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PCP (Provider – Customer – Product) Triangle: How Can Manufacturing Intelligence be Maintained?

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Abstract

Limited insight is available regarding the benefits of an Integrated Product Service Offering (IPSO) as a possibility to encapsulate a technology. This paper applies a framework termed the PCP (Provider – Customer – Product) Triangle to two cases. The PCP Triangle aims to identify benefits (including technology encapsulation) and risks of IPSOs in a systematic manner. In one case, a technology is the core of the offering and IPSO is an alternative as a business model. The other case concerns biogas production, where know-how to control the production is one of the key assets of the provider to add value. By doing so, it validates the PCP Triangle further with cases and explains how it can be used. The results show that the PCP Triangle is a simple but effective tool to describe and visualize the flow of information around the product by discussing strategies for keeping the firm's intelligence in manufacturing. The paper also discusses the IPSO's contribution to environmental performance.

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Keywords: Business Model; PSS strategies.

1. Introduction

Integrated Product Service Offering (IPSO) brings various types of benefits and risks to its provider. According to a number of articles (e.g. [1-6]), benefits include closer commitment to a customer and getting in-service knowledge and better control of a product, while risks include product malfunction and the customer's failure in commitment, depending on its contract formulation.

Most of the articles address some types of benefits, and virtually no method enables to, in a systematic manner, address and classify benefits and risks for the provider. More specifically, limited insight is available for such benefits of an IPSO as a possibility to encapsulate a technology (to keep Intellectual Property Rights or secret information) and shorten time to market as well as reduce the risk of technology appropriation [7], despite this businesswise critical issue for a wide range of manufacturers (see e.g. [8]). Therefore, this paper aims at creating better understanding of how to manage these benefits and risks with IPSOs.

In order to identify these benefits and risks of an IPSO in a systematic manner, a theoretical and generic framework termed PCP (Provider – Customer – Product) Triangle is employed [9]. The PCP Triangle is a modeling scheme that captures and describes the flow of information between provider, customer and product as well as uncertainty associated with the information of those three entities and the business environment. Note that service is indirectly described with the PCP Triangle.

This paper applies the PCP Triangle to two cases in industry. In one case, technology is the core of the offering (for industrial cleaning) and the IPSO is adopted as a business model. The other case is biogas production, where know-how to control the production is one of the key assets of the provider to add value. It also adopts the IPSO model. More concretely, the paper validates the PCP Triangle further with

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cases and proposes how it can be used. The paper also discusses the IPSO's contribution to the environmental aspect.

The remainder of the paper is structured as follows: Section 2 describes the PCP Triangle based on the literature [9]; Section 3 applies it to the two cases; and finally, Sections 4 and 5 discuss and conclude the paper, respectively.

2. The Provider – Customer – Product Triangle

2.1. General framework

To analyze benefits and risks of an IPSO systematically, a framework is needed. The PCP Triangle introduces information flow among the concerned entities as a central parameter forming the framework. It aims at analyzing information flows among a provider, its customer and the core product and benefits and risks of an IPSO. This is based on the fact that information flows play a crucial role to bring benefits and risks in IPSO. Figure 1 depicts this theoretical framework to analyze risks and benefits of an IPSO (the labels such as B1 are explained below) – termed the PCP Triangle. Here, the information addressed includes: physical conditions, behaviors, and functions of a product; signals taken in by a product; and operation and maintenance of a product. The flow of these types of information can be regarded as communication. From the viewpoint of effect, this flow can be classified into the mere moving of information, control of a recipient or even commitment to a recipient, through extending the notion of communication theorized as a process of expression, interaction, and influence in the socio-psychological discipline [10]. Using this framework, benefits and risks of an IPSO are explained. Note that the provider's staff, such as service technicians, is modeled as part of the provider. In addition, the "customer" can refer to different actors such as a payer, a value recipient, or a regulator. However, the PCP Triangle focuses on customers that could have access to products. Tables 2 and 3 summarize the benefits and risks, respectively.

2.2. Analysis of IPSO benefits

The benefits originating from the first four flows of information, i.e. from B1 to B4, are already reported in much of the literature. As seen in Table 2, the references listed are merely examples, meaning that other literature addressing the issues is available. For instance, IPSO may give a provider a better opportunity to obtain information from the product use (B1) (e.g. in-service knowledge as discussed in [3]) as well as, in the other direction, the control of the product (B2), as reported in e.g. [4]. Information exchange between provider and customer is also addressed in much of the PSS literature. The IPSO enables a provider to get more information from a customer via a closer relation (B3) [4] and fulfill more commitment to a customer (B4), as reported in e.g. [1].

