Master Thesis Report

Breaking Uncertainties for Product Offerings
- “A Holistic Framework of Uncertainty Management for Planning, Designing and Developing PSS”
(Product/Service System)

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Abstract

In the last decade, PSS (Product/Service System) emerged as a new effective business model in helping manufacturers increase significantly productivity and customer’s satisfaction, whilst minimizing environmental impact. PSS contributes drastically to the development of an innovative transaction trend, in which rather than just providing physical products separately, industrial Companies are more focusing on integrated service offers and customer’s need fulfillment.

However, to implement successfully PSS, manufacturers have to overcome many challenges and uncertainties. The uncertainties in the PSS planning phase are related to market, environment or company analysis; reliability, product/service integration, supplier coordination etc in the design and development stages are considered as potential uncertainties. Uncertainty is defined as “State of deficiency of information related to a future event” (Sakao et al., 2009). In which, risks derived from negative side of uncertainties may reduce efficiency of the model or even make the implementation process fail to some extent. If the uncertainty is resolved in a favorable way, risks can be seen as potential business opportunities for the development of PSS Companies.

While many Companies already have their own uncertainty management initiative; others just utilize their long time experience to treat uncertainties. Therefore, numerous Companies are seeking a comprehensive uncertainty management framework that could be applicable in most circumstances. In order to fulfill this urgent need, our thesis aimed to develop a holistic framework in order to manage risks occurred in PSS planning, design and development stages. Based on previous valuable PSS researches and useful empirical data collected, our dissertation first determined successfully critical uncertainty factors and potential business opportunities exploited from those. In addition, the research investigated elaborately PSS product quality thresholds and producers’ perception on reliability of their products before constructing a general uncertainty management framework. In which the whole management process based on Active Risk Management philosophy, included Risk Management Planning, Risk Identification, Risk Assessment and Prioritization, Risk Quantification, Risk Response Planning, Risk Tracking and Control were introduced as a helpful guideline to support PSS Companies to treat effectively uncertainties in PSS planning, design and development.
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Abbreviation:

B2B – Business to Business
CAD – Computer Aided Design
DFA- Design for Assembly
DFM- Design for Manufacturing
FMEA- Failure Mode and Effective Analysis
FMECA- Failure Mode Effects and Critical Analysis
FTA- Fault Tree Analysis
HSD-Risk – High Speed Database-Risk
ICT- Information Communication Technique
IPSO- Integrated Product Service Offering
IPSE- Integrated Product Service Engineering
IPS2- Industrial Product/Service System
LoA- Limit of Authority
LiU- Linköping University
PSS – Product/Service System
P.O.S- Product Oriented Services
QFD- Quality Function Deployment
RPN-Risk Priority Number
R.O.S- Result Oriented Services
TMH- Toyota Material Handling
SMEs- Small and Medium Enterprise
SysML – System Modeling Language
SWOT- Strength Weakness Opportunities and Threats
U.O.S- Use Oriented Services
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Allan Ashok Kumar & Giang Chau Trinh
1. Introduction

Chapter 1: This chapter deals with the introduction to the topic and background in the area of study. This is provided to facilitate a quick grasp of our study along with the Aim of our thesis, Expected outcome from our research, as well as summarizing the report structure.

1.1. Product/Service System historical perspective

To comprehend a new business concept, one needs to understand the consumer behavior and how production has been evolved since World War II. The beginning of production shared qualities like long life cycle and with increase in production led to low price of manufactured goods. This was sustained by the development in technology and overture of new management principles like Taylor’s principle. But in the long run, this led to decrease in profitability as customers had no motivation to buy new products. Therefore, Companies started to reduce product life cycle in order to increase material consumption which in turn led to more impact on the environment. Therefore, with new concerns about environment and providing incentives for Companies to make profit from the new concept, PSS (Product/Service System) has set goals to minimize the impact of consumption by consumers. This is done by using alternative schemes of product and increase overall resource productivity and dematerialization.

