ method to achieve customer requirements for quality. This scenario corresponds to the current situation.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 3.

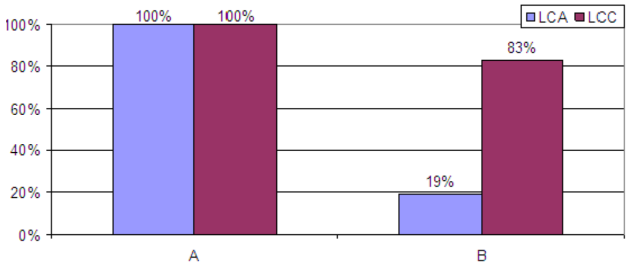

Figure 3. Summary of LCA and LCC in Case Study B

The results of the comparison show that Scenario B has a lower environmental impact and cost than Scenario A. The main difference is that traditional sales are settled using the existing methods, while IPSO are better able to adapt to new methods such as the Twister™ method.

Discussion about the LCA – Lindahl & Larsson [11] discuss among other things chemical eco-toxicity, and it shows that the floor care with polish has an even greater environmental impact than the result shows, which also applies in this example.

Based on that IPSO applied, there is greater opportunity to carry out the floor care and change the technology and methodology without violating the contract. This leads to the rapid conversion to new technologies that have lower environmental impacts such as the Twister™ method.

Discussions about the LCC – In an earlier study, it [11] was estimated that frequent maintenance took place every third day of the year's 365 days. In this study, the decision was made to build upon the previous results, but when the LCC is calculated from a usage rate that is lower than this, it is possible to discuss the differences between conditions in each method. If the LCC had been based on an equal use frequency as in the LCA it would have resulted in a cost increase; this occurs when periodic maintenance takes place, and would affect Scenario A for the worse. At the same time, this shows the sensitivity analysis of the LCC that increased utilization does not affect the cost of Scenario B significantly.

The difference between the two floor-care practices arose from the periodic maintenance. It should be noted that the cost for the scrubbing of a polish-treated floor and then the application of new polish does not include the time when the premises can not be used. Since the Twister™ method is easier to use than polish, time savings and cost reductions are achieved.

4.3 Case Study C – Soil compactor [7]

In this study, the functional unit was compaction of soils corresponding to a distance of one meter in width, 550 mm. Here ground refers to soil, sand, gravel, crushed rock and paving blocks.

Swepac International AB (Swepac) manufactures and performs service on soil compactors. From its manufacturing facility in Ljungby, Sweden, Swepac distributes soil compactors of different sizes to rental companies who then rent them out to different users. The IPSO Swepac provides its customers reconditioning, maintenance and repairs. Swepac strives to increase its machines' lifetime and leasability. This effort has resulted in several design improvements, some of which are interchangeable eyebolts, protective moldings and materials, to increase its soil compactors' leasability and technical lifetime.

A soil compactor is used to compact mainly soil in order to create a strong base. In this research, the soil compactor called FB 250 was studied (Figure 4).

Figure 4. Soil compactor FB 250.

Leasability and lifetime – A soil compactors' technical and economic lifetimes differ, especially in comparison with its leasability. It is easiest to get new machines, which makes it likely that the rental firm can maintain a higher price on those. This is valid as long as the customer, i.e. user, has a greater willingness to pay for the new machines than the older. That the client would rent a new soil compactor before renting an older one is partly to avoid problems in service, but also for more psychological reasons (it feels better to work with new and refreshed equipment). The context (e.g. misuse and irresponsible use) in which a soil compactors are used in general reduces the overall leasability to be shorter than the technical lifetime. This means that the rental firm probably has more functional machines in its inventory that can only be rented at a lower price or when newer machines already are leased. In this study, it is assumed that the rental firm's goal is to maximize its profits by hiring out soil compactors at as high a price as possible. This implies that considerations have only been taken towards estimated leasability and technical lifetime linked to repair and maintenance needs. The leasability assumes the number of years the soil compactor can be rented out without lowering its price.

