



Investigating the sustainability potential of a supplier integrating approach to Product-Service Systems

A Case study in the PC industry

Master thesis in Master degree program - Supply Chain Management

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Abstract

Product-Service Systems (PSS) are seen as a mean to achieve a circular economy and a sustainable consumption. Many authors point out the importance of supply network involvement to realise the sustainable effect. However, the PSS literature lack reasoning about the effect supplier integration on PSSs sustainable mechanisms. The **purpose** of this thesis is to develop an understanding of how supply network integration in a PSS offer affects its sustainable mechanisms and how these are affected by product and industry context. This purpose is addressed through an exploratory single case study investigating the views of several actors from an extended supply network of a focal firm within the PC industry. Somewhat surprisingly the **results** show that none of the involved actors have incentives to enhance sustainable mechanisms. The two reasons for this are; (1) Contextual factors of the PC industry make long term product use in PSSs economically unfavourable and (2) Despite that the SIPSS approach have the potential to support sustainability more than a normal PSS, complexity, incentive dilution, and product-service decoupling makes this potential hard to achieve. **Theoretical implications** of this research is that the supplier network have big impact on the sustainable potential of PSSs and that a decoupled service and product offer also have big impact on the sustainable potential. Thus these two features are important to be considered in PSS research. **Practical implications** are that demands on practitioners are high in regards of decision making connected to sustainability, and that there is a need for governmental support in order to enhance sustainability incentives, in industries where incentives for sustainable mechanisms are weak.

Keywords: *PSS; Sustainability; Supply Network, PC-industry*

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1 Introduction

This chapter is divided into 1.1 Background, 1.2 Problem discussion and 1.3 Purpose and research questions. The background is written as a funnel moving from a circular economy, via circular business models, specifically product-service systems (PSS), to a supplier integration view of PSSs.

1.1 Background

Within the industrial ecology and sustainable growth field a concept called “Circular Economy” was introduced by Pearce and Turner during the 1990s (Andersen, 2007). 25 years later, European commission adopted the communication “Towards a circular economy: A zero waste programme for Europe” (European Commission, 2014) as a step towards a new focus of a circular economy in Europe.

Circular Economy (CE) means that as much material and energy as possible shall be recaptured from products before they end up as landfill, which is a generally agreed on view of the term (Ellen Macarthur Foundation, 2013). According to Su et al. (2013) a CE can be achieved by maintaining and reusing products as far as possible, refurbishing products at end of use and finally recycling at end of life. Instead of a conventional open-ended economy where raw materials are taken from the ground, made into products, used and then disposed the idea of a CE is to cycle material, products and energy into the system again (Andersen, 2007).

According to Tukker (2013) the so-called Product-Service System (PSS) approach is the most effective instrument for moving towards a resource efficient, circular economy. Mont (2002) define the concept of a PSS as “*an integrated system of products, services and supporting networks that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models relying on transactional sales.*” (Mont, 2002, p. 239). In a PSS business model the emphasis of the offer is on sale of use rather than on sale of product (Baines et al., 2007).

Since mid-1990s, PSS has been a popular subject for researchers engaged in sustainability in business and have been seen as a way to combine sustainable production with economical benefits. Today, the body of literature is almost unanimous about the needs of sustainable production and consumption which aims at sustainable and environmentally-oriented design and production (Tukker, 2013). As a direct mean for achieving sustainability, PSS is often

discussed as a key concept (Mont, 2002). Sustainability researchers argue that PSSs has potential to radically lower environmental impacts thanks to its focus on delivering a function, rather than a product (Tukker, 2013). Mont (2002) highlights how PSS offers a product, and system of integrated products and services, that are intended to reduce environmental impact through alternative scenarios of product use. However, recent studies have according to Reim et al. (2014) acknowledged that PSS business models may not be the panacea for a sustainable future and could even create negative effects on environment.

Authors agree that product-service systems will not automatically create a CE or a sustainable future. However, Reim et al. (2014) and Geum and Park (2011) highlight design of a PSS to be core to the environmental effects it may have. Similarly, Manzini and Vezzoli (2003) discuss how to specifically design PSSs in order to avoid rebound-effects and sub-optimisations. When doing this they connect PSS with a life-cycle approach and argue that sustainable benefits rely on taking wider perspectives throughout supply networks. Manzini and Vezzoli (2003) argue that all actors in a product life-cycle need to have aligned interests in PSSs in order to gain environmental benefits. Mont (2002) also contribute to this idea by arguing that supplier involvement is key to create sustainable product-service systems and that a system thinking will help creating bigger responsibilities regarding sustainability. Lockett et al. (2011) also share the view that PSSs need close co-operation to become sustainable and while a lot of literature have focused on provider-customer relations they point out the importance of involving suppliers in the offer. Collectively these authors describe that PSSs requires an increased focus on integrating suppliers, customers and other actors in PSS offers to fully achieve its sustainable mechanisms, in this report this type of PSS viewpoint is called a Supplier Integrating Product-Service System (SIPSS).

While both Lockett et al. (2011), Mont (2002) and Manzini and Vezzoli (2003) find that PSSs need to be seen out of a network perspective to support its sustainable benefits they also find that this could be hard to achieve. Manzini and Vezzoli mean that a SIPSS will get complex and imply complex relationships. Lockett et al. argue that a SIPSS need to align both incentives and interests, which is hard because of different actor objectives and risk transfer. These authors further argue that effective information sharing is needed which is problematic since an increased number of actors in a PSS may lead to fear of information leakage. Mont (2002) argue that an increased number of actors involved is part of a sustainable PSS but that it also creates inertia and slows down change towards more sustainable solutions.

1.2 Problem discussion

According to Ellen McArthur Foundation (2013) the basis for a CE is a transition towards PSS business models, changing from ownership to performance based payment models, to translate products designed for reuse into attractive value propositions. In their report they argue that the main obstacles for such transition has to do with an inability to move away from a linear lock-in effect caused by traditional supply chain management thinking (Ellen McArthur Foundation, 2013). However, the report does not discuss industry characteristics, such as product capital intensity or product development pace, as factors that influence this transition. On the other hand, literature within PSS argue for a need of products of capital significance with relatively long product life-cycles in order to trigger incentives for resource efficiency, such as take-back and remanufacture (Mont, 2002; Tukker, 2004). Thus, there are different views regarding the potential of PSS's sustainable mechanisms for industries dealing with less capital intensive and fast developing products.

Several authors argue that the sustainable mechanisms of a PSS do not automatically make a PSS sustainable, however they all agree that with the right PSS design its mechanisms can enhance sustainability (Mont, 2002; Tukker, 2004; Reim et al., 2014). Other authors such as Lockett (2011), Mont (2002) and Manzini and Vezzoli (2003) argue that a PSS must be viewed as a broader network than the focal company if a PSS should enhance sustainability. These authors also discuss difficulties with a supplier integration that needs to be overcome if its sustainable benefits shall work. However, there is a lack of knowledge in literature regarding how this general reasoning of a SIPSS applies to the sustainable mechanisms of a PSS. In other words, there is a lack of empirical studies for how an inter-organisational product-service system design affects the sustainable mechanisms of a PSS. Above authors both promote and problematise a supplier integrating approach to PSS merely using logical reasoning to discuss possible problems. Both Lockett et al. (2011) and Manzini and Vezzoli (2003) highlight the need for a deeper understanding of practical issues with expanding the PSS throughout the supply network.

Conclusively, several authors argue that a PSS is foremost suitable for products of capital significance with relatively long product life-cycles and advance technology since these factors will increase incentives to enhance resource efficiency, product life, take-back, reuse and recycle. (Mont, 2002; Tukker, 2004). However, other authors such as Ellen Macarthur Foundation (2013) have ignored these characteristics and hence there is a lack of knowledge

regarding how the sustainable mechanisms of a PSS are affected when these characteristics are less present or absent. This mean that whether a PSS can enhance sustainability in an industry with short product life-cycles and with responsive supply chains such as the PC (personal computer) industry is not agreed on by different authors. In regards to this, these authors also call for a need of taking a system wide perspective to PSSs for sustainable mechanisms to reach their full potential.

This thesis thereby intend to find how the mechanisms of a sustainable PSS design work in a business-PC supply chain context and what problems or possibilities there might be with applying it out of a network perspective.

1.3 Purpose and research questions

The **purpose** of this thesis is to develop an understanding of how supply network integration in a PSS offer affects its sustainable mechanisms and how these are affected by product and industry context.

In order to fulfil the purpose of this research and answer to the research problem, two separate research questions have been developed. Firstly, the mechanisms of a sustainable PSS need to be explored and more specifically what drives these mechanisms among the actors contributing to the PSS offer. The different actors need to be explored to evaluate in what way they enhance or counteract the sustainable mechanisms of a PSS. RQ1 therefore aim to answer how the drivers, in an actor network, for sustainable PSS mechanisms can be characterised. RQ1 has thus been formulated as:

RQ1: What drives supply network actors, of a PC-industry PSS towards the sustainable mechanisms of a PSS?

To answer the purpose of whether incentives for a sustainable PSS can be aligned out of a network perspective it is important to understand why it is hard to pursue and what possibilities it may produce. RQ2 therefore aim to characterise barriers as well as understand possibilities related to SIPSS. RQ2 has thus been formulated as:

RQ2: How can barriers and possibilities of aligning actors towards SIPSS be characterised and how are product and industry characteristics influencing these?

2 Literature overview

This chapter is a literature overview of theories and practices that form the basis of this research. It contains concepts related to logical reasoning of how a PSS drive sustainability, issues with this logic and concepts and issues on supplier involvement in PSSs. This thesis will use the theory chapter as a basis for how a PSS drive sustainability and as a common language throughout the report.

2.1 Product-Service Systems

The process of manufacturing companies switching their focus from product focus business towards a product-service-bundled solution is called “servitisation of business” (Vandermerwe & Rada, 1989). The concept of Product-Service System (PSS) is a specific type of value proposition that a business offers to its clients and a special case of servitisation (Tukker, 2013). The purpose of this service integration is to provide sustainability, as well as increased customer value in order to achieve competitive advantage (Goedkoop et al., 1999; Mont, 2002). In a PSS business model the emphasis of the offer is on sale of use rather than on sale of product (Baines et al., 2007). Within literature there is no widely accepted definition of a PSS, though, a definition of PSS commonly referred to is Mont (2002); *“an integrated system of products, services and supporting networks that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models relying on transactional sales.”* (Mont, 2002, p. 239)

Within literature there have been many attempts to suggest different types of PSS, but one of the most widely cited is Arnold Tukker’s (2004). Tukker (2004) describe PSS as a spectrum of stages based on the level of product versus service dominance in the value proposition, visualised in Figure 1.