In contrast, the information flow between a customer and a product is not often discussed in the literature. However, as analyzed in the case study in [9], changing how information is exchanged between these two entities can be one of the reasons for adopting IPSOs. This indicates the IPSO's power to decrease the amount of information flow from a product to a customer (and thus to other competitors) (B5), and as well as in the other direction (B6).

The literature [9] explains the type B2 with another meaning – shortening time to market. In general, the uncertainty of a product and a customer decreases along the development process of an IPSO or a product. However, the risk for technical malfunction becomes too high if the technology is introduced too early. Thus, there is a threshold on the uncertainty under which market launch becomes feasible. In the case of Integrated Product Service Engineering (IPSE), a manufacturer can monitor and control its products better and even mitigate risks in a different way when ownership stays on the provider side, compared with a traditional product sales contract where the customer owns the product after purchase. This increase in the level of uncertainty allowed creates a shortened time to improve the quality of the technology.

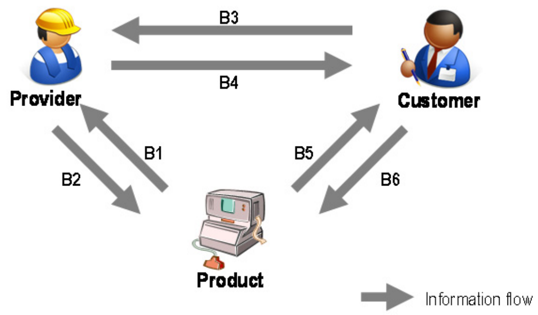

Fig. 1. The PCP Triangle - theoretical framework to analyse risks and benefits of an IPSO (based on [9]).

Table 1. Summary of the benefits of an IPSO for a provider.

	Benefits of an IPSO in general	Relevance with encapsulating a technology (X=low, XX= high)
B1	Gaining in-service knowledge [11]	X
B2	Provider's improved control of a product [4]	XX (especially in the case of a new technology) Shortening time to market – get first customer's adoption of a new technology
B3	Provider's getting more information from a customer [4]	X
B4	Provider's closer commitment to a customer [12]	X (encapsulation contributes to closer commitment)
B5	Keeping information away from a customer [9]	XX (for IPR of a technology)
B6	Reducing a customer's involvement in a product operation [9]	XX (for IPR of a technology)

2.3. Analysis of IPSO uncertainties and risks

To analyse the risks of an IPSO, it is fundamental to identify uncertainty rather than to begin with risks, because if the uncertainty becomes a risk it depends on conditions such as the business model. Uncertainty is defined here as a lack of information, and is classified into two types, i.e. aleatory and epistemic uncertainty [13]. In an IPSO business, major sources of uncertainty can be classified into the physical product, the service, the customer (including the user), and the business environment. This is depicted in the PCP Triangle shown in Figure 4, while Table 3 shows the proposed categorization. The rest of this section first illustrates each uncertainty category and associated risks. Then, it discusses the relations of the risks to the benefits presented in Section 2.2.

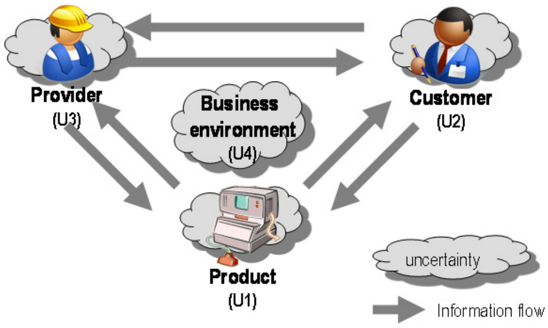

Fig. 2. Uncertainty types depicted in the PCP Triangle (based on [9]).

Table 2. Summary of the risks of an IPSO for a provider.

	Uncertainty	Major risks of an IPSO
U1	Product function (e.g. [1])	Product malfunction
U2	Customer/user's commitment and understanding [14]	Customer's failure in commitment and understanding
U3	Provider's activity (incl. service) [15]	Provider's failure in commitment
U4	Change of business environments [9]	Prerequisites change in case of a result-oriented contract

The type U1 is the uncertainty of product function. This has been one of the major issues in the engineering aspect of PSS as discussed in [1]. Major IPSO contents are physical products, maintenance, and repair (e.g. [16]). This also indicates that one of the reasons for providing an IPSO is uncertainty of a product's function. If the contract is based on result or performance of the product function, this uncertainty becomes a risk for the provider. Note that the provider bears the costs for among other things time for repair engineers and spare parts, while it gains income as a result of the performance.