Scenarios – In this study, a number of scenarios were designed to compare traditional sales with IPSO. The scenarios were created after consultation between the authors and Swepac. The differences between the various scenarios are described in the simplified section below, after which the various scenarios are presented more clearly. Figure 5 describes the principles of the main scenarios (Traditional Sales and IPSO) which are compared in this study. The letter "A" represents how a soil compactor is distributed from Swepac to a rental firm. The letter "B" represents a compactor that a rental firm rents out to a customer, who then returns the compactor to the rental firm when the lease period is over. The letter "C" represents the maintenance and the repairs Swepac conducts for the rental firm, thereby increasing its leasability. Only Scenario A applies the traditional sale while the other scenarios assume IPSO. The different scenarios are summarized in Table 2.

Table 2. Summary of scenarios

Scenario	T/I*	Surface Treatment	Leasability	Reconditioning
A	T	Varnished	5 y	0 time
B	I	Varnished	6 y	1 time
C	I	Galvanized	6 y	1 time
D	I	Galvanized	9 y	2 times

* T / I stand for (T)raditional Sales and (I)PSO.

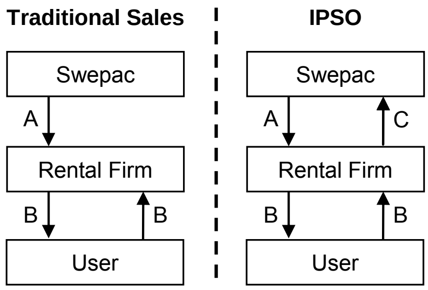

Figure 5. Description of the main scenario differences between traditional selling and IPSO.

Scenario A: Swepac only manufactures and sells soil compactors through traditional selling. This means that technological innovations that increase the technical lifetime are not valid. The scenario does not include any refurbishment, which adversely affects the lifetime of the compactors' components. The color wear and other wear makes the machines look unattractive after five years, making them harder to rent out.

Scenario B: This scenario is a reflection of the IPSO Swepac had previously, and includes the repainting and reconditioning of machinery. By reconditioning and repainting, the leasability is extended to six years.

Scenario C: To increase longevity and avoid repainting, the paint has in this scenario been replaced and certain parts galvanized. In order to compare how the galvanizing and vanishing are different, in consultation with Swepac it was assumed that soil compactors' leasability is six years.

Scenario D: This scenario implies that performing two reconditioning jobs could ensure a technical life of nine years. In the current situation, this scenario is not likely since the traditional economic thinking provides an amortization period of five years, after which most rental firms choose to buy a new machine. The scenario aims therefore to demonstrate the potential benefits that can arise when the technical lifetime is prolonged.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 6.

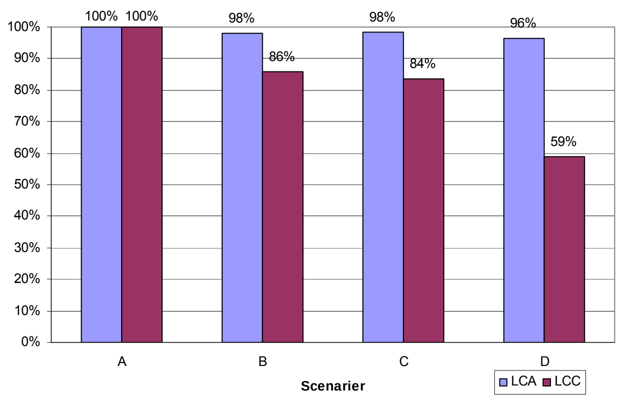

Figure 6. Summary of LCA and LCC in Case Study C.

Based Scenario A being set to be the reference value and thus becoming the scenario that all scenarios are compared with, the comparison shows that there is a clear correlation, both environmentally and economically, between traditional sales and IPSO. The results also show that the difference between the varnish and the zinc coating is not excessively large. But since varnish may have a greater impact than the findings in this study, it is likely to assume that the scenarios involving varnish (Scenarios A and B) have a greater impact than what is reported in Figure 6. Using zinc for galvanization is also preferred when the cost is lower.