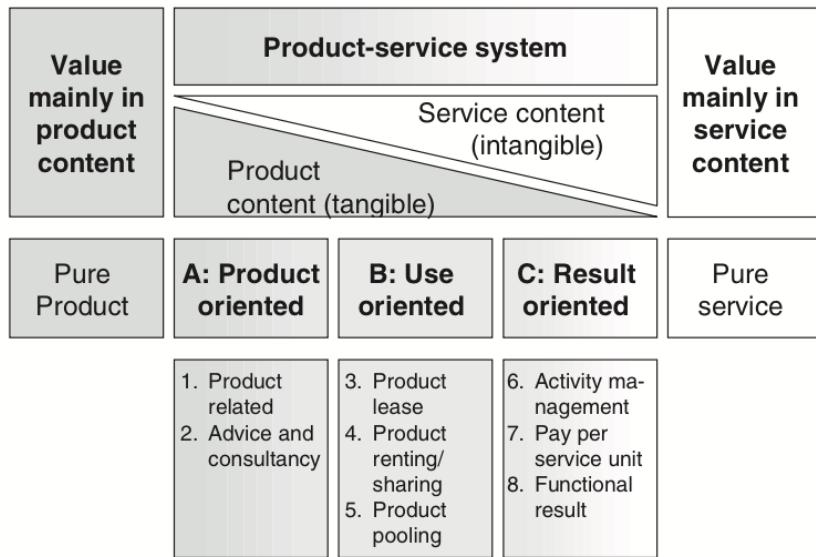


Figure 1, A categorisation model for PSSs regarding their level of service or product dominance and associated business models (Tukker, 2004).

Figure 1 describe how value is created for customers through an interface between value dominant in product content, and value dominant in service content. Depending on the balance between product and service content the delivered value itself, and the process of delivering this value, is affected (Baines et al. 2007; Tukker 2004; Yoon et al., 2012). Companies with a small amount of service content are plotted to the left of this spectrum and companies with high service dominance in their product/service bundled offerings are plotted to the right. Tukker (2004) have embraced this shift in demand and developed three classifications of PSS business models, depending on their different product-service content, which are further subcategorised into eight types of business models. These are displayed in Figure 1. The longer towards the right the more is ownership of products are shifting towards the provider and furthest to the right is the complete functional offer.

2.1.1 Sustainability and PSS

Since mid-1990s, PSS has been a popular subject for researchers engaged in sustainability in business (Tukker & Tischner, 2006). Today, the body of literature is almost unanimous for the needs of sustainable production and consumption that aims at sustainable and environmentally oriented design and production (Tukker, 2013). As a direct means for achieving sustainability PSS is often discussed as a key concept, especially in early literature (Mont, 2002). Sustainability researchers argue that PSSs has potential to radically lower environmental impacts thanks to its focus on delivering a function, rather than a product

(Tukker, 2013). By creating bundled product-service offerings Vandermerwe and Rada (1989) argue that companies can more easily defend themselves from low-cost economies and develop sustainable capabilities. Tukker (2013) describe PSS as one of the most effective instruments for moving society towards a resource efficient circular economy and Mont (2002) highlights how PSSs offers a product, and system of integrated products and services, intended to reduce environmental impact through alternative scenarios of product use.

The logic behind increased sustainability through PSS business models, and the logical reasoning for why PSS has been put on the sustainability agenda, is a changed focus towards final customer needs rather than a focus on products fulfilling a need (Tukker & Tischner, 2006; Baines et al., 2007; Mont, 2002). This is what researchers often refer to as a functional economy (Mont, 2002). In a functional economy the economic objective is to create highest possible use-value for longest possible time while consuming as few material resources and as little energy as possible (Stahel, 1997). In a functional economy, Mont (2002) describe that customers purchase mobility instead of cars, cleaning services instead of washing powders and movies instead of DVDs etc. According to Mont (2002) a functional economy has potential to lessen environmental strain since ownership of products remains with providers. She argues that as ownership shifts, products are treated as capital assets rather than as consumables, thus creating incentives for providers to increase and prolong product's life and minimise loss of resources. As a consequence of this *ownership incentive* reasoning, Mont (2002) and Tukker (2004) argue that PSS business models has potential to decrease the total amount of produced products since producers are encouraged to take back used products, upgrade and refurbish and reuse them again. Thus, Mont (2002) argue that the offer is dematerialised and that less waste is incinerated or landfilled. This *ownership incentive* is a core feature for mechanisms that drive sustainability in PSSs which is further elaborated in next chapter

2.1.2 Mechanisms driving sustainability in PSSs

Although there is a consensus in literature regarding PSS potential to drive sustainability issues, possibilities and mechanisms for reducing environmental burdens differ depending on PSS business model (Tukker, 2004; Reim et al., 2014). Mont (2002) argue that in order for a PSS to be successful in lowering environmental impact the paramount goal of a PSS should be to minimise environmental impact of consumption by considering four sustainability elements. In

Table 1 below these elements are presented together with a conclusion about her arguments for these.

Table 1, Goals with reducing environmental burdens in a PSS (Mont, 2002).

Goal	Argument
Closing material cycles	<i>"A number of ecological advantages can arise from the sale of services. For instance, it may encourage the producers' interest in the reuse and increase of the recyclability rate of products. The services could include new, used and refurbished products. Ideally, this could lead to completely closed product cycles under the responsibility of the manufacturers" (Mont, 2002, p. 242).</i>
Reducing consumption through alternative scenarios of product use.	<i>"The environmental impacts of the use phase come from the efficiency of each unit of function delivered and the total amount of a delivered service. The design of PSSs can provide an incentive to manufacturers to design products that are more efficient in their use phase only when the producer will be paying for the environmental effects and resource consumption during this phase, that is, when the conditions internalise use-related environmental costs" (Mont, 2002, p. 242).</i>
Increasing overall resource productivity and dematerialisation of PSSs	<i>"If the operation of the product-service is a cost for the company that has internalised it, the producer might be interested in providing maintenance that helps to extend product life and thus reduce the quantity of the product required for delivering the service that is less product per unit of services and thus less environmental burden" (Mont, 2002, p. 243).</i>
Providing system solutions seeking the perfection in integrating system elements along with improving resource and functional efficiency of each element	<i>"The substitution of energy and materials with efficient services may influence overall resource consumption. Increasing the intensity of use, if products are shared or used jointly, may potentially minimise the total number of products and the capacity for use can be more fully realised resulting in greater resource efficiency and less impact on the environment" (Mont, 2002, p. 243).</i>

In addition to this Mont (2002) highlight that the PSS concept in this interpretation is theoretical and that environmental potential of PSS elements in

Table 1 has not been yet evaluated. When a PSS assists re-orientation of current unsustainable trends in production and in consumption practices it is, according to Manzini and Vezzoli (2003), usually referred to as a Sustainable or Eco-efficient PSS. Though, like Mont (2002), Manzini and Vezzoli (2003) insist on that more cases need to be studied to better identify these potentials, as well as constraints.

Tukker (2004) have identified a number reasons for differences in environmental performance of product sales and PSSs. With his presentation of theses differences he include an estimation of different mechanisms environmental reduction, as described in Table 2.

Table 2, Sustainable potential of different sustainable PSS mechanisms (Tukker, 2004)

Impact	Mechanism
Incremental/average impact reduction (10-20%)	Efficiency improvements of incremental innovative character with product-related services. Improvements such as maintenance contracts which lead to more intensive use, prolonged product (goods) life, and less use of energy or consumables during the use phase.
Average/high impact reduction<br (<50%)<="" b=""/>	Product-designer taking true life-cycle costs into account (e.g. with pay-per-service unit contracts). Doing this creates strong incentives for providers to optimise energy/consumables use and recycle products.
	Intensifying use or prolonging life of capital goods significantly, e.g. by using product renting or sharing business models, compared to traditional product systems. Doing this also creates incentive for faster replacement by newer, more efficient models.
	Use of considerably less energy and other auxiliary materials during the use phase, e.g. in a product pooling situation. Various consumers share energy and auxiliary material use during the same use phase.
	Use of high economy of scale allowing for use of technology, which is significantly more efficient. E.g. washing machines in a laundry using gas heater water rather than water heated by electricity used in homes.
Potentially very high impact reduction<br (<90%)<="" b=""/>	Using radically different technological systems, e.g. a functional result system.

Based on Tukker's (2004) categorisation of PSS business models he and Reim et al. (2014) develop reasoning for how each business model respectively should perform in relation to these mechanisms. In following sections, Tukker's (2004) and Reim's et al. (2014) discussion of the effects of each type of PSS is summarised.

2.1.3 Business models effect on the PSS's sustainability

For **PO business models** environmental benefits relate to more well organised maintenance or automatically generating information (e.g. through product monitoring), which improve the product's or service's function by prolonging the usage of the PSS offer, according to Reim et al. (2014). Additionally, take-back agreements allow for a high efficiency recycling and reuse process for PSS providers (Tukker and Tischner, 2006).

In **UO business models** providers usually maintain ownership of their products. This increase incentives for prolonging products lifecycles involved in the offer, which make repairs and maintenance increasingly important (Reim et al., 2014). However, with UO business models providers must address the issue of rebound effects and careless behaviour (Tukker, 2004). That is, negative effects on environment caused by changes in customer behaviour (e.g. increased wear and tear) as customers are released of ownership (Manzini & Vezzoli, 2003).

Since **PO and UO business models** seek to make intensive use of a product, innovations in the business model will according to Reim et al. (2014) mainly be made to ease maintenance, remanufacturing, and increase the durability of the offer. Innovations in these business models are generally incremental since the services are related to a particular product, which characteristically stay the same throughout innovations (Tukker, 2004). In order to reach a higher level of sustainability (e.g. creating value from waste or delivering functionality) and reach the full potential of a PSS Bocken et al. (2014) argue that further innovations to the business model are needed.