Mont defined PSS as “Pre-designed system of products, services, supporting infrastructure and necessary prearranged networks that can fulfill consumer needs on the market and, at the same time, minimize environmental impact”. A classic example of PSS is leasing of photocopiers and printers to individuals and organization by offering diversification services, giving opportunities to the provider to upgrade, remanufacture and modularize the design and production. (Lindhal and Olundh, 2001). It is to be noted that the term PSS is shared and related to other coined terms like ‘Servicing’ [White et al. 1999], ‘Functional (Total care) Products’ [Alonso-Rasgado et al., 2004], ‘Functional sales’ [Stahel, 1997] and ‘Service Engineering’ [Tomuyama, 2001] (Tan and McAloone, 2006).

With manufacturing companies getting saturated in terms of competition, Companies are looking for new ways to break even in the market. From this new research perspective, PSS (Product/Service System) gives a new scope in terms of strategies in both material and immaterial elements (e.g., information technology, consulting) with the key claim that, customer needs are fulfilled by intangible services (Roy and Cheruvu, 2009). Also, a major challenge for

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designing holistic design for PSS is to treat services on par with basic physical products (Sakao et al., 2009).

One of the ideal elements of PSS development is that all three stakeholders i.e. Customer, Company and Society, benefit from the service systems. It has followed other strategies like Integrated Product Development, which combines marketing and product development (McAlone & Andreasen, 2002; Andreasen & Hein, 1997). This has not only opened up new business opportunities, but a major reason has been the ability of PSS to create added value. This new business concept has created opportunities for Companies to focus on fulfilling the customer needs, and lowering environmental impact by providing goods that consumers can benefit from and services, which offer system solutions to fulfill the desired functions (Tukker, 2004; Lindah and Olundh, 2001).

Increase in service activity had lead to increased incorporation of services in the design area, whereas previously manufacturing companies focused on the physical product design. The benefit from this has been a less negative impact on the environment, by companies now in control of the product usage phase, therefore controlling the energy and resource consumption (Sakao et al., 2009). Services is now used as a differentiation strategy to overcome its competitors (Allmendinger and Lombreglia, 2005), although more knowledge is lacking in designing of services with solution, as well as deficit in innovation in the field of industrial service innovation management (Edvardsson and Olsson, 1996; Busse, 2005).

This change in production philosophy having the base of good economic opportunities, has led companies to concentrate on physical products whole life-cycle. This trend has shifted the primary attention of the company to look more into the usage phase and end-of-life phase, which includes remanufacturing and maintenance (Sundin and Bras, 2005). Remanufacturing is also an important aspect of Product/Service System. It enables environmental conscious manufactures to extend product life and integrate the used physical product back into the production chain (Sundin et al., 2009).

1.2. **Background to our research**

Uncertainty of an offering has been highlighted as one of the aspects making PSS different from physical products. This research is done in joint collaboration between Cranfield University from UK and Linköping University located in Sweden. We have studied a qualitative research by conducting surveys and interviews with PSS Companies. In addition, we have used the IPS2

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conference papers to guide us with different researcher’s publication on PSS design and development.

Uncertainty becomes a key issue which is dealt with PSS in developing/designing phase. The profitability from maintenance support/services is precisely depended on the right analysis of the risk assessment (Oliva & Kallenberg, 2003). Different Companies are using different tools for risk management, and have various response measures set for the expected uncertainties involved in product design and development. Although risk has a negative effect, opportunity has a positive effect on uncertainty (Jabagchourian & Cvetko, 2002). This is what we will try to ascertain in this research of how Companies perceive certain uncertainties as opportunities.

1.3. Aim of the thesis and research questions

The aim of our research is to design a new general framework for uncertainty factors, which can be used by Companies to check the risks involved in planning, designing and developing PSS. This will be conducted through a survey and one to one interview among PSS Companies primarily located in Sweden.

- Identify key uncertainties while using PSS in planning, design and development stage.
- Investigate which uncertainties could be seen as opportunities for PSS provider compared to traditional product oriented provider.
- Inspect on the perception on reliability, the issue being balance between the long life of the product vs. profit margin.
- Develop a general framework for uncertainty in planning, design and development phase for PSS. In the general framework, we propose elements to identify, measure, assess risks and quantify them.

