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ENGINEERING IMPLICATIONS OF INTEGRATED PRODUCT-SERVICE OFFERINGS

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ABSTRACT

In recent years there has been a shift in mechanical industry from a focus on physical products to product-service systems (PSS). The objective of this paper is to map out engineering implications and challenges based on five empirical examples of integrated product-service offerings (IPSOs). The paper is mainly based on case studies at Swedish manufacturing companies of different sizes. The following IPSOs were studied: (1) Lighting Function, (2) Core Plugs, (3) Material Handling, (4) Plate compacting, and (5) Thrust. These examples show that the orientation towards IPSOs implies several important strategic implications for a provider. Based on the examples, a discussion is presented concerning existing and potential engineering issues related to engineering requirements, development process and risks and opportunities with IPSOs.

Keywords: product service systems (PSS), business strategy, business and engineering challenges

1 INTRODUCTION

In the search for strategies toward increased competitiveness, a trend among manufacturing companies is to create value for their customers by offering solutions consisting of combinations of hardware, software and services, tailored for the specific needs of the customer [1-4]. This may not be a new concept per se, but it is a new concept for several manufacturing companies. These offerings are sometimes referred to as product service systems (PSS) [5] and integrated product and service offerings (IPSOs) [6].

The transition to IPSOs places new and more demanding requirements on product and service development and production, along with new requirements for companies in the way they relate to and build up relationships with customers. Existing IPSOs are normally developed by the companies' marketing departments, and are based on existing products optimized for traditional sale [7, 8]. With IPSOs, the skill to combine different types of products and services into a desired function becomes more crucial [3, 4]. In order to be able to deliver, companies need to continually develop their value chains and the competence of their personnel [9, 10]. It is important to organize the company and develop its logistics to be able to deliver a solution and create opportunities for take-back of the products used in the offerings. The business models and the business strategies used in the companies are also important to understand when studying how the product development process is affected [11].

From an engineering viewpoint, one question is how companies can develop attractive combinations of traditional product offerings with services: combinations that customers want and are prepared to pay for and at the same time can be efficiently provided, with sane risk-taking and long-term profit. Another important question is what kinds of parameters should be addressed to do so.

Morelli [12] argues that the design of an IPSO falls into a different domain than that of a traditional product, and that the design discipline has no methodologies to operate in such domains. Sakao and Shimomura [13], in the context of sustainable production and consumption, argue that a much larger framework than product design is needed, because the business model is ultimately changed; they suggest the use of disciplines such as engineering, marketing, and management. One important argument is that the shift in business models towards IPSOs implies a new mind-set and organizing framework at the industrial company [2]. Because of the above, the authors' earlier research has focused on the development of a method for Integrated Product Service Engineering (IPSE). IPSE is defined as *an integrated design process with the aim of developing an integrated product and service offering, where the physical product(s) and service(s) included in the offer are developed together*.

2 OBJECTIVE

The objective of this paper is to, map out engineering implications and challenges associated with IPSOs, and highlight those with five case studies.

3 METHOD

The paper is based on five case studies [15, 16] at Swedish manufacturing companies of different sizes. Two are large and three are SMEs (small and medium-sized enterprises) according to the European Union's definition [17]) were conducted. Some complementary studies have also been made at banks (especially for financial solutions) and pure service companies (for comparison and refinement of the issues to study).

The primary data collection method in these studies has been qualitative research interviews [18]. The main purpose was to obtain a deeper understanding of the manufacturing company's current business and product development activities regarding IPSOs vs. traditional selling of physical products. A second purpose was to investigate potential needs for methodological support for development of IPSOs [6, 11, 19-21].

Some companies were studied in-depth during an extensive time period with several interviews carried out on-site; others have been studied through interviews with company managers during meetings and workshops with several companies participating. Respondents were e.g. product and service developers, CEOs, and customers. In most cases, face-to-face interviews were recorded.

Question areas in the semi-structured interviews (for the purpose of this paper) were: *number of IPSOs compared to total sales volume; profitability for IPSOs vs. traditional sales; customer's perceived value of IPSOs; customer involvement in IPSO development; contract forms; provider experiences of IPSOs (pros and cons); and uncertainty associated with IPSOs*. Besides these question areas, other areas beyond the scope of this paper were touched upon, depending on the focus of each project.