Tukker (2004) further develop this thesis and connect it to each type of business model and specific of interest is that the **PO business models** lack ownership incentives where **UO business models** have various levels of it. For example a provider of product lease systems principally take responsibility for maintenance, repair and control which can create incentives for prolonging the product life-span as well as incentives for more efficient use of energy/consumables. However, in most cases companies who offer leases buy the products they lease and are therefore not responsible for product design. Thus, the incentive is not automatically passed on to a designer or manufacturer. A product renting or sharing will support an intensified use in a way a lease won't and have much higher incentives to intensify use and prolong life (Tukker, 2004).

In **RO business models** the provider and customer agree only on a result, with no particular product or service necessarily considered for fulfilment, thus allowing for the provider to have a high degree of freedom in designing the agreed upon service (Manzini & Vezzoli, 2003). Since operational savings potentially will benefit the PSS provider to generate revenue, incentives for the provider to improve resource utilisation are extremely high (Tukker & Tischner, 2006). In contrast to PO and UO business models, Reim et al. (2014) argue that this give manufacturers incentives to try fundamentally new ways of to operate. Thereby creating incentives for radical innovations with means of fulfilling function and enhancing resource utilisation, subsequently leading to improved sustainability.

Tukker (2004) discusses the sustainability potential of result oriented PSSs to be higher than for UO and PO business models. However, he also find that potential of **RO business models** to vary to a great deal. Even though activity management business models have great potential in using resources much more efficient in many cases efficiency gains are not realised through efficient use of capital goods and materials, but in personnel costs which have little sustainability related improvement. Pay-per-service business models make the provider take life-cycle costs into account, which give the provider incentives to improve product design and could radically improve environmental performance by providing incentives to prolong life of capital goods. A pay-per-service use will also give the customer incentives to minimise their consumption, which minimise rebound effects. Tukker (2004) argue that the highest environmental gains that can come from a PSS are if a functional result is provided rather than a use or product related service. Here, the provider offer a result and hence has a higher degree of freedom in designing a low-impact system. Figure 2 summarise Tukkers (2004) discussion of environmental effects of different types of PSS.

PSS type	Impacts compared to reference situation (product)				
	Worse	Equal	Incremental reduction (<20%)	Considerable reduction (<50%)	Radical reduction (<90%)
1. Product-related service	←-----→				
2. Advice and consultancy	←-----→				
3. Product lease	←-----→				
4. Product renting and sharing	←-----→				
5. Product pooling	←-----→				
6. Activity management	←-----→				
7. Pay per unit use	←-----→				
8. Functional result	←-----→				

Figure 2, Tentative sustainable potential of different PSS types (Tukker, 2004).

2.2 Supplier involvement in PSS

Tukker's (2004) discussion regarding sustainable mechanisms of PSSs leads down to a subject of supply network alignment regarding PSS sustainability. Tukker argue that a PSS must be designed to align interests throughout the value chain. Traditionally, researchers within the PSS literature have focused on provider-customer relations as important to the PSS offer (Locket et al., 2011). Johnson and Mena (2008) suggest that supply networks, which support the provision of PSSs, are different to those for the provision of products or services. While there is a considerable amount of academic knowledge on the role of upstream supply networks in the context of traditional product centric manufacturing, Locket et al. (2011) argue that there is less work in the context of PSS. The traditional, provider-customer, view is something that a number of authors point out to be insufficient since the content exchange in a PSS is considerably different from that of a product.

2.2.1 Importance of a supplier integrated PSS

Lockett et al. (2011) research on the suppliers involvement of PSSs and argue that PSS providers need close co-operation with suppliers to become sustainable. Mont (2002) concludes that a PSS approach requires much closer collaboration with suppliers and customers than a normal sales approach. Cohen et al. (2006) also discuss this view by concluding that while a product offer is normally provided by one company a PSS is often provided by a combination of different members of a supply network. Collectively these authors describe that PSSs need an increased focus on integrating suppliers, customers, and other actors who contribute to the PSS offer to fully achieve its sustainable mechanisms (Locket et al., 2011; Mont, 2002; Manzini & Vezzoli, 2003). The viewpoint, that suppliers are influencing the PSS offer and should be integrated, is in this thesis called Supplier Integrating Product-Service Systems (SIPSS). Figure 3, visualise how the SIPSS view differ from the traditional provider-customer view of a PSS.

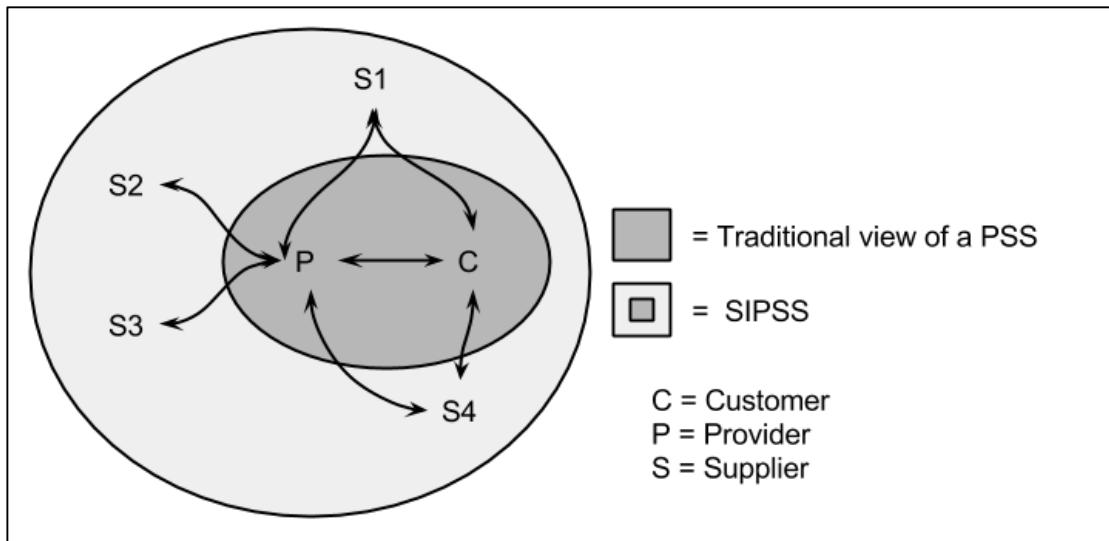


Figure 3, The SIPSS view versus the traditional view of a PSS

Manzini & Vezzoli (2003), Lockett et al. (2011) and Mont (2002) all discuss the need of supplier integration in a PSS. Specifically they conclude alignment of actors interest towards sustainability and resource efficiency of the PSS to be the goal of the integration. If not properly set up, Lockett et al. (2011) and Mont (2002) argue that a PSS can both reduce revenues for suppliers and make the business less sustainable, this because of sub-optimisation resulting from unaligned actor interests.

In Lockett et al. (2011) case study they saw that a closer partnership including risk- and reward-sharing had a better potential to create competitiveness for both the PSS provider and its suppliers while a less integrated relation had negative impact on the suppliers businesses. Regarding sustainability their case showed that a unaligned PSS network led to an increased number of scrapped repairable parts. Lockett et al. (2011) conclude this to be an issue of different actors interest not being aligned. The supplier with repair and maintenance responsibilities had a higher profit on new spare parts than used which caused him to rather exchange than repair parts. By this the authors conclude that an alignment of interests towards the PSSs sustainability goals is crucial when creating a sustainable PSS. Related to this, Mont (2002) point at the specific relation between the service and manufacturing organisations. As when these companies are tightly integrated a clear transmission of economic incentives are more likely which allow service activities to drive product design changes.

A second aspect of a supplier integration that Mont (2002) and Manzini and Vezzoli (2003) highlight is the importance of expanding the responsibilities of suppliers throughout the life-cycle and not only to a limited period. Mont argues that if an actor wants to successfully

implement a PSS they need to expand their involvement in life-cycle phases, which automatically will grow the responsibility of the service and its products.

2.2.2 Problems with a SIPSS approach

The above-mentioned authors also problematise the integrated network of suppliers towards a sustainable PSS. Mont (2002) finds problems with a SIPSS approach as it increases the number of inter-organisational relationships and might increase inertia and cause slower change, which can slow down the sustainable PSS transition. Mont (2002) also argue that there is not enough studies within field of supplier integrated PSSs to fully understand what problems and implications it have. However she argue that a supplier integrated PSS is probable to have the same issues as an integrated chain management approach, such as: internal environmental management trade-offs, choosing the right actors who have the power to change, information sharing/transparency barriers and general change resistance in the moving from product sales to service innovations.

Both Lockett et al. (2011) and Mont (2002) argue that effective information sharing is crucial to both achieve sustainable benefits of a PSS but also to create the type of partner relationships that will be needed in a sustainable PSS. Lockett et al. also find that closer relationships promote information sharing and vice versa. However they argue that PSSs could potentially lower information sharing because of the increased number of actors included in the offer and a fear of information leakage. Lockett et al. (2011) also find that partnering can potentially mean collaborating with competitors, which together with the risk of information leakage potentially lower competitiveness.

Conclusively Manzini and Vezzoli (2003) propose that even if a systems perspective increases complexity it is the most promising way to achieve sustainable PSSs. Mont (2002) also suggests that a strong actor in the network need to be coordinating the PSS to deal with this complexity.

2.3 Chapter summary

The literature that has been presented in this chapter relate to product service-systems, its inherent sustainable mechanisms, and how a system wide perspective (the SIPSS concept) affect drivers for these mechanisms. Figure 4 describe the relation of these different theoretical areas and how they contribute to the search of a sustainable future. PSS is a mean to achieve sustainability by giving actors drivers to enhance sustainability because of sustainable mechanisms such as shift of ownership. Literature also argue that a supplier integration is important to fully support these mechanisms and avoid sub-optimisations within the supplier network.