Discussion about the LCA – The results of the LCA were influenced largely by the leasability that applies to each scenario. Generally, the results show clearly that the longer the leasability the soil compactor is assumed to have, the less environmental impact per meter-packed soil. With IPSO, there is an increase in the motivation to provide a product with optimal leasability.

Since Swepac performs reconditioning and develops good relationships with rental companies, it creates a better familiarity of how soil compactors works in operation and which parts need replacing. Swepac works on reducing the need of repairs and reconditioning by sharing its knowledge to rental firms and by gradually make improvements.

One improvement that Swepac has done is to galvanize some components. However, the LCA result shows that zinc used for galvanization can provide a greater environmental impact. It should be noted that data for both painting and repainting show that the environmental impact is limited, e.g. no transport to and from repainting are included in the results. Thus, it is reasonable to assume that a galvanized soil compactor can be better environmentally than a varnished one. This is where the difference between Scenarios B and C is not very large.

It is difficult to give a full picture of what portion of total environmental impact the repairs have been. A faulty component does not directly lead to preventing the soil compactor form working, but if not addressed it might imply that other more vital components are damaged. The need for repair depends on external factors such as handling during use. However, it can be concluded that with IPSO, in this case Scenarios B, C and D, there was a reduced need for repair.

In the LCA, shipments have been handled carefully. However, it is difficult to know how often transportation to and from the repair is needed and who in Scenario A performs the repair. It should be seen as self-evident that the more repairs, the more transportation, and that more transportation will lead to greater environmental impact. Clearly, many of the movements of the different scenarios are equal and cancel each other out in the comparison.

Discussion about the LCC – The discussion here is primarily to highlight observations that have not been possible to estimate economically.

A rental service should strive to be able to rent a soil compactor as long as it can get the same benefit as the renting of a new one. Through refurbishment and implementing measures that make soil compactors look like new, the number of years soil a compactor can go out to the customer not only increases, but also the number of years it may go out to the customer at the right price. Thus, it is in the rental company's interest to have a leasability perspective. In this case, the result shows that soil compactors by IPSO are, in the long-term, better than to buying into the traditional forms of selling.

Through refurbishment Swepac creates a cross-fertilization of product development. By adapting soil compactors the production facilitates refurbishment, and thus reduced working hours when the step should be performed. With refurbishment, knowledge is created about the conditions for developing better products, with less need of repair and with a longer lifetime. There are also several practical advantages to reconditioning as opposed to an increased risk of repairing. Foremost is refurbishment can be scheduled when demand for soil compactor use is low, thus avoiding loss of income, such as during winter months, when fewer construction jobs are carried out.

The study found that zinc coating for the galvanization of soil compactors is better in cost terms. It is clarified that

Swepac most likely would not have galvanized certain components if they did not use the IPSO approach. The reason is partly that traditional selling does not try to increase a product's lifetime to a high degree, mainly to avoid saturated market demands. It was through refurbishment that Swepac found that it is cost beneficial to galvanize certain components to avoid the costs incurred in repainting process.

The study has not included costs incurred when a soil compactor breaks down and when the work is delayed. This is where it is difficult to estimate the losses/expenses suffered by the user. However, it should be regarded as self-evident that higher costs and reduced revenues will be incurred when the repairs must be performed, and hence it should be an endeavor to reduce the risk that soil compactors will break. It was found that IPSO helps to gradually reduce this risk.

It has been revealed during the study that Swepac in some instances may give discounts. The discounts vary depending on the relationship between Swepac and the customer. This would lead to life cycle costs of leasing firms being reduced when the relations between them and Swepac are developed. This relationship development is a cornerstone of IPSO. Since the result still shows the benefits of product-service offerings versus traditional selling, it has not been considered necessary to clarify the benefits of IPSO by applying any discounts to the outcome.

The cost of transportation is not included in the study. It is then the rental company which is responsible for these costs, and such costs vary depending on where the rental company is located.

4.4 Case Study D – Core Plugs [6]

The functional unit in this study is the service a paper mill has of supplying a core plug used for paper rolls, that is sent to a customer once for a single use.