In parallel to the case studies above, surveys were also conducted in Sweden, Japan, Italy and Germany [22, 23]. This study covers 34 companies, some of which are Swedish companies already included in the Swedish studies above.

4 EXAMPLES OF INTEGRATED PRODUCT SERVICE OFFERINGS

The cases studied are (1) Lighting Function, (2) Core Plugs, (3) Material Handling, (4) Plate compacting, and (5) Thrust. In this section, the cases are presented in an abbreviated way, i.e. only the more important aspects for the purpose of this paper are highlighted. The cases are summarized in table 1.

4.1 Lighting Function offering

Background – Panasonic "Light and Trust Service"[1] before used to sell fluorescent lamps by the piece to its customers. However, six years ago Panasonic started to provide Lighting Function to its customers. Among the motivations to begin this business was to differentiate from competitors, as price competition was quite severe in the lamp business.

Another motivation was to eliminate the load on lamp users from handling the lamps at end-of-life (EOL), since fluorescent lamps need special care upon disposal due to the content of mercury. In addition, attention was paid to environmental management systems in companies in general, and this business was regarded to have potential to contribute to environmental issues. Therefore, the company shifted its contracts with customers from selling to rental of lamps and, at the same time, began to take responsibility for care of the used lamps.

The customer need – Customers need lighting, but do not need to own physical lamps to get lighting. Morover, lighting is rather taken for granted. This means that employees do not want to be bothered by maintaining the Lighting Function. In addition, as described above, customers increasingly want environmental-friendly management of their facilities.

Description of the IPSO – Lamp users make rental contracts and need not take care of the EOL of lamps. An actor is introduced into this business model to provide services of offering light with end users, described as "light-offering company" in Figure 1, while the provider of physical lamps is shown as "lamp-producing company". This was a key for this business to become successful; it needed too big a change for the lamp provider to offer the Lighting Function, mainly because the

[1] http://panasonic.net/eco/data_file/e_06.html, visited Jan 13, 2009.

company organization did not fit with the service activity. Instead, Panasonic's conventional dealers, whose main function was sales, were capable of taking that function. The flow of physical lamps is shown in Figure 1, where two other special actors, contractors for recycling and EOL, are involved .

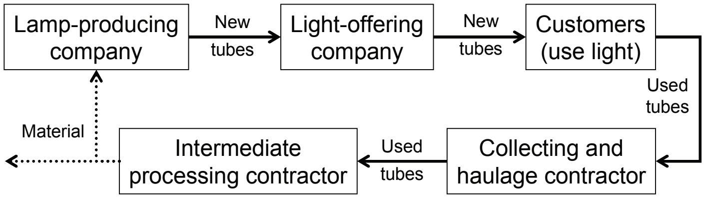

Figure 1. The Light-offerings material flow (interpreted from Panasonic[2]).

Potential business implications and challenges – As of March 2007, 4,200 business sites of 740 companies utilized the service[3]. This shift from selling per piece to rental contracts had a large implication on the provider's business model. In the previous business model, the larger number of lamps that were bought, the larger the income for the manufacturer. In the new model, the less the lamps were changed, the more the manufacturer saved. There were three main business challenges. First, the lamp manufacturers found much uncertainty in changing their business models from selling to rental. Second, the economy of closing the loop of lamp flow was uncertain. Third, there was no system supporting this material flow, including take-back and recycling, which was also a reason behind the second challenge.

Resulting engineering implications and challenges – Moving to IPSOs had implications on engineering activities at the lamp manufacturer. The biggest change was in the influence of the length of the lifetime of the lamps. In the conventional business model, prolonging the lifetime of the lamps contributed to strengthening the brand, and indirectly the probability for customers to buy. In the IPSO business model, longer lifetime contributed directly to the manufacturer's economy. Other activities, such as maintenance during the life cycle, have the same type of influence. Therefore, it will be important to grasp which actors that take and activities that cause the different types of costs, as it has influence on the engineering activities. Thus, design for life cycle (e.g. design for disassembly) becomes much more crucial to the manufacturer. In addition, optimizing physical products can fall at a different point than before.