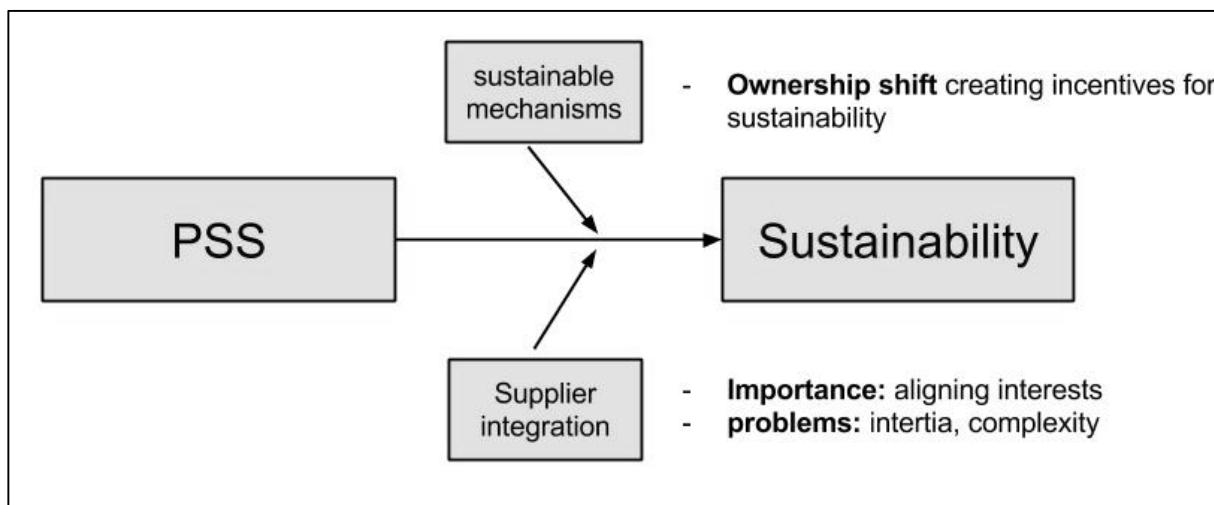


Figure 4, The relation between different theoretical areas and how they support the search for sustainability

3 Research methods

This chapter covers the research methods of this thesis. The methods consists of an exploratory research purpose, with an abductive and qualitative approach. The chosen research strategy is a case study with a single holistic approach. Empirical data was collected through semi-structured interviews and pattern matching was used as primary data analysis method.

3.1 Research purpose and approach

Since the relation between Product-Service Systems and Sustainability in the context of SIPSS was poorly described in earlier research two research questions were developed in order to explore *why* and *how* this relation is affected by a SIPSS approach. These questions were formulated as open-ended questions in order to answer to the research purpose of gaining understanding of the research problem. In accordance to Edmondson and McManus (2007) reasoning of these characteristics this research has been of exploratory purpose.

Further, this study aimed to find subjective answers to, and develop an understanding of, if and how supplier integrating PSS business models drive sustainability. In order to answer this, data was collected in the form of words and illustrations through qualitative interviews. Accordingly, and in compliance with Edmondson and McManus (2007) description of the characteristics of a qualitative study, a qualitative approach was used.

3.2 Research strategy

This thesis aimed to study a PSS out of a SIPSS perspective to find difficulties and possibilities with such perspective. Because of the complex environment to be studied it was favourable to be able to use a full variety of evidence. Because of the complex situation and the different actors' unique connections both documents and interviews needed to be gathered to capture interrelated difficulties (Yin, 2003). Because of this a case study strategy was favourable for studying the phenomenon of whether it was possible to use a SIPSS perspective to enhance sustainability effects of a PSS.

For this research a single case study was chosen since this approach allowed for better depth in the analysis and deeper analysis of specific problems. One downside with single case studies can be difficulty with generalising results outside of the specific case context. However, this research aimed to generalise the understanding of problems and not specific

causality. In this research a holistic approach was used since interrelated relationships and processes would be hard to study separately, one organisation at the time.

3.3 Data collection

In this research interviews, direct observation and documentation were used as primary data. Interviews made out the biggest part of the primary data collection and according to Yin (2003) the strengths with this method is that it focus directly towards case study topic and that it is insightful.

3.3.1 Case study

The selected case study was a study of an IT service provider in this thesis called SysCo. One of its services is a workplace solution in which they supply customers with IT related services and hardware for workplaces. The focused area of this research was SysCo's Hardware Life-cycle Management service (HLM) of laptops which is part the overall workplace solution. SysCo have a number of connected suppliers; ReCo who administrate take-back and sales of used equipment as well as hardware financing and ManuCo1, ManuCo2 and ManuCo3 who supply the laptops. All interviewed actors are listed in Table 3.

SysCo and their suppliers was an interesting case to study for this research based on their immaturity when it comes to circular business models and circular economy. They were in the starting phase of a circular economy initiative and also act in an industry that was immature when it comes to circular business thinking. This means that when studying possibilities and boundaries with applying circular business models in a supply network SysCo and its suppliers was an interesting case. The supply network is no success case within circular business models but was of interest since it provide a PSS case striving for hardware circularity.

The products in the case did not match the parameters of persistent, capital-intensive, long-lived, highly technological products that usually are necessary in successful PSS (Tukker, 2004). This means that the case would show how a previously unexplored context of business PCs affect a PSS's sustainable mechanisms.

Table 3, Company descriptions.

Interviewed company	Company description
SysCo	SysCo is a large North America based international IT consultancy firm with 70 000 employees in 40 countries. The Swedish organisation have 4500 employees.
ManuCo1	International China based PC manufacturer with 60 000 employees.
ManuCo2	International North America based PC manufacturer with 330 000 employees.
ManuCo3	International North America based PC manufacturer with 110 000 employees.
ReCo	Nordic based IT hardware re-marketing company with 250 employees.

3.3.2 Interviews

Interviews were held with actors that were considered important to catch both the whole case, how it works and ambiguities in how the different actors perceive the situation. Involved respondents where from; manufacturers ManuCo1, ManuCo2 and ManuCo3; the service provider SysCo; and refurbisher and financer ReCo. With these actors 16 interviews where conducted face-to-face with a length of 1-2 hours. See Table 4 for a detailed interview list. Respondents where environmental spokesmen, sales specialists, and a number of different managers involved in the service. Other actors, such as maintenance or logistic partners, were out scoped of the research since they were considered to have limited knowledge and opinions about the specific case.

The case involved three PC-suppliers who all were of big importance to interview in this case. The chosen interviewees among PC suppliers were persons within environmental affairs and key account managers in relation to SysCo. This, since these respondents were considered to be particularly knowledgeable about what drove their sustainable efforts and how their relation with SysCo can leverage or be a barrier for this.

Table 4, Details of conducted interviews

Type of interview	Company	Interviewee - position	Time
Workshop	[SysCo] – PSS provider	[CSR] - CSR and environmental coordinator [SM] - Service Manager [PM] - Product Manager	3h
Semi-structured interview	[SysCo] – PSS provider	[SM] - Service Manager	1,5h
Semi-structured interview	[ManuCo1] – Manufacturer 1	[EA] - Environmental Affairs [KAM] - Key Account Manager	1,5h
Semi-structured interview	[ReCo] – Remarketing company	[HS] - Head of Sales Sweden	1,5h
Semi-structured interview	[ManuCo2] – Manufacturer 2	[KAM] - Key Account Manager [EA] - Environmental Affairs	2h
Semi-structured interview	[SysCo] – PSS provider	[SS1] - Specialist Seller	1,5h
Semi-structured interview + observation in refurbish factory	[ReCo] – Remarketing company	[RM] - Remarketing Manager	3h
Workshop	[SysCo] – PSS provider	[CSR] - CSR and environmental coordinator	1h
Results review	[SysCo] – PSS provider	[SM] - Service Manager [PM] - Product Manager	1h
Semi-structured interview	[ReCo] – Remarketing company	[RS] - International Remarketing Sales manager	1,5h
Workshop	[ManuCo3] – Manufacturer 3 and PSS provider	Various members from environmental affairs and sales	3h
Semi-structured interview	[SysCo] – PSS provider	[CSR] - CSR and environmental coordinator	1h
Semi-structured interview	[SysCo] – PSS provider	[PM] - Product Manager	1h
Result discussion	[SysCo] – PSS provider	[CSR] - CSR and environmental coordinator	1h
Semi-structured interview	[SysCo] – PSS provider	[SS2] - Specialist Seller	1h
Result discussion	[SysCo] – PSS provider	[CSR] - CSR and environmental coordinator [SM] - Service manager [PM] - Product manager	1h

ReCo, who was the owner of the PCs through their lease model, were important to interview in order to understand how their processes work and how these processes affect SysCos service. ReCo was also a good source of information for how the second hand market of PCs work. Because of this both hardware knowledgeable remarketing managers and market knowledgeable remarketing sales managers were interviewed.

At SysCo interviews were held with both sales persons and persons responsible for the workplace service. Sales interviewees contributed with the voice of the customer and service responsible persons with the workplace service intentions.

3.4 Literature review

A literature review was conducted around the areas of; sustainable business models, circular economy and PSSs and their ability to promote sustainability. Most weight in the literature review were put on sustainable PSSs and upstream actors of PSSs. The literature review were conducted in two steps. First the keywords (sustainable AND environmental) and (PSS AND product-service systems AND servitisation) were used in *the journal of cleaner production* after the year 2000, which generated 42 articles. The second step was using the literature review of Reim et al. (2014) to complement with articles outside of *the journal of cleaner production*. Wherever interesting articles that potentially promoted to the subject were found these were included. This structured literature review made the literature framework extensive and provided good opportunities for analysing the results found in the primary data.

3.5 Data analysis

The main method used for data analysis was a pattern matching method. Patterns were created based on the literature review and on the content of collected data. This technique allowed for an exploration of whether general predictions within the PSS literature would hold true within the PC-industry. Patterns created based on literature mainly regarded the sustainable mechanisms of a PSS but also contextual prerequisites for successful sustainable PSSs. The collected data was later grouped in regards of these patterns and was used to answer research question one regarding drivers and context. Patterns to answer this question were also created based on the content of the data analysis, such as what role warranty played in the case and what role image related hardware played in the case.

Regarding the second research question there was a lack of previous data and patterns were hence mainly created based on the collected data and not literature. These patterns were grouped into barriers and possibilities where barriers was split into different patterns such as contextual barriers, supplier configuration barriers, interest alignment, data sharing or increased complexity barriers. Thus, this study did not only move from theory to data but also from data to theory in an attempt to explore the SIPSS concept. In effect, this study combines a deductive and inductive approach and thus use what Saunders et al. (2012) describe as an abductive approach.

3.6 Method evaluation

In this chapter the chosen method is evaluated regarding what implications the chosen methods may have on the result of the research.

3.6.1 *Credibility and transferability*

In order to strengthen credibility a triangulation of evidence have been done in this case study by using multiple interviewees for the same data source. Three PC-suppliers were interviewed and at ReCo three different persons were interviewed with similar questions. In order to further enhance construct validity drafts of interview forms were read by both supervisors and critical informants from the case company. The questions asked in interviews were in some cases beyond the interviewees' knowledge and decision level, which to some extent lower the credibility. However, this was a known issue and the answers to these questions were hence analysed with regard to the persons knowledge and position.