In general, providers benefit more from the earlier introduction of technologies to a market by the better window of opportunities (e.g. [17]). Thus, addressing the trade-off between time to market and technical risk is an issue. IPSOs can bring a better way to address the issue, because a provider can release the product earlier (i.e. with a higher possibility of malfunction) with a plan to take care of potential malfunction with services.

The type U2 is uncertainty deriving from a customer and a user. In an IPSO, value is often co-created (see co-creation discussed in the context of innovation in [18, 19], i.e. created together between a provider and a customer (and/or user), rather than delivered. This means that the involvement of a customer/user is needed in these cases, and the provider is dependent on the customer/user [14]. In some cases, commitment by a customer/user, e.g. the daily check of a machine's condition, is a prerequisite for a contract (see an example in [20]. This commitment by a customer/user has uncertainty. This type of risk exists in the process of developing an IPSO as well. In other words, the provider and the customer may not reach agreement on a contract. This is especially relevant to the IPSO as it may be difficult for a customer to understand.

This paragraph points out that the risk originating from U2 (the customer) has a trade-off relation with benefits in general, and is not grounded in the case. First, it concerns the control of product (B2). Having a customer's commitment is risky in a sense, as explained above. It also reduces the provider's control of the product, leading to reduced benefit. Then, it appears removing a customer's commitment at all is the best solution. However, it is not the case in general, because it is not always the best from the economic aspect. It should be emphasized that these two factors have a trade-off relation, and thus an optimal point should be found. Second, it concerns a closer and longer customer relationship (B4). Having a closer and longer relationship with a customer could make a provider responsible for more. Thus, this risk may be in proportion to this benefit. The provider should determine the point where it can take the risk and the benefit.

The type U3 comes from the provider itself. This risk refers to the risk of failures in, for instance, achieving the tasks as planned and includes a failure of service. This has rarely been addressed in the literature. This uncertainty is influential on the provider's closer commitment (B4).

The last type, U4, is caused by a change of business environment. Especially in the case of result-oriented IPSOs, where the provider promises a certain result, this uncertainty can become a risk. E.g., possible change of regulations is a risk if it prevents the provider from keeping its promise.

3. Application to the cases

3.1. Technology-intensive offering

The company and its business – This section describes an offering of industrial cleaning [21], where its technology is the core of the offering. Qlean Scandinavia AB in Linköping has developed a method called the Qlean Method (QM). The QM is based on cleaning with highly purified water (here termed Qlean Water (QW)), which allows for cleaning/removing various forms of dirt without any additives. When QW comes into contact with dirt, it not only loosens e.g. algae and exhaust fumes, but also functions equally well on removing e.g. grease, oil, fingerprints and flux. The QM is used for cleaning e.g. building exteriors, large transformers, oil-contaminated stones, and hydroelectric dams, as well as industry components and PCBs before various forms of surface treatment.

The company uses a unique water purification method to produce QW for use in its QM. The "raw" material is often normal tap water. For each volume of normal tap water used by the QW purification equipment, the output of QW is approximately 60%, leaving about 40% rejected. When applying and using QW, the water's temperature is preferably around 4-10°C, but higher temperatures also work, although they provide no improved cleaning effect. Depending on the object to be cleaned, several different techniques are used for applying the water, e.g. high and low pressure spray nozzles. The company's business is to provide its QM to various customers, and it gets paid for the result.

Description of the offering on the PCP Triangle – The offering in this case is removal of oil, lime and algae contaminating large power transformer stations and power insulators, as shown in Figure 3.

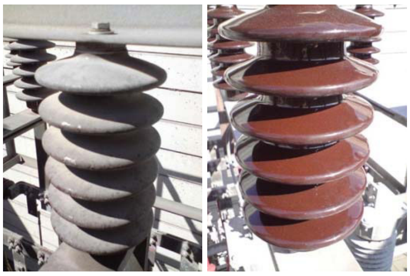

Fig. 3. Insulators before (left) and after (right) cleaning with the QM.

Depending on the access and degree of soiling, low or high pressure solutions are used for applying the QW. The core product in this case, besides the equipment for applying QW and equipment for treating the used QW, is the QW purification equipment. The customer is a power grid network owner. How to secure high QW pureness quality, in combination with how to, in an effective and efficient way, apply the QW on the object to be cleaned, are of key importance. This affects the performance of the offering significantly, and therefore also the provider's profitability as well as the customer's cost for the offering. This is the principal intelligence owned by Qlean Scandinavia AB as well as its competence.