More uncertainty emerges due to the longer period of rental contract compared to ordinary sale per piece. Thus, the company has to consider more risks and opportunities during the commitment to customers. Simultaneously, different types of uncertainty are produced as compared to the sales contract. Instances include malfunction of physical products and failure of service delivery. In a longer term, it is also an issue of how to address new technologies that may be introduced during the contract period.

Considering the wider range of responsibility in the rental contract, finding potential customer needs will be different from that in the sales business.

4.2 Core Plugs offering

Background – Polyplank AB[4] has developed a recyclable composite material composed of recycled thermoplastic resins and organic fibers. The granules can be used for traditional string and injection molding, and since all the company's products are recyclable, they can take back used products and reuse the material. The benefits of the material are many, e.g. one can use normal production equipment for plastics. In addition, the material is suitable for use in screens, coverings and as lining material. Pieces of the material can be cut and screwed into wood, and can be placed directly in the ground where it will never rot. It is also easy to keep the surface clean using high-pressure washing. This implies that this material can, in most applications, advantageously replace wood and even pressure-impregnated wood.

[2] http://panasonic.net/eco/data_file/e_06.html, visited Jan 13, 2009.
[3] http://panasonic.net/eco/data_file/e_06.html, visited Jan 13, 2009.
[4] www.polyplank.se, visited Jan 13, 2009.

The customer need – The paper mill industry needs core plugs for its paper bobbins, pictured in Figure 2. It used to have plugs made of formaldehyde boards, with the drawback that they could only be used once, which implied that the paper mill's customer had to pay to dispose of used core plugs. Another problem with these core plugs was that they sometimes cracked and destroyed some of the paper, not only causing extra waste for the paper mill, but also extra costs for its customers.

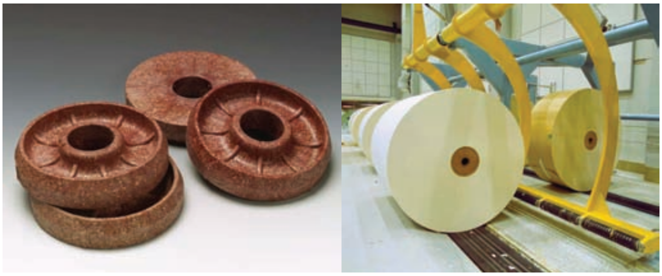

Figure 2. The core plugs and core plugs integrated in the paper bobbins (Polyplank[5]).

Description of the IPSO – The provider offers a reusable core plug based on its recyclable composite material that includes a take-back system of worn-out core plugs, as seen in Figure 3.

Supplier → Paper mill company → Paper mill's customers

Figure 3. The material flow of core plugs.

The provider delivers core plugs to the paper mill company, which integrates them in its paper bobbins and sends these downstream to its customers. After this, the paper mill takes back used core plugs from its customers. If still okay, the core plugs are reused; if they are worn out, they are sent back to the provider, who will reuse the material to produce new core plugs.

Potential business implications and challenges – Traditionally, this type of product is sold by the piece, and business models are built upon the inherent condition that the customer constantly needs to buy new products. The customer's focus is then often on price.

The IPSO shifts the focus from selling pieces to instead providing a better solution. This has several implications, e.g. on the cost calculation. An example illustrates this (**Error! Reference source not found.**). If the cost for a traditional core plug is 10 units per piece, of which 80% is material cost and 20% is production cost, this is the cost to get the function once. However, if Polyplank's core plugs is returned and can be used several times at no material cost at all, only costs for reverse logistics. If worn, the material of the plug is used again. Suppose material use three more times at an additional fifth of the original cost (ie no material cost, only re-manufacturing cost, which is estimated to be the same as for new production), the average cost per life cycle *of the material* can be reduced from 10 down to 4.25 monetary units (10+2+2+2+1=17 units for 4 times usage of one remanufactured core plug life cycle). Cost per function is considerably lower, depending on the number of times each re-manufactured core plug can be used. An important note is that the provider in this case takes over the end-of-life treatment cost from the paper mill's customers (1 unit, to the right in Figure 4).