For the data analysis a pattern matching method was used, which according to Yin (2003) is strengthen internal validity and thus according to Shenton (2004) the credibility. This study used the theoretical framework as base for both data collection and data analysis, which work as a guide for the logical reasoning and connect it to reasoning done by other authors. Specifically Tukker (2004) and Mont (2002) were used as theoretical frameworks to guide the analysis and to find patterns.

With regards to transferability or external validity and single case studies a common concern is according to Yin (2003) generalisability of results. He argues that case studies overall are generalisable to theoretical propositions but not to universes. This means that by studying PSS implementation problems through a single case study the result will be contributing to the generalisable theory of PSSs within the specific context of the case, but not further. The companies' different perceptions and problems associated to PSS implementation will not be universal but they will help contribute to analysing the problems with implementing PSSs within the context of this case, which in turn can create a generalisable theory.

Yin (2003) also bring up problems with using interviews as primary data and group them into; bias due to **poor questions, response bias, inaccuracies due to poor recall** and **reflexivity**. All of these weaknesses are possible to avoid with the right preparation and interview design (Yin, 2003).

To avoid **bias due to poor questions** interview questions were tried in advance on supervisor, friends or relatives and reconstructed after critique. The interviews were also semi-structured which gave room for follow-up questions and discussions outside of the specified questions.

There was a risk of **response bias** in this research since SysCo was the client of the thesis which could cause interviewees give limited answers because of their customer-supplier relationships. To limit this bias interviews were always held at the interviewees work-space to make them feel more comfortable. It was also pointed out that full anonymity was offered.

Inaccuracy due to poor recall was avoided by documenting all reasoning directly at the interview and through summarising directly after interviews. All interviews were recorded in order to go back and listen to specific reasoning again.

Reflexivity was avoided by asking indirect questions which enriched the interviewers understanding about a certain subject instead of asking direct questions about certain subjects. Thus the risk of respondents answering what he/she thinks the interviewer wants to hear was reduced.

3.6.2 Dependability

In order to strengthen the dependability of this research all documentation regarding data collection methods, such as interview guides and data evidence from these, has been kept and to some degree been included in the results as citations. Additionally, all interviews were recorded in order to reduce risks of misinterpretation and to facilitate for later review. Interview guides have been tested, evaluated, and externally revised ahead in order to minimise the risk for the participants to misinterpret the questions. According to Shenton (2004) these efforts are such which reduce errors and biases in research and enable for future researchers to repeat the work, and hence enhance dependability.

However, since data collection methods used in this research were restricted to semi structured and in-depth interviews their inherent weaknesses in relation to dependability are important to highlight. Semi structured and in-depth interviews are according to Saunders et al. (2012) are not intended to be repeatable since they reflect the reality of the time they were collected and are therefore hard to repeat with the same results.

4 Results

The result chapter is based on empirical data from numerous interviews in the studied case and is analysed in a supplier integrating PSS context. The chapter is divided into two different blocks where the first block, containing chapter 4.1, 4.2 and 4.3, answer RQ 1 and bring empirically data for block two. Block two, containing chapter 4.4, is of more analytical character and address implications of a SIPSS approach with regards to findings from block one, see Figure 5, chapter 4.4 aims to answer RQ 2.

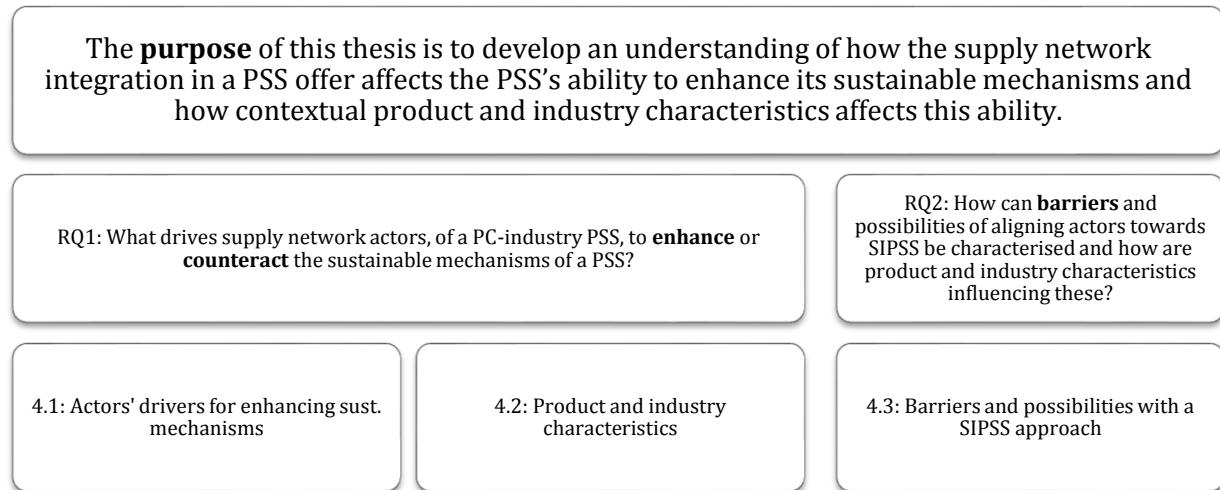


Figure 5, Guide in which result chapter that answers what research question.

4.1 Actors' drivers for enhancing sustainable mechanisms

This chapter presents the results of whether and if the different actors are driven to enhance or counteract the different sustainable mechanisms of a PSS. Table 5 view a summative picture of enhancive and counteractive factors in relation to each sustainable mechanisms, which is then followed by an ampler analysis of these.

Table 5, Involved actors' drivers for sustainable mechanisms.

Sustainable mechanisms	ManuCo	SysCo	ReCo
	Business models: Linear product oriented, revenues through occasional sales	Business model: Circular result oriented activity management, continuous revenues	Business model: Linear product oriented, revenues through occasional sales
Efficiency improvements	+ Responsibility of warranty <i>enhance</i> drivers to reduce/improve maintenance efforts.	- No drivers as this actor rely on manufacturers' warranty.	- No drivers as this actor rely on manufacturers' warranty.
Product designer taking true life-cycle costs into account	+ Responsibility of warranty <i>enhance</i> drivers to improve robust computer design.	- No drivers – low power over product design.	- No drivers – no power over product design.
Intensify use	+ Linear business models and focus on traditional sales <i>counteract intensified use</i> .	+ Customer demand provide incentives for faster replacement by new models and thus <i>counteract intensified use</i> .	- Linear business model and focus on traditional sales <i>counteract intensified use</i> + Targets for high second hand value drives ReCo to influence customer to use take-back services and thereby <i>promote intensified use</i> .
Prolong life	+ Linear business models and focus on traditional sales <i>counteract prolonged life</i> . + Customer demand for robust computers <i>drives incentives for designing robust computers</i> .	+ Rely on manufacturers warranty for product related issues which cause a decoupling from hardware issues and thus <i>remove incentives for prolonged life/use</i> . New product replacement lower costs. + Potential for customer lock in effect <i>drive prolonged first hand use</i> .	- Linear business model and focus on traditional sales <i>counteract prolonged first hand use</i> . + However, targets for high second hand value drives ReCo to influence customers use behaviour through penalty fees for abnormal wear and tear which <i>enhance product life</i> .
Use of considerably less energy/materials in the use phase	No drivers, apart for customer demand for e.g. energy efficient products.	No drivers.	No drivers.
Use of high economy of scale	No drivers.	No drivers.	No drivers.
Use of different systems	No drivers.	No drivers.	No drivers.

4.1.1 Manufacturers

The PC manufacturers interviewed all rely on **linear business models** with traditional sales of computers. ManuCo1's Key Account Manager responsible for the relation towards CGI express that; "*Product-sales is our only source of income, we have unlike competitors refrained from after-sales engagements*" [ManuCo1-KAM]. Whereas ManuCo2 say; "*we make money on computers but also on services, financing, take-back and remarketing ... we are, because of our service offers, a competitor to SysCo which can be problematic ... In the SysCo case we only sell computers*" [ManuCo2]. Both ManuCo1 and ManuCo2 express that manufacturing and traditional sales of computers are their core businesses in the case-PSS, which in turn counteract the sustainable mechanisms of intensified product use and prolonged product life. However, both ManuCo1 and ManuCo2 express that they are driven to build robust computers to maintain a strong market position "*We don't need ownership incentives to build robust computers, the support function is super expensive which make us want to avoid failures within a warranty period by all means*" [ManuCo2]. Both actors argue that the software, operating system and technology development cause a computer's end of life rather than hardware failures and that they are keen on building robust computers even without ownership incentives.

The PC manufacturers interviewed have drivers to take true life-cycle costs into account, which is a sustainable mechanism of a PSS. These drivers are in the studied case represented by the **manufacturers warranty**, which can be 3 or 5 years in a B2B setup. During this time the PC manufacturers repair all hardware related problems that are not caused by careless use. According to ManuCo2 (as cited earlier) and ManuCo1 their warranty drives them to build robust computers because they argue support functions to be expensive. One of ManuCo1's Key Account Managers, for example, say that "*the cost of increasing warranty from 3 to 5 years is low in comparison to a new computer*" [ManuCo1-KAM], and thereby argue that they already design computers to last more than 5 years. According to Tukker (2004) a maintenance contract is an example of a minor efficiency improvement of a sustainable PSS. Because of the warranty's limited duration in relation to the products life span of this case the manufacturers' warranties could be seen as this type of minor efficiency improvement. Since the manufacturers' warranties only take hardware failure life-cycle costs into account during a limited period of time they do not fulfill all features of a true life-cycle costs mechanism. However, interviews also revealed that none of the actors are interested in leasing computers that are unsupported by warranty. Both ReCo and SysCo state that hardware warranty

support is the most crucial feature if they were to set up a workplace solution with second hand computers. One Sales Manager at SysCo express that; “*Without warranty the risk will be too high for any business workplace solution*” [SysCo-SM]. Thus, a longer warranty of a computer could in this case have potential to give a much higher sustainability improvements than Tukker (2004) suggests.