The following objectives led us to frame the following research questions:-

Research Question 1: What are key factors leading to uncertainty in PSS design and development and which uncertainty is considered as an opportunity?

Research Question 2: From the provider’s perspective, how much reliability of a PSS designed product is expected in order to fulfill customer satisfaction whilst continuously creating opportunities/profit for the company in the usage phase?

Research Question 3: How will Active risk management be beneficial in the proposed framework, in order to overcome the uncertainties involved in planning/ designing and developing of PSS?
1.4. Expected outcome from our research

The proposed outcome from this research would be a holistic framework for uncertainty management in both planning and design/development phases in PSS Companies. This framework is also expected to become a valuable guideline for Companies who have major concerns about PSS and a strong desire to implement this PSS approach in the near future.

- Creating a new framework for uncertainty management for PSS Companies.
- Main types of uncertainties PSS Companies in Sweden are facing and the opportunities various Companies perceive from these uncertainties.
- To make it beneficial for organizations who want to implement PSS, by making it easier to assess the risk and see the benefits in pursuing ahead with PSS strategy by knowing about the best tools/methods for risk management practiced in PSS Companies.
- Mostly to be used by organizations designing medium technology to high technology products.

1.5. Scope and Delimitation of the Thesis

The whole dissertation was focused only on the planning, design and development stage of PSS. Companies who had implemented PSS as a business model or Companies with major focus on service sector were approached for investigation. The objective was to get to know the best practices and tools used by various Companies in order to ascertain the risks and overcome the uncertainty factors. The tools and risk management approaches used by the Companies were compared with the available literature’s information.

Since, the time period to carry out detailed investigation into the Companies was restricted in our masters program. The time factor led us to concentrate only on the planning, design and development stage of PSS. The delivery is a very important stage for PSS but due to the scope of the thesis duration was limited, this respect of PSS phase in uncertainty management was not carried out in this dissertation. Although, we did manage to look into, ‘when the uncertainty is actually addressed’ in the planning/design/aftermarket and delivery stage of PSS. We didn’t use this section for our analysis, as we felt the scope was too broad, but also it is partly covered in ‘Active Risk Management’ which will be studied in detail in this dissertation.

Since, we are based in Sweden to carry out this research; we would be only looking at Companies located in Sweden who are using PSS.

As Uncertainty Management is still a relatively new area of study with respect to PSS, we feel more research needs to be carried out in the future, based on our initial study in order to build a more comprehensive framework.
1.6. Outline of the report

To elucidate on the whole structure of the report to enable easier reading for the reader, we have eight chapters as follows;

- The first chapter is the introduction to our topic PSS. We give the benefits of PSS and state our objectives, research questions and scope of our dissertation.
- The second chapter deals with the methodology carried out in this research. We outline how the topic was selected and how the search was conducted to find relevant sources for the research journals to the topic concerned. In addition, the methodology for our data collection is mentioned in this chapter along with the limitations faced in the whole process.
- The third chapter elaborates the literature review in context to the topic of our research. The literatures used were mainly related to the topic of generic product and PSS development, with focus on planning, design and development phase. Risk management and the latest tools Companies use for risk assessment is also found.
- Fourth Chapter discusses about theoretical framework synthesisization, on how the main uncertainty factors were chosen and why. Also a brief description about each factor and why it was used in our framework development prototype.
- In the fifth chapter, we present our findings from the survey and interviews. It also gives the background of the Companies, which we selected to collect our data from.
- Sixth chapter is followed with analysis of our finding. We will show the applicability of our uncertainty management framework and highlight what is the main uncertainty factor for Companies using PSS.
- The final chapter is discussion, where we comment on the analysis and evaluate the generalization of the new framework for uncertainty management for PSS Companies in planning, design and development phase. Conclusion is made, where we state the overall process and summarize the finding our research. Also the future research needed from this dissertation is stated.
2. Methodology

Chapter 2