For the provider, the major challenge is to ensure that they get back worn-out core plugs. The offering not only implies an improved earning potential for the provider, but also improves the customer value for both the paper mill company and its customers, e.g. by removing the cost for end-of-life treatment of used core plugs.

Resulting engineering implications and challenges – An engineering challenge has been to develop a core plug that not only can withstand extreme demands for strength and measurement accuracy, but also do so for several life cycles instead of one. Related to this, it is also important that the core plug within limits has a geometrical design that is easy to store and handle in a take-back system. Added to

[5] www.polyplank.se, visited Jan 13, 2009.

this, even though the provider gets back the core plugs, it is of interest to reduce the material needed for each core plug This is because it not only reduces the initial cost, but also the production cost (less material to process and transport) and entails less risk if the core plug gets lost during the use phase. A final, but not at least important challenge is to accomplish the above without mixing in other materials that could jeopardize the core plug's recyclability.
The solution in the end, following advanced strength calculation and testing, was a core plug 33% lighter than the original, and one that could withstand a 33% higher load.

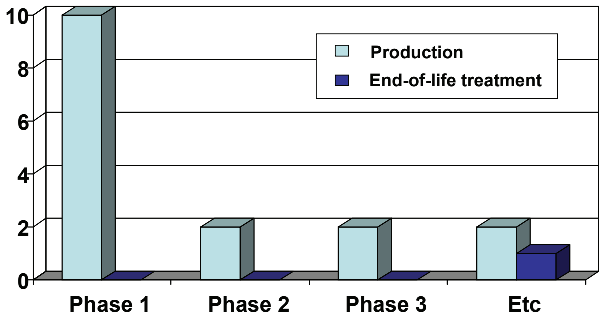

Figure 4. Illustration of the Core Plug offering's costs over the estimated length of four traditional life cycles.

4.3 Material Handling offering

Background – Toyota Material Handling Group[6] is one of the world's leading actors in the forklift truck industry, and has been active in the business for over 50 years. Today, the company's products are actively marketed in over 70 countries around the world.
The customer need – For the Material Handling provider's average customer, the forklift truck is something needed but not a core business. However, if the forklift trucks do not work, they can cause a major impact on the customer's operation. The customers' main focus is on "cost for warehousing", "time for delivery", "capacity change" and "function availability"; of those, "function availability" is considered by the Material Handling customer to be the most important [24]. The most crucial function to improve and have control over (including its sub-functions) is the time for reaction to malfunctions.
Description of the IPSO – Through a complete range of *products and services* rental programs (short, medium or long-term rental), the Material Handling provider offers trouble-free material handling operations worldwide. Examples of benefits are that they provide a flexible solution that can be adjusted depending on the customer capacity needs [25]. These solutions also help the customer to avoid the uncertainty of forklift truck running costs, as well as eliminating the need to tie up capital, which could be better used in other areas of the customer's business. Examples of different offers within a rental solution are:

- rapid response to ensure that the customer's operations keep running;
- guaranteed performance levels with a money-back commitment;
- total support from the company's service organization with rapid and guaranteed response times;
- ability to change or upgrade equipment without additional cost, subject to 3 months' notice;
- ability to return equipment if it is no longer required without additional cost, subject to 3 months' notice; and
- option of including a truck driver as part of the rental agreement.

Potential business implications and challenges – The traditional business approach is to sell forklift trucks with additional service; however, this provider's message is "***Don't buy trucks! Remember - you don't have to own a truck to use it!***" The business concept is to anticipate customer needs and deliver solutions for efficient materials handling, i.e. to provide the right forklift truck for the customer-defined application with the right power pack – delivered fast – and with each forklift truck

[6] www.toyota-forklifts.eu, visited Jan 13, 2009.