4.1.2 System provider

One of SysCo’s Sales Specialists explain that “*our desktop management service is our primary competence and business*” [SysCo-SS1] in which they are supporting workplaces with all software related functions. To give this service a platform they provide computers and other IT hardware in a Hardware Life-cycle Management service (HLM). Outside this they have a service desk to handle software issues within or outside of their desktop management service. The Sales Specialist at SysCo explain that; “*both desktop management and service desk are profitable while HLM is seen as a necessity to run the others ... SysCo would never sell only the HLM-service because of this*” [SysCo-SS1]. SysCo have thus **decoupled the desktop management service from the HLM-service** and some customers even have their own HLM solutions while still running SysCo’s desktop management service. As of today SysCo is responsible for few life-cycle related costs. Most of the costs related to hardware are covered by manufacturers warranty and, due to this, product life-cycle costs are decoupled from SysCo’s services. SysCo express that “*older computers would make their desktop management more expensive to perform, with more errors and more images to maintain*” [SysCo-SS1]. SysCo is outsourcing all hardware related activities such as transportation, installing images, take-back and re-marketing. SysCo’s Sales Manager say that “*it is not through hardware sales we make our revenues, we don’t earn money by prolonging the computer use cycle*” [SysCo-SM]. Because of this SysCo take no hardware related life-cycle costs into account in their business model and neither have any incentives to do so. Computers are most often used for 36 months while the “full service” run on a longer contract.

The only incentive found to affect SysCo to encourage longer hardware use is **customer lock in**. One of their Sales Specialist express that; “*the biggest reason to sell financing and take-back solutions is to get a bigger customer lock in*” [SysCo-SS1]. Apart from this SysCo neither have any incentives to use its own partner ReCo instead of the customers’ own finance or take-back solutions.

4.1.3 Re-marketing actor

The re-marketing actor of this case, ReCo, use a lease business model which is based on (1) finance, (2) first-hand lease, and (3) take-back, refurbish and sales of second hand computers. ReCo's two revenue sources are lease of first hand computers and sales of second hand computers, where the second revenue source is their profit generator. The length of ReCo's first hand lease is governed by their customers (SysCo in this case) and in turn by the warranty period SysCo negotiates with manufacturers. Though, ReCo push their customers to use the most common laptop warranty (36 months) since they speculate this will generate the most profitable second hand value with their current lease model. SysCo, for example, say; "*ReCo push us to encourage take-back after 36 month since they are interested in the hardware's residual value ... longer cycles cause lower volumes for ReCo and is therefore something they counteract*" [SysCo-SM]. This means that ReCo to push for shorter leases as **linear business model** (sales of second hand computers) favour these.

ReCo's business model drives them to push for high **second hand value**. In order to maintain high second hand value the company refurbish laptops and apply penalty fees for customers who return broken or worn out hardware. ReCo's business model is, according to their Head of Sales Sweden, a tool for prolonging hardware's life through creating a second use cycle. ReCo mean that their model create the longest possible life for a laptop, though it is still unclear what happens to the laptop after it has been sold. ReCo's Head of Sales Sweden express that; "*A short first use-cycle secures the possibility of finding a second customer, which makes the total life longer*" [ReCo-SA]. Apart from fees for increasing second hand value ReCo lack the incentives for improving efficiency improvements during use, such as repair and maintenance. During the first-hand lease period the laptops are covered by the manufacturers' warranty, which release ReCo of this responsibility. Nor does the lease model make ReCo feel incentives to reduce consumables in the use phase (e.g. reducing energy consumption) since their lease model do not cover costs in the use phase, which is in line with theory of lease-options according to Tukker (2004).

Further, since ReCo purchase the laptops they then lease, incentives for affecting the above-discussed mechanisms are not passed on to the manufacturers, who are responsible for product design, as the warranty expires. Nor is ReCo interested in prolonging this warranty since their main source of profit is second hand sales and 36 months old computers are viewed to generate the most profitable second hand value. This results in a PSS where products are decoupled from the service and as both manufacturers and remarketer make their

profits on transactional sales have no business model incentives to prolong the life of products.

4.2 Product and industry characteristics

From the interviews it can be concluded that product characteristics in the case-PSS have large influence on the PSSs sustainable potential. These findings have been thematically grouped into five characteristics; market-value, image bearer, personal item. technological development pace and scale of market. Each characteristic have been found to affect the potential of sustainable mechanisms in different ways, as summarised in Figure 6.

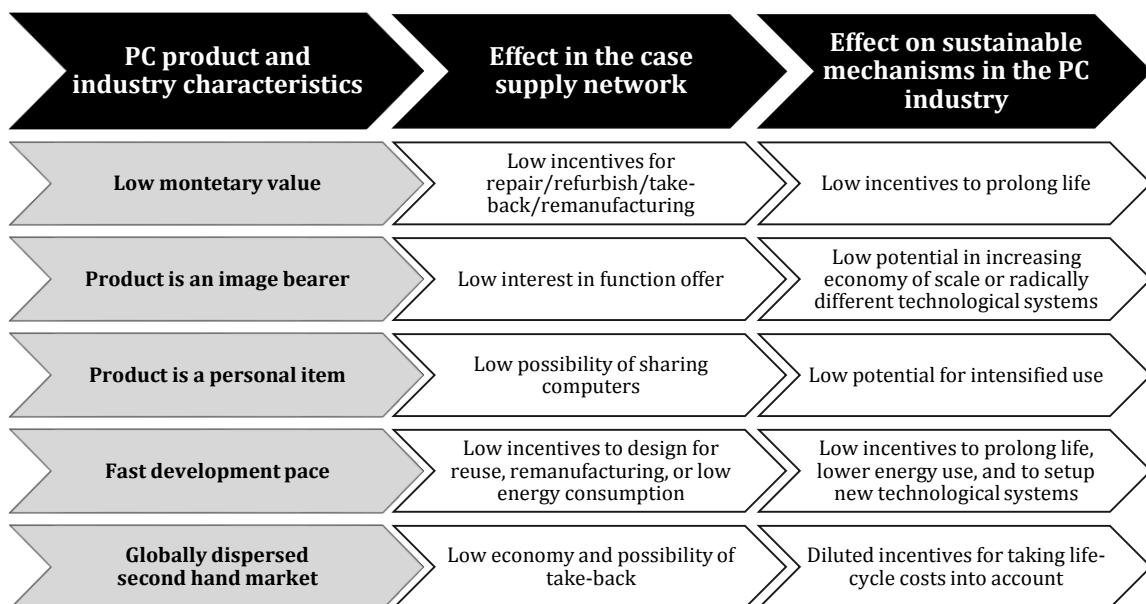


Figure 6, Causal connection between Product and industry characteristics and Effects on sustainable mechanisms

Mont (2002) reason about the **market-value** of a product as a condition for enhancing the drivers for resource efficiency within a PSS. She argues that a product must be of significant monetary value to produce incentives for maintaining ownership, prolonging product-life, and more far-reaching resource efficiency measures such as take-back and remanufacture. This phenomenon is something that the results of this study confirm. The laptop has shown to be a product that holds too low monetary value to induce interest for some of the sustainable mechanisms of the PSS. Environmental coordinator at ManuCo1 express this as; “*a computer isn't capital intensive which makes repairing or refurbishing it non-profitable*” [ManuCo1-EA]. Conclusively the products low monetary value makes incentives to prolong its life lower.

This issue, of a product with low capital value also manifest itself in consumer behaviour and that customers choose IT-hardware depending on what **image** they want to reflect. ManuCo1's The Key Account Manager express this as; "*hardware is image related towards a company's customers and employees, new computer hardware is seen as a sign of wealth*" [ManuCo1-KAM]. This behaviour make a functional offer harder as customers want to decide upon specific hardware. ManuCo1 also express that; "*trends within mobility makes desktop computers disappear and with that also almost all possibilities of sharing computers*" [ManuCo1-KAM]. Another consequence of this it that the laptop is a product which is used as a **personal item**. Thus, lowering the potential of intensified use through e.g. pooling solutions. This trend, of IT as an increasingly image related & personal products, is also something which one of SysCo's Sales Specialists argue that manufacturers are trying to enhance; "*Manufacturers are trying to force consumers behaviours on to the B2B market in order to increase sales, and they are quite successful*" [SysCo-SS2]. Thus this behaviour can therefor be expected to increase than decrease and is thus a significant contextual barrier.

A third product characteristic is **fast technological development pace**. This relate to the first finding regarding market-value in the sense that high technological development pace negatively inflict the market value of older products. ReCo's Remarketing Manager express that; "*the real age limit is somewhere at 7-8 years, after that the laptop is too old even for development countries*" [ReCo-RM], which is agreed upon by all actors. Historically, the issue with this lifespan has been that design of products has changed so dramatically during this time period that component have become completely out of date and materials/chemicals used in previous products have been banned through regulations. Thus, causing incentives for take-back and remanufacture to shrink. ManuCo2's environmental coordinator exemplifies this by stating that; "*using recycled components are problematic because of the fast development pace, both technical but also regarding chemicals or harmful materials such as mercury in screens ... I also think that longer hardware cycles and standardisation will limit innovation and sustainable innovative products will reach the market slower*" [ManuCo2-EA]. This reasoning contribute to a push for new products and resistance toward standardisation since product innovation is viewed as important for launch of less environmentally harmful products. An example of this is the big improvements in energy use.

Another characteristic that have been found during interviews is that the **scale of the market** for second hand computers is international and globally dispersed. ReCo's Remarketing Sales manager express this as; "*all second hand market is on export, for newer computers it is often*

northern Europe but older computers are sold to developing countries far away from Sweden” [ReCo-RS]. The international market together with that; “*the diversity of models are huge which makes spare part logistics expensive and complex*” [ManuCo1-KAM] makes the second hand market diversified and dispersed throughout the world. ReCo argue that because of this take-back or financing becomes complex for the second life-cycle of computers. However neither ReCo or ManuCo’s see a business opportunity in taking back old or broken computers because of their low value as spare parts or material.

4.3 Barriers and possibilities with a SIPSS approach

This chapter answer the second research question of how barriers and possibilities of a SIPSS approach can be characterised with regards to product and industry characteristics. The chapter is divided into three subchapters of barriers and possibilities treating aligned interests, the effect of decoupled service- and product-offers, and finally a discussion about a dilution of responsibilities and incentives, see Table 6.

Table 6, Barriers and possibilities found with a SIPSS approach.