A crucial information flow in this current offering is, therefore, the control of the QW purification equipment: the purer the water is, the easier it is to clean, and the water consumption decreases as well as the amount of used QW that need to be purified (absorbed substances need to be removed from the QW).

At the moment, the existing models of the QW purification equipment have no automatic, built-in intelligence to reduce the uncertainty of the QW pureness; instead, it is manually monitored and controlled by the company's staff, who knows how to change the equipment's settings. The next version will include built-in intelligence that will be able to support this and reduce the QW pureness quality risk.

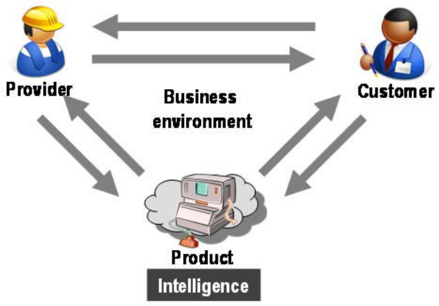

Fig. 4. A future industrial cleaning case described in the PCP Triangle.

Another key uncertainty is on the status of the QW purification equipment, e.g. the filters' remaining lifetime and how the operation of the equipment affects this. Current QW purification equipment models require that the operator manually monitors and controls the status, and this is tricky to do. Because of this, the company will start to implement more advanced and remote monitoring functions in order to build up statistical knowledge based on all its QW purification equipment. By doing this, it will be able to perform more controlled and optimized maintenance, and at the same time improve the uptime of its equipment.

Figure 4 describes an offering in the future with the equipment's automated control: although some intelligence remains at the provider, the major intelligence will be embedded in the core product. Obviously, Qlean Scandinavia AB wants to protect its intellectual property (avoid letting competitors get access to its knowledge and solutions) even in the current offering where the core product has some built-in intelligence.

3.2. Know-how intensive offering

The company and its business – The other case is taken from biogas production. Biogas is often regarded as "carbon neutral" since no new carbon dioxide is emitted to the atmosphere. This section is based on the authors' interviews with Swedish Biogas in Linköping AB (the biogas provider, hereafter) and its related companies (details are reported in [22]). The biogas provider uses various types of organic wastes and residues in the region such as: slaughterhouse waste; residues from the food industry; food waste from households, shops and restaurants; stillage water; and grain. An aerial view of a biogas production plant in Linköping is shown in Figure 5. The provider produces biogas for vehicles and gets paid by companies such as a city bus operating firm for delivered normal cubic meters of biogas.

Fig. 5. A biogas production plant in Linköping.

Description of the offering on the PCP Triangle – The product in this case is a biogas production facility, while the customer is a transportation firm, e.g. a city bus operator. One barrier to success of this business is to find suitable materials that can be used for biogas production, something which has become harder since more actors are interested in these types of materials. Another related barrier is the cost of transporting the incoming materials for the biogas production – this is because the density is often quite high (due to the high percentage of moisture) in relation to the potential biogas output. Referring to this difficulty to obtain certain materials as a background, uncertainty around the product (U1) is high. Note that there are several essential operating parameters in biogas production depending on the incoming materials: temperature, retention time, organic load and syntrophy [23].

The biogas provider indeed has had to spend significant resources on developing techniques to improve the gas production process in order to make the process more productive and balanced, i.e. easier to manage and control. This has lead the provider to perceive its own in-house knowledge as the most important for this business.

This know-how to control the production can be regarded as key intelligence for this business. As a result, the information flows B1 and B2 become crucial, as shown in Figure 6. B1 represents the flow of information such as types and portion of incoming materials, while B2 denotes the provider's control of the facility in the production process. As a result, this business is suitable to be carried out in the form of an IPSO, rather than selling the product to a customer who becomes responsible for operating the product.

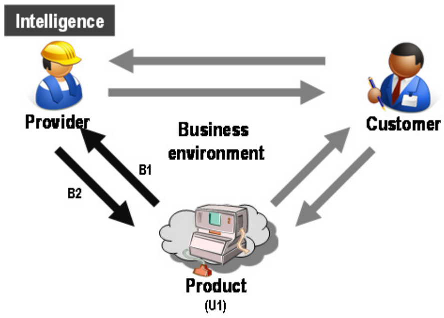

Fig. 6. The biogas production case described in the PCP Triangle.