fully supported though its own service system in order to ensure maximum productivity. The business focus is changed to extending the products' lifetime and/or reusing and utilizing products in a more effective way, e.g. through remanufacturing. The IPSO in this case means that the forklift truck is first used for a long-term rental contract. When it ends, the forklift truck is often still in good condition and can be interesting (with or without modifications) for another customer with less demanding material handling. The second contract is normally a short-term contract, and depending on several parameters, the forklift truck can be sent out on more than once. In some cases, the same forklift truck may go out on different rental contracts during a year, and in order to guarantee its quality, the truck is more or less remanufactured between these different rental plans. However, before every contract begins, it undergoes a remanufacturing process in the provider's own special remanufacturing workshop in order to secure functionality. After being used in one or more rental contracts, the forklift truck is finally sold out or scrapped.

Resulting engineering implications and challenges – The new business model implies several engineering challenges. Since the focus is on improving the life cycle, and especially function availability during the use phase, it follows that it is not only a question of developing more durable forklift trucks, but also develop for less maintenance, which, if needed, is fast and easy to perform. A way to do this is to change key components into more durable - and possibly more costly to produce – components, but whose life cycle cost is lower, since they need limited maintenance or none at all, and can be used in several phases. These design improvements mostly deal with enhancing the accessibility of product parts that need to be changed [26]. Another engineering challenge is to monitor the use phase, e.g. to predict maintenance and service and to support the user's operation and use of forklift trucks. Many engineering challenges are linked to remanufacturing, and a proper take-back system, including e.g. reverse logistics and industrial remanufacturing, should be in place and facilitated by the provider [27]. Since the rental portion is growing, remanufacturing issues are becoming more and more important.

4.4 Plate Compacting offering

Background – Swepac AB[7] has developed plate compactors since 1993, and is now Sweden's market-leading provider. A full range of products is offered, with machine sizes and equipment options for all areas of application. For more details about this case refer to [28].

The customer need – In Sweden and the other Nordic countries, construction equipment like e.g. plate compactors is normally provided by rental companies. From a depot network, the rental companies offer their customers, e.g. a building construction company, a variety of machines. These rental companies also perform some level of service on their machines in order to improve use phase. When a construction company rents a plate compactor, it is normally crucial that this machine works with a high degree of reliability. Therefore, the rental company needs to secure the functionality of its machines. Furthermore, based on experience, in order to reduce the wear of rental equipment, it is preferable that they look new and are in good shape, since this has proven that customers will tend to take better care of them.

Description of the IPSO – The provider takes full responsibility for the product after delivery; this means everything from the rapid supply of spare parts, technical support and service to pure service agreements. This implies that the rental company that owns the machines avoids unexpected costs for repairs and spare parts. The rental company has a number of different offerings for the servicing and maintenance of their machines, which means that it is performed either at the customer's premises or in its own workshop. The provider also has posted service guidelines on the web directly for users, in order to reduce the travel needs of service technicians. A service agreement is offered at fixed price, providing a safeguard against unforeseen costs for the customer. The provider's customers (i.e. rental companies) and dealers abroad are trained thoroughly at their plant or at home.

Potential business implications and challenges – Since the provider wants to produce more durable hardware products, this implies that fewer spare parts are sold at risk of less income. The provider also faces a business risk with the servicing and maintenance contracts at fix price if not kept under control.

Resulting engineering implications and challenges – The provider's aim has been to make plate compactors which withstand tough conditions in a difficult environment. Plate compactors that require few spare parts and have a low maintenance cost was sought for. In addition, at remanufacturing it was

[7] www.swepac.com, visited Jan 13, 2009.

found that the cost for repainting is high, and therefore, the amount of repainting was reduced by adapting the plate compactor design. New materials were used instead of the traditional selection. For example, the bottom plate working against the ground was made of special steel in every compactor, prolonging the physical lifetime. Another example was the hood of the compactor, which was made of colored polyethylene plastic instead of painted metal, as seen in Figure 5. This gave a better finish, where scratches are not easily spotted, and if there is severe damage to the hood, it can be changed to a new one without going through a repainting process. The metal hook used for transporting was replaced with a textile strap and a chain, which significantly reduced damages occurring from transportation, since this made it is easier to position grabbing device, of e.g. a tractor . They have also, for some models, changed and adopted the filter for the air inlet, e.g. the air inlet is placed so the ingoing air is cleaner, and the filter has been adapted for the plate compactor in a manner that allows it to capture more particles than an ordinary filter would. Since the compactors are used in a very particle-filled environment, this kind of filter markedly prolonged the technical lifetime of the engine.
Finally, but not least important, in order to recoup the maintenance cost and need, the company's products are mainly based on standard products, and its customers can access information about those components via the web, and if needed, can purchase them in the nearest store. In the future, Swepac plans to develop products with longer service intervals, and components and material will be chosen to ensure that they last throughout a normal life cycle.