Polyplank AB manufactures and sells products consisting of a mixture of recycled plastic and wood. This unique material can be reused directly without further treatment. This study focuses on core plugs used by paper mills, which they use to plug the cores on which paper is rolled up and which follows the roll out to the customer. Through selling through the IPSO concept, Polyplank collaborates closely with its customer, the paper mill, and can thus take advantage of the core plugs when the paper mill's customers send them back to the paper mill.

Handling of used plugs – There are three main scenarios for what happens with the paper mill's customers used core plugs:

- Disposal by the paper mill's customer;
- Reuse by the paper mill (sent out to new customers); and
- Recycling by Polyplank.

Disposal by the paper mill customer – In some cases, used core plugs at the paper mill customer disappear or are discarded. This quantity is very small in comparison to the other two scenarios, and therefore this study is distinct from dealing with the core plugs not reused or recycled.

Reuse of core plugs – The most common scenario and the paper mill's most advantageous, is the reuse of core plugs. This means that core plugs after a period out at the paper mill customer are returned to the paper mill; after washing and quality control, these core plugs can be reused for new customers. If the core plug is worn out it is sent to Polyplank where it is recycled. Normally, the core plug is reused several times. With the IPSO concept, Polyplank aims to achieve a level of quality that will enable their core plugs to be reused several times. Even the paper mill's customers benefit from this approach; instead of the handling and the cost of discarding core plugs, they can easily send them back.

Recycling – When core plugs are finally discarded, they are returned to Polyplank where they are grinded down and sent to injection molding in order to become new core plugs. In practice, almost 100% of all incoming used core plugs become new core plugs.

Scenarios – A number of scenarios were created to compare different alternative potential offers that Polyplank or its competitors could offer paper mills. The main difference between the different scenarios is the number of times the core plug's material is reused by Polyplank, and how many times the mill can use the core plug before it is sent back to Polyplank for recycling. Table 3 describes the different scenarios. In the first scenario, virgin plastic is used in order to compare the pros and cons of Polyplank materials based on recycled plastics.

Table 3. Summary of scenarios.

Scenario	T/I*	Ingoing material	Use at final customer	Material use
A	T	Virgin material	1	1
B	T	Polyplank material	1	1
C	I	Polyplank material	1	6
D	I	Polyplank material	5	3
E	I	Polyplank material	5	6
F	I	Polyplank material	5	9

Scenario A: This scenario corresponds to the traditional production of core plugs and is a competitor to Polyplank's core plug offering.

Scenario B: The paper roll with the core plug is only used one time.

Scenario C: This scenario corresponds to what happens if the paper mills for unknown reasons do not reuse the core plug, but send it directly to recycling and have done so five times.

Scenario D: The paper mill customer returns the core plug back to the paper mill company where it is reused four times before it must be replaced. It is assumed that all replaced/discarded core plugs are returned to Polyplank, which through its recycling process reuses the material for new core plugs. Each plug can be recycled twice before the material eventually must be discarded.

Scenario E: The paper mill customer returns the core plug back to the paper mill company where it is reused four times before it must be replaced. It is assumed that all replaced/discarded core plugs are returned to Polyplank, which through its recycling process reuses the material for new core plugs. Each plug can be recycled five times before the material eventually must be discarded.

Scenario F: This scenario corresponds to what happens if recycling increases. The paper mill customer returns the core plug back to the paper mill company where it is reused four times before it must be replaced. It is assumed that all replaced/discarded core plugs are returned to Polyplank, which through its recycling process reuses the material for new core plugs. Each plug can be recycled eight times before the material eventually must be discarded.

Summary of LCA and LCC – The compilation of the LCA and LCC is presented in Figure 7.

Based on Scenario A being set as the reference value, it becomes the scenario that all scenarios are compared with. The comparison shows that there is a clear correlation, both environmentally and economically, between the choice of materials, recycling rate and recycling rate for the use of a core plug.