SIPSS features	Empirical findings	Implications
Aligning interests	Interests in <i>PSS product portfolio</i> is difficult to align	Supplier integration creates increased complexity in product portfolio interests which is a <i>barrier</i> for supplier integrating PSSs
	Interests are difficult to align because of an <i>environmental initiatives conflict</i>	An increased supplier integration increases complexity in aligning environmental interests which is a <i>barrier</i> for SIPSS
	Aligned interests can help in <i>prolonging product use in PSS offer</i>	Aligning interests can leverage a prolonged product use which is a <i>possibility</i> for SIPSS
Decoupled product and service	Responsibilities of hardware and service is taken by different actors	A <i>risk</i> of SIPSS is a decoupled product and service which weaken a PSS’s sustainable mechanisms
Responsibility and incentive dilution	<i>Life cycle costs and design incentives</i> are spread out on different actors	Splitting life cycle costs on different actors dilute a PSSs sustainable design incentives and is a <i>barrier</i> for SIPSS
	<i>Lease model</i> is diluting <i>ownership incentives</i>	A lease model supplied by a third party dilute a PSSs sustainable ownership incentives and is a <i>barrier</i> for SIPSS
	<i>Take-back incentives</i> are diluted because of a third party financing	Splitting life cycle costs dilute possible take-back incentives and is a <i>barrier</i> for SIPSS

4.3.1 Aligning interests

A key factor of a SIPSS is to integrate suppliers in the PSS offer and thus get aligned interests in the PSS and its sustainable function. Interviews have shown both problems and possibilities with aligning interests and three different discussion areas have been found; **PSS product portfolio, conflicting environmental initiatives** and finally possibilities with aligning actors interests towards a **longer product use**.

Actors in the studied case have proposed different interests in the formation of the **PSS's product portfolio**. Back-end, e.g. ReCo's refurbish and hardware specialist and SysCo's service and product managers see cost saving potential in using a more standardised product portfolio throughout the whole PSS. ReCo's remarketing manager express that "*Standardisation give better economy in refurbishing and better profit in sales*" [ReCo-RM] and SysCo's service manager say that "*Fewer models would decrease service production costs*" [SysCo-SM]. Front-end e.g. SysCo sales and ReCo sales express that customers demand is for differentiation and that standardisation initiatives would be unaligned with both customer interest and cost-savings. SysCos sales specialist say "*The customer choose the product they want, regardless of extra costs*" [SysCo-SS1] and ReCo's sales manager that "*The thought of standardisation is good but will never work, nobody wants to buy it*" [ReCo-RS].

As interests in the **PSS's product portfolio** vary throughout the supply network, a SIPSS approach seem to increase complexity in the product portfolio. Some actors propose that an agreement throughout the PSS of a more standardised product offer would create economy of scale effects that promote e.g. maintenance and thus sustainability. Though, respondents with customer contact find this hard and against the customer demand. The SIPSS idea is that closer cooperation should realise aligned interests in a PSS's sustainability goals. But as involved actors do not have aligned interests about a product portfolio within their own company its seems unlikely that closer integration would create aligned interests throughout the supply network. The main reason for this seems to be that the actor in contact with the end-customer do not have any incentives to account for other actors' wishes about what products to push for. Nor does this actor have enough knowledge about what would be the best products to push to the end customer in regards of sustainability. Regarding the case this knowledge seems hard to obtain as there is no common understanding of what product portfolio would give all actors the best abilities to support sustainability. Therefore all actors

try to create solutions that are independent of what suppliers of hardware or services they work with and aligning interests of the product portfolio is seen as a barrier for a SIPSS.

All interviewed actors have **environmental concerns** and are claiming to work actively towards environmental goals. However, the different environmental programs seems to be in conflict in the studied case. ManuCo2 express that environmental-report requests from SysCo is often very theoretical and require manual work to address but also sometimes go against ManuCo2's policies of what information to rely on. ManuCo2's environmental spokesman express; “[SysCo] want to use life-cycle analyses, LCA's to measure us against competitors, this is an analyse method that we don't believe give fair results ... [ManuCo2] answered 600 CSR questionnaires last year, transparency is important but all different ideas on environmental work gets problematic” [ManuCo2-EA]. ManuCo3's Key Account Manager have another view and say; “we have LCA numbers on all of our models so the customer can know their emissions” [ManuCo3-KAM]. Because of this it becomes problematic for different actors to work together towards the same environmental goals. As ManuCo2 express the diversity in environmental initiatives is a problem of its own and thus it gets harder to tie it towards a specific actor. All involved manufacturers have customers outside of the studied PSS which makes it hard to coordinate environmental initiatives and thus align interests towards the sustainability mechanisms of a PSS. Because of this it is logical to assume that an integration of actors in the PSS offer do not overcome these problems but rather expands them.

In interviews with SysCo and ReCo the respondents were asked what possibilities and barriers that exist for leasing computers in a second use cycle instead of selling them out of the PSS offer. Thus **prolonging the product use in the PSS**. As discussed in 4.3.1 warranty from manufacturers seems to be important. ReCo's Remarketing Manager also express that; “Someone need to be interested in supporting the computers, not because second hand computers need more support but generally because IT needs a lot of support ... There is a market for second hand lease in Sweden, especially as a short-term lease to for seasonal employees” [ReCo-RM]. SysCo's Sales Manager also express that; “Our model is useable on second hand computers” [SysCo-SM]. Adding to this hardware manufacturers are interested in selling extra warranty; “extending warranty up to e.g. 5-6 years is a good affair for us” [ManuCo1-KAM]. These three actors all seem to be interested in a second lease cycle and ReCo claim that there exists a market for it. For it to work the actors need to work cross organisational in a way they do not work today. SysCo explain that extended warranty creates

a risk since the second customer is unknown when purchasing it. By other means a PSS with second hand computers needs a closer cooperation and sharing of risk than today. The interesting feature of this possible setup is that it demands close cooperation and aligned interests of the involved actors and also promote the sustainable mechanism of prolonging life. A SIPSS possibility is therefore to be able to develop new ways of working by being able to share risk and knowledge with suppliers.

4.3.2 Decoupled product and service

The technological system of this case' PSS is based upon traditional sales of laptops. Laptops in turn has proven to be a globally dispersed consumer good with low capital value and high technological development pace, which mainly seem to have negative effects on the sustainable mechanisms of a PSS. All of the companies supporting this PSS use linear business models in the sense that they acquire most of their revenues through transactional sales - except for SysCo. Manufacturers part of the PSS is to make money from sold computers and ReCo make money from acquiring these computers after a first use cycle and sell them on a second hand market. SysCo is the dominant service provider and should thereby, theoretically, benefit from a product that allows them to sell their services for a longer period of time. Though, the PSS SysCo provide can, and arguably should, be seen as a PSS offer divided in two - one service part and one product part.

Interviews with several SysCo respondents has shown that the services included in the PSS have been designed to be independent of specific product and/or hardware supplier. SysCos service manager express that; "*We make some percent on hardware but I would rather see it as a zero-revenue-invoice ... its not our business*" [SysCo-SM] where the sales specialist say "*there is an interdependence between hardware and service and we strive to keep a low differentiated product portfolio, but the service is designed to work independent of brands and models to attract all possible customers*" [SysCo-SS2]. By doing so SysCo are free use any hardware supplier in their PSS offer and customers are allowed to almost freely choose the product they prefer since this is, as written earlier, considered an important sales pitch. This have the effect that SysCo take no hardware related life-cycle costs into account in their lease model and thereby do not have the incentives to prolong the products life. Manufacturers are instead responsible for this through warranty for 36 months and as this expires SysCo order new products through ReCo who, again, push for a short, 36-month long, lease due to their linear business model. Figure 7 visualise how the service offer is consistent and give SysCo

continuous income and the products are used for 36 months and then sold out of the offer. ManuCos only have income at the point of sale as well as ReCo who also only make profit on sales of second hand computers. This makes the service offer continuous but the product offer linear.

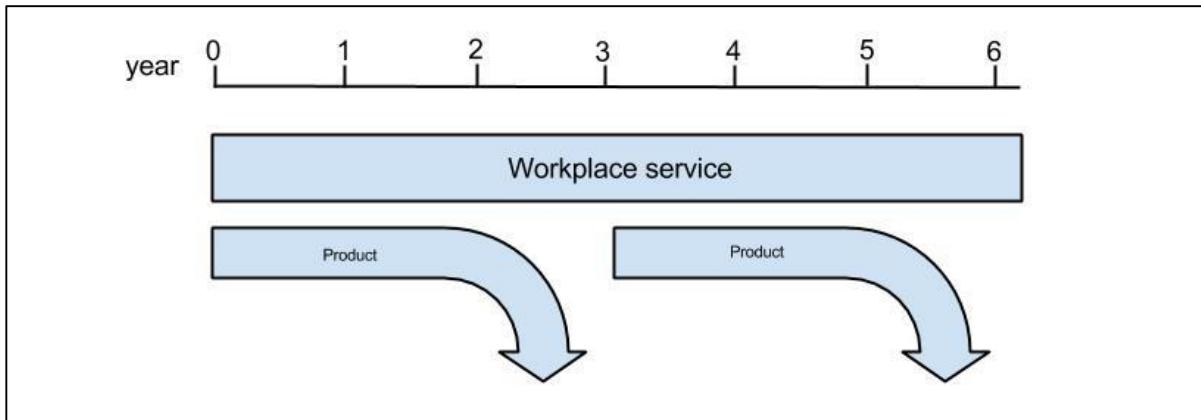


Figure 7, The decoupling of service and products in the case PSS including different actors main profit occasions.

Above reasoning mean that possible costs savings related to hardware do not benefit the provider SysCo in economical terms but rather their customers through price reductions. Thus, incentives for such improvements are rather low and of classical market related type rather than resource efficiency related. SysCo's Sales Managers say that; "*A longer lease would give a lower price for the customer, not lower costs for SysCo*" [SysCo-SM]. Conclusively a decoupled service and product offer is the biggest barrier of a SIPSS aiming to enhance sustainability.

4.3.3 Responsibility and incentive dilution

Parts of the main findings regarding barriers and possibilities of the SIPSS possibility to support sustainability thinking has to do within responsibility and incentive dilution. It is found that when numerous actors create a PSS offer together with partner like relationships, as apposed to one strong actor providing a PSS alone with volatile supplier relationships, sustainable responsibilities and incentives seems to be diluted. This chapter reviews this phenomenon regarding three different types of sustainable PSS incentives; **responsibilities of the life-cycle costs, lease model and ownership incentives** and **take-back incentives**.

Responsibilities of the life-cycle costs are divided in the case-PSS and vary to a great deal depending on if they regard the first use cycle or any of the latter, as seen in Table 7.