Figure 5. Plate Compactor FB465 (source: Swepac[8]).

4.5 Thrust offering

Background – Marine Jet Power AB[9] (MJP) has for more than 20 years designed, manufactured, and marketed propulsion for fast-going boats larger then 15 meters with engine power of 500-15 000 kW per water jet unit, as illustrated in Figure 6. In general, water jets are applied for boats with speeds from 25 knots and upwards. For a rich case description, refer to [29].

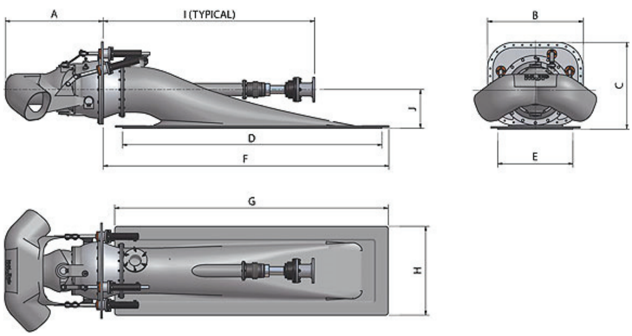

Figure 6. Principal blueprint of a water jet aggregate (source: MJP).

The customer need – This provider has three customer categories, each with different needs and requirements: navy/coast guards, commercial ferry shipbuilders, and yacht shipbuilders. Here, only the

[8] www.swepac.se/data/files/produkt_pdf/FB_465.pdf, visited Jan 13, 2009.
[9] www.mjp.se, visited Jan 13, 2009.

commercial ferries are described. Due to increased fuel prices and stricter environmental legislation, fast-going ferries are under pressure, and this is a decreasing customer segment. Commercial ferries can have up to 4,500 running hours per year, but season-based traffic lines are common, as is the use of "spare vessels", which means that each vessel may be in dry dock several months per year. Large customer companies carry out service themselves, including the water jet. They prioritize low price for spare parts, and try to buy directly from the offering company's suppliers; but a market for pirate parts has also appeared. Proper schedules for maintenance, where spare parts can be ordered in well in advance, could improve the service. Smaller customers usually do not have their own service units, and maintenance is often poor or non-existing; the vessel is run until breakdown. In this case, there is a need for fast delivery of spare parts and service. The customer is the shipbuilder, and the provider usually has no contact with the end-user company. The shipbuilder prioritizes price, performance, and delivery accuracy, while the operator (ship owner) prioritizes fuel efficiency, durability, reliability, service cost, available spare parts and service and performance.

Description of the IPSO – The offering is water jet propulsion systems. The advantages over traditional propellers for watercrafts are higher efficiency (at speed over 25 knots), lower vibration, protected propulsion, superior maneuverability, and lower waterborne noise. The offering can be divided into six primary components: (1) calculation for configuration, (2) the water jet (with pump unit, steering unit and hydraulics), (3) the control system, (4) documentation, (5) training and service of personnel, and (6) support and warranty. Moreover, after-sales activities include services and spare parts. This offering is provided together with a large number of strategic partners and exclusive suppliers.

Potential business implications and challenges – One major business challenge is to improve the service and maintenance of thrust equipment for commercial ferries. Instead of operating ferries until breakdown, or service being carried out by a company's own service team independently from the provider, a regular preventive service scheme would improve e.g. spare part logistics and longevity of propulsion equipment. The advantage for the customer is obviously higher availability and lower maintenance cost, but also lower environmental impact with reduced replacement of worn parts, and better transportation logistics for the delivery of spare parts. For the provider, proactive service could improve the current situation of the late order of spare parts, dissatisfied customers, and pirate copies.