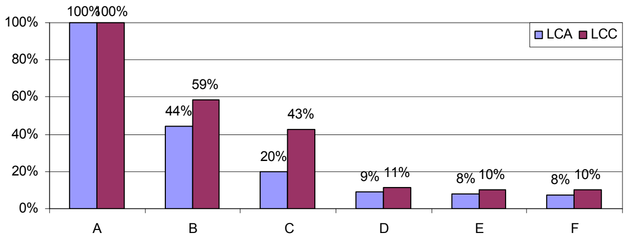

Figure 7. Summary of LCA and LCC in Case Study D.

The comparison clearly shows that if Polyplank would apply the traditional sale of core plugs as Scenario A shows, it would also impact the environment and causes the cost to increase significantly compared with current IPSO that Scenario E represent. This is where today's IPSO represents an environmental load of eight percent and a cost of 10% of the total, which stands for traditional selling.

Discussion about the LCA – The LCA results are discussed in relation to choice of materials and recycling rate.

The largest gain with core plugs based on Polyplank material is the use of recycled compared to virgin plastics for the core plugs in Scenario A. It gives a significantly reduced overall environmental impact. The more times the material of the plug can be reused, the less environmental impact. Polyplank's IPSO based sales has increased its ability to take full advantage of its materials.

Since the Polyplank core plug can be reused the overall environmental impact per use is decreased; however, reusability puts higher requirements on quality regarding durability. It has been confirmed that the core plug that Polyplank manufactures has sufficient quality to withstand at least five reuses, which helps reduce the overall environmental impact. If Polyplank would not work under IPSO and instead focus on selling more plugs, it would result in an increased environmental impact. To summarize, Polyplank IPSO-based selling helps to increase the possibility that the core plug reuse rate will increase.

Given the close cooperation between Polyplank and the paper mill, Polyplank can recycle core plugs, leading to a reduction in material consumption. The result shows that this gives a reduction in environmental impact compared to core plugs produced on virgin materials. The result also shows that the more times a core plug is recycled, the more the environmental impact is reduced.

Discussion about the LCC – To clarify, the LCC results are discussed for the different scenarios, such as differences in choice of materials and recycling rate.

The use of recycled instead of virgin plastic reduces the life cycle cost. Without the economic benefits of using recycled plastic, the question is whether or not core plugs would be made of recycled plastic, and it is therefore not surprising that the results demonstrate this.

When the paper mill does not need to consume as many core plugs, the life cycle cost per core plug is lower each time it is reused. From a traditional marketing perspective, this may in the short term be seen as something negative because it reduces demand for new core plugs. The interesting thing to consider is if Polyplank can offer a core plug which has a lower cost per use; if so, it is highly probable that that plug would take market share.

The results show that recycling is more cost effective than the use of virgin core plugs. However, there are many uncertainties in this case, when variable costs such as salaries are not included, and fixed costs of buildings and machinery are not considered. These costs are, however, not with the option of using virgin material.

5 CONCLUDING DISCUSSION AND CONCLUSION

Many researchers have emphasized that IPSO facilitate a dematerialization of the society and stimulate design of products that are beneficial for the environment [14-17]. The fact that the provider often keeps the ownership during the use phase also often implies a responsibility for the cost of maintenance and service [18]. This means that the supplier is interested in developing durable products with a long lifetime and low maintenance costs, something that effects how the company designs its products. In relation, this also generates economic drivers for reuse of the product and its components [19], something that potentially reduces the environmental impact regarding raw material and energy use for manufacturing [20, 21].

The four case studies described are in line with previous research by having the IPSO approach preferable from an environment as well as an economic perspective. The internal costs for maintenance imply that the supplier makes money on reducing those by e.g. reducing the resource consumption [16, 17].

It seems that IPSO enables a lower environmental impact than traditional business models as also described by e.g. Mont [22]. IPSO is not only positive from a business perspective but also from an environmental one. However, from these four case studies it is not possible to draw a general conclusion that IPSO always is preferable from an environmental perspective as also concluded by Lindahl & Ölundh [23] and Alonso-Rasgado et al. [24].

In conclusion, the calculations made in the four case studies show that the IPSO sales approach is both environmentally and economically preferable in comparison to their traditional selling approaches.

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