4. Discussion

4.1. Cross-case analysis

This section conducts cross-case analysis after presenting the authors' own analysis of case specific benefits and risks based on Section 3 (note that the one from Section 3.1 is the future offering). Tables 3 and 4 show case-specific major benefits and risks, respectively, and they show similarity between the two cases. I.e. major benefits are: gaining process knowledge and reducing the risk of the knowledge being revealed (encapsulating a technology in a broader sense). Major uncertainty exists around the product, which creates a major risk in decrease in production performance.

Table 3. Case-specific major benefits of the two IPSO.

	IPSO in Section 3.1 (Cleaning)	IPSO in Section 3.2 (Biogas)
B1	Gaining in-service data of the device (not in real time) used for creating in-service knowledge	Developing techniques to improve the biogas production process
B2	Better control of the device	Easiness to manage and control the biogas production process
B3	Not available	Not available
B4	Not available	Not available
B5	Keeping the knowledge of the process away from the customer	Keeping the production technique away from the customer
B6	Reducing the possibility of the knowledge revealed	Reducing the possibility of production techniques revealed

On the other hand, consider a commodity sales case, where the uncertainty level of the product is negligibly low and no intelligence is required for the product's functioning. The application of the PCP Triangle to the two cases in Section 3 as well as the commodity sales case above reveals a possibility for the PCP Triangle to indicate the potential for an IPSO (or result-oriented service, more specifically speaking). Table 5 attempts to use the level of U1 (the product's uncertainty) and the intelligence owner in order to indicate the potential for result-oriented service. Note that no actual case is available for C5, C6, and C7 where the level of U1 is negligible and the intelligence exists to control the product. The two cases described in Section 3 are used to exemplify the categories of C1 and C3.

Table 4. Case-specific major risks of the two IPSO.

	IPSO in Section 3.1 (Cleaning)		IPSO in Section 3.2 (Biogas)	
	Major uncertainty	**Major risks**	**Major uncertainty**	**Major risks**
U1	QW pureness	Decrease in achieved cleanness	Incoming materials' variety (e.g. food wastes)	Decrease in biogas production performance
U2	Negligible	Not available	Negligible	Not available
U3	Negligible	Not available	Negligible	Not available
U4	Negligible	Not available	Negligible	Not available

Table 5. Classification of cases using the two key parameters.

ID	Level of uncertainty about the product	Intelligence owner	Potential for result-oriented service
C1	Substantial	Provider	Yes (e.g. by remote control)
C2		Customer	No
C3		Product	Yes (e.g. by tech. encap.)
C4		None	No
C5	Negligible	Provider	Not available
C6		Customer	Not available
C7		Product	Not available
C8		None	No

Note: "tech. encap." means technology encapsulation.

4.2. Environmental performance

The use phase of a product life cycle has the highest environmental impact in many cases. The environmental impact from the use phase is changed by how the product is used as well as the product characteristics as defined in the design. Thus, changing the operation of a product could contribute to decrease the life cycle environmental impact substantially. Therefore, the PCP Triangle can be useful to depict measures to decrease the life cycle environmental impact. For instance, software installed in an automobile, monitoring the driving and recommending a more fuel-efficient way of driving to the driver, is a good example of intelligence embedded in a product. Note that the cases addressed in this paper make less environmental impact as compared to alternative technologies, but have the potential to decrease environmental impacts even more with the intelligence. This type of contribution has seldom been discussed (compare with the IPSO's contribution to the environment in general reported in e.g. [24]).

5. Conclusion and future work

This paper has provided additional insight into benefits and risks of IPSOs for a provider and important factors for them through two case studies in a systematic manner. The PCP Triangle, which is a unique tool to classify the benefits and risks, was powerful in achieving this. One insight is the level of uncertainty about the product, i.e. the predictability of the product's functioning and the inputs to the product in the future; the other is who possesses the intelligence to control the product's functioning. The paper ended with an attempt to use those two parameters to indicate the potential for result-oriented service. The result is expected to contribute by helping manufacturers to describe and design their strategies of how to maintain their manufacturing intelligence.

Although this paper provides greater understanding about IPSOs, there is still a need for further research. Among others, the attempt above is to be investigated furthermore. This work will be done with more cases from industry that the authors have access to. Another future work is developing a method for the integrated analysis of benefits and risks.

The scope of the PCP Triangle is information flows, while other types of relevant flows for IPSO also exist, e.g. money and material. The authors have begun to structure and analyze the framework for this as well [25]. Combining these two could be a subject of important future work.

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