Resulting engineering implications and challenges – The provider (together with a strategic partner) makes hydrodynamic calculations of water jet configurations for the shipbuilder to reach the requested performance for the specific vessel, both concerning intake dimensions and engine configurations. By so doing, the provider can often recommend an engine configuration with less power needed then the customer initially had foreseen. This is something which saves a lot of money, both at purchasing and during operations (the engine stands for 35% of shipbuilding cost, compared to the water jet cost of max 5%). The intake is designed to get optimal flow into the pump unit, and is often designed by the shipyard. The engineering challenge for the provider is to communicate optimal dimensions. The control system, including sensors, electrical circuit boards, CPUs, and control panels, is in the marine industry usually delivered by the water jet provider, since the steering is handled by the water jet. In this case, it is developed with a strategic partner. Currently, a modem for remote diagnosing is also being designed, which will be interesting as remote monitoring can be performed. The control system is the most complex part of a water jet propulsion system. Communication and coordination of functionality with the water jet provider is needed.

Moreover, an important advantage for this provider is the possibility to access most parts of the water jet in water, i.e. the design allows maintenance without putting the boat in dry dock, something that reduces cost for users. The major challenge for engineering is the constant communication of these advantages to customers already at the tender phase, or even before the shipbuilder initiates the design of a vessel. If shipbuilders do not take into account this important knowledge about optimized performance, both initial cost and in-use cost (e.g. fuel consumption) will be unnecessarily high. It requires well-functioning communication between the development engineers and sales and service partners internationally. Also, end-customer priorities need to be communicated to engineering counterparts at the shipbuilder company to avoid short-term cost saving solutions.

5 DISCUSSION AND CONCLUSIONS

In this section, existing and potential engineering implications and challenges identified in the above presented five cases are discussed.

5.1 Engineering requirements for IPSOs

Several of the researchers' earlier studies (see e.g. [6, 11, 19, 20, 22, 25, 30, 31]) have highlighted that companies often have started their move into IPSOs by bundling traditional products with services. However, a problem with many of these IPSOs is that the technical specification for a product sold with a traditional business model differs significantly from a product adopted for an IPSO. For example, manufacturing companies are in general organized for the traditional business logic of selling physical products, focusing on producing to as low a cost as possible, and sell the result for as high a price as possible. However, IPSO changes that business logic, since with a contract based on function availability the physical products and services become an internal cost for the provider and not an income, as in the case of Lighting Function or Plate Compacting offerings. The engineering focus changes from developing products that can fulfill customer requirements for as low a price as possible, to developing a total offer, including physical products and services, that for as long a time as economically suitable, can provide solutions to the customers' needs.

As explained in the Lighting Function and Core Plug offerings examples, the logic of calculating the profit for a provider can be quite different, and so can the requirements for engineering activities. Furthermore, as illustrated in the Core Plugs and the Material Handling offerings examples, it is positive from the provider's perspective if ingoing components can be reused for other customers. In order to do so, this also implies that ingoing products need to be balanced between a high degree of customization and at the same flexibility, so they can be reconfigured (ranging from upgraded to down-graded) in order to fulfill other customer's needs. The remanufacturing of forklift trucks in the Material Handling example illustrates this, and the provider has e.g. been involved in several engineering-related studies that in more detail have evaluated potential engineering improvements to facilitate remanufacturing, e.g. by changing the system or the physical components [27, 32, 33].

A related challenge is the difference in customer demands for traditional products and IPSOs [34]. It can be a tricky challenge to manage both a part of market that has realized the advantage of IPSOs, and another part that has not. Not all customers are willing to have the kind of close relationship to a provider that IPSOs usually require, as pointed out by [3, 4]. This implies that even the small company needs to be prepared to offer both traditional products *and* IPSOs (in different customer-specific variants), which for example the Thrust offering illustrates, where the customers are very different regarding own facilities for conducting service and maintenance.