Table 7, Important hardware life-cycle costs and responsible actors.

Cycle	Responsibility	Cost	Actor
1st cycle	Warranty	Hardware failure - repair or replace cost	ManuCo
	Abnormal wear	Hardware failure - replace cost	1st customer
	Normal wear	Loss in second hand value	ReCo
2nd cycle	Breakdowns	Repair costs/replace cost	2nd customer
	Recycle	Unknown	Unknown

The true **life-cycle costs** of the first use-cycle are split between manufacturers, SysCo and ReCo. The fact that true life-cycle costs are split on other actors than the designer is unaligned with the mechanism according to Tukker (2004) hardware manufacturers express that they have incentives to build robust hardware because of market drivers and expensive support function, as reasoned in 4.1.1. But as software related service costs are taken by SysCo, second hand value risk is taken by ReCo, and all second use-cycle costs are taken by the second customer it is questionable whether the manufacturers have incentives to design the PC with all of these in mind and not only the ones caused by warranty.

With regards to the above it is evident that the divided **life-cycle cost responsibilities** provide less design incentives, caused from economic incentives, for manufacturers and also operating systems providers. Interviewed actors argue that these kind of incentives work good with normal market mechanisms, as reasoned in 4.1.1, however as SysCo do not find value in prolonging life of computers, because they have no profit on these, they will not pass that on with design market demands to the manufacturer. Nevertheless are manufacturers interesting on making products that last longer as they will not support new operating systems anyway. These two examples show that dividing true life-cycle costs on a numerous number of involved actors do not create incentives to account for them in product design.

For **ownership incentives** to travel throughout the SIPSS it is important that the different actors set up relations which utilise business models that allow for this. In the case the ownership of the products are handled by a lease model from ReCo towards the end customer, via SysCo. A lease model is by earlier research discussed as a business model which can

induce sustainable owner incentives. However, the lease model used in this setup are rather a financial setup used as an instalment plan for customers. When SysCo's lease plan reaches its end their customers have the freedom to choose between buying the computer or to purchase a take-back service for ReCo to take back the hardware.

This setup seem to dilute **ownership incentives** for a couple of reasons. The first reason is that SysCo involve another take-back actor than the manufacturers. By doing so a third actor (ReCo) gets involved in life-cycle related costs and thus responsibilities for these become blurred and spread out over numerous actors. Owner incentives thereby does not travel back to manufacturers, who are in control of design, as they may have if SysCo leased from manufacturers directly. ReCo's Head of Sales express that; "*[ReCo have no possibilities in affecting PC design, we adopt instead*" [ReCo-HS]. Also, the lease itself dilute ownership incentives since it is viewed as a financial plan rather than a result oriented solution for the customer. As a conclusion a third-party financer dilutes important sustainability incentives and is thus seen as a barrier for a SIPSS. Secondly a lease model is a barrier for sustainable PSSs as it is seen as a financing solution rather than a shift of ownership.

A theoretical idea is that if manufacturers bear true life-cycle costs and own the products they have incentives to both design for long term usage and **take-back** and resell/refurbish/remanufacture hardware. In the case two different opinions were found, ManuCo2 who themselves own a refurbish and remarketing company who resell hardware with an approach similar to ReCo. ManuCo3 however also have refurbishing activities but show a unique interest in bringing material and components back to the manufacturing site and argue that; "*We recycle plastics from old computers and use it in our new computers*" [ManuCo3]. This truly shows that manufacturers can have better possibilities for take-back they have the ownership instead of a third party such as ReCo. It also shows that choosing the right partner who have interest in the sustainable PSS is of high importance since not all players see the same potential.

5 Discussion

This thesis aimed to answer if and how Product-Service Systems thinking can be applied to an IT-hardware supply network to enhance sustainable effects since this is considered a prerequisite for a Circular Economy. The subchapters below will provide a summary of the answers to the research questions and ultimately the purpose of the thesis. Subsequently theoretical, practical and policy implications are discussed with a final discussion of limitations and further research.

5.1 Summary of answers to research questions

Research question one is answered in Table 5, drivers to enhance or counteract sustainable mechanisms and Figure 6 context characteristics effect on sustainable mechanisms. The majority of the findings regarding question one is that a PC supply network is driven to counteract sustainable mechanisms rather than enhancing them, this because of limiting contextual factors presented in figure 6, such as low monetary product value, that new products are seen as a image factor and a fast development pace.

The answer to the second research question is summarised in Table 7, with the main findings being that a SIPSS approach might be useful for enhancing a PSS's sustainability but that many problems with doing so arise. Aligning interests is problematic, and actors show no interest in doing so. There are also two major risks with creating a SIPSS; incentive and responsibility dilution and decoupled services and products. This makes barriers of the SIPSS thinking imminent and possibilities (in the PC industry) few.

The answers of the research questions fulfil the purpose of developing an understanding of how the supply network integration in a PSS offer affects the PSS's ability to enhance its sustainable mechanisms. The findings are that a supply network integration to large extent lower a PSS's ability to enhance its sustainable mechanisms because of a number of barriers. Industry and product characteristics heavily affect the mechanisms potential and thus also the potential of a supply network integration.

5.2 Theoretical implications

Within the traditional PSS literature the PSS provider is often discussed out of a manufacturer's perspective (Tukker 2004; Mont, 2002). Out of a SIPSS perspective where the manufacturer is not always the provider but rather a supplier to a PSS provider some problems related to the traditional reasoning appear. In the traditional reasoning a PSS is based on a certain manufacturer's hardware where services are developed around that hardware. As this is reversed, and hardware is instead placed into a service provider's offer, it seems that the PSS lose some of the most substantial sustainable benefits the traditional perspective argue it is meant to induce. If the manufacturer remain within the periphery of the PSS, as in SysCo's case, ownership incentives promoting sustainable mechanisms seems to be diluted. Hence, integrating the manufacturer in the PSS is of great importance for sustainability. Further, if the SIPSS is not designed with sustainability goals in mind (e.g. through use or result oriented business models between supplier and provider) our research find that the provider will design its services to be decoupled from hardware design in order to avoid life-cycle related costs. If one relate this to Tukker's (2004) figure describing a PSS, Figure 1, our reasoning of the above described situation is that SysCo's business model would position itself far off to the right as an activity management business model, since their business mainly revolve around services and they strive to create a function to fulfill the customer's need. SysCo's suppliers on the other hand (ManuCo1, ManuCo2, ManuCo3 and ReCo) all position themselves to the very left of Tukker's scale since their business models are almost entirely product focused. This create a split in the full SIPSS which SysCo has solved by decoupling the product offers from their service offers. This split also affects the sustainable potential of the SIPSS as a whole. If e.g. product oriented business models are part of the SIPSS it seem these business models set the bar for the sustainable potential of the PSS. Even though the provider is using a result oriented business model the sustainable potential of the offer will be limited by its suppliers business models.

This mean that when analysing or discussing PSS's out of an environmental perspective, the setup of involved actors have major effects. If ownership is shifted away from the manufacturer towards e.g. a financier or service provider the sustainable mechanisms of a PSS loose some of their potential effect. Geum and Park (2011) specifically highlight the design of a PSS to be important for its sustainable potential, where this research specifically highlight the importance of supply network design to be of high importance. Manzini & Vezzoli (2003), Lockett et al. (2011) and Mont (2002) all discuss the need of supplier

integrations in a PSS and this research directs that need towards an increased importance of supply network design rather than its integration. Integrating suppliers and aligning interests might still be important but our research find harmful risks, within incentive dilution and decoupled services and products, that can come from such integration. However this research also contribute to the idea that a PSS will not become sustainable without all surrounding actors involved.

5.3 Practical and policy implications

As for practitioners and managers our findings do not only highlight the importance of aligned interests and close cooperation throughout the supply network, but also the importance of policy changes in industries where incentives for sustainable mechanisms are weak.

Practitioners in industries with similar characteristics as in the PC-industry need to be aware of contextual barriers which put great demands on these to make conscious decisions in regards to sustainability. By purchasing, and thus promoting, products with relatively long life-cycles and marketing these as sustainable alternatives towards customers purchasers may for example use product image issues as an advantage to leverage a demand for sustainable products. The car industry could for example be an inspiration as this industry successfully has managed to make sustainable cars (e.g. Tesla) to be something of a high status symbol.

A parallel to this is also the importance of governmental initiatives. In order to enhance the demand for sustainable, long-lived products where incentives for such are weak governments must make sustainable choices economically beneficial. E.g. through tax regulations or enforcements by law. By doing so incentives within these industries can be enhanced and sustainable innovation may be accelerated.

Further, the dynamics and characteristics in these industries described as barriers in this study are likely to change within the decades to come. Access to finite resources will successively decline and thus make them increasingly expensive, causing proactive work with resource management to be important as incentives for take-back, reuse, and remanufacture will be enhanced.

5.4 Limitations and further research

The quality of data collected through interviews may have been lowered because of the chosen interviewee selection method. Involved respondents were chosen on the basis that they would be likely to have good insight in the PSS offer, however these showed to have mainly operational positions. These respondents where asked questions of strategic and speculative character since the chosen case was immature to its circular SIPSS thinking, which likely lowered the quality of data.

The case explored in this thesis was no success case regarding circularity which might have caused an imbalance in the ability to see barriers rather than possibilities of the given approach. Due to this we suggest further research to be focused on success cases regarding circular economy to better highlight possibilities with a similar approach. Also, we suggest data collection to revolve around interviews with persons in strategic positions since these are likely to be more appropriate to answer questions dealing with the SIPSS perspective.

The ability of effectively answer the research questions was lowered because the choice of a single case study, this applies specifically for RQ1 as drivers for sustainable mechanisms are from one specific case. The context is considered to have a big impact on the results but was an interesting context to study due to different ideas regarding its sustainable potential from circular economy and PSS authors. It is hence recommended that more case studies are conducted in other contexts to further develop the understanding of a supply network integrations effect on a PSS's sustainability potential. However, the network setup found in this case is similar to other cases in the PC industry whereby the results is considered to have high generalisability in this and similar industries.

Specifically the difference between a single manufacturer as PSS provider and a PSS offer spread out on different actors is very interesting. This research does not evaluate the difference but merely only researches on the barriers for such approach. Therefore a suggestion for further research is to do a multiple case study comparing these two setups regarding sustainable incentive dilution.

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