Another challenge is to identify engineering requirements for IPSOs, since customers are not normally used to expressing those. When expressing their needs customers are often still focused on the physical part of the offering and the initial price, and not on the use phases, and the functions and services acknowledged as was the case with different customers and user priorities in the Thrust offering example. This also challenges development engineers at the provider to expand their perspective into a broader range of areas where the physical products are used. They need to learn to balance both numerically measureable physical product requirements with user experiences, often difficult to measure and express with traditional engineering tools, and evaluate different combinations of products and service that fulfills the needs. Moreover, the number of actors are many not only the customer, but also for other actors in the life cycle supply chain; this involves the provider company itself, its suppliers, and users from different companies, such as described in the Material Handling and Core Plug offerings examples.

Developing an IPSO as a package requires tight communication and close collaboration between different actors throughout the life cycle supply chain and different functions within a provider company, as implied above by several examples. This was especially true in the Lighting, Plate Compacting and Thrust offerings, where substantial communication and collaboration was needed between the product developer, strategic partners, and dealers. Different engineering requirements need to be transferred to those responsible for engineering tasks. Services and physical components need to be developed together to form a united package in an optimal way. This is needed more than in developing physical products. Furthermore, it is sometimes necessary to change the development processes.

Large provider companies are often organized with different functional units (departments), and thus tend to be less flexible and less efficient when they begin a new type of business due to more rigid structures and higher overhead costs. Our empirical studies show that smaller companies often have a more flexible and integrated organization (with fewer units and people involved) [19], [22-23].

5.2 Risks and opportunities

From the five case studies, it is obvious that a key to IPSO business models lies in whether the provider is able to control the physical products during the pre-use, use and post-use phases. The take-back of used products has an especially important impact on the business model [27], with possibilities for remanufacturing, e.g. illustrated by the Core Plugs and the Material Handling offerings. Provider control can be exercised e.g. through kept ownership, certified user training, or via service contracts [25].

However, how the products are designed also has a potentially important influence on reducing risk. Examples of engineering issues to work with include how easy it is to measure use and remote diagnosing, e.g. like the Thrust offering provider develops. The reason for doing this could e,g. be to obtain information concerning need of maintenance, and gain control, if the physical equipment is correctly used, and if possible improve the use through use training. Better control can also be obtained through better working procedures; maintenance performed by the provider; upgrading of software or electronic hardware; or replacement to newer equipment.

At the same time, provider access to the physical product can for many reasons be delicate during the use phase. Stops for maintenance, upgrading or replacement need to be avoided if the product is used in key activities, where customer revenue depends on runtime. From the customer perspective, any operator training due to such changes also must be avoided for cost and convenience reasons. The customer may want to employ the help of service providers other than the IPSO provider in case of e.g. malfunction, especially when the IPSO is a part of a larger system. Altogether, this sets tough requirements on the provider to be innovative when it comes to technical solutions, e.g. for remote maintenance (see the Thrust offering example), and knowledge about customer operations (as in the Material Handling offering), in order to minimize trouble in the use phase, and attractive maintenance contracts.

Another applicable solution that often convinces the user to accept the provider's access to physical products during use is through design of attractive technical solutions for maintenance. This can be done e.g. by innovative special service and maintenance equipment and tools, spare parts and consumables that are handled and offered only by the provider, and not by pirate service providers. However, as illustrated in the Plate Compacting offering example, it could also be the other way around if this is a more suitable solution. Instead, for the last several years the provider has made it very easy for the owner to access information about the specific plate compactors' components via the web, such as blueprints, component lists, etc. The provider only needs to handle and store a few specially-designed spare parts. It is recommended that the provider carefully evaluates long-term economic and knowledge management consequences of actors and their roles for each specific case.

5.5 Conclusions

This paper has mapped out some engineering implications and challenges based on five empirical examples of integrated product-service offerings. Furthermore, illustrated by those examples, a discussion has been presented concerning engineering issues related to engineering requirements, development process and risks and opportunities with IPSOs. Several important engineering issues to consider have also been highlighted, and can be used for the development of new offerings. Future research will be to further develop these engineering issues into design recommendations, and to further validate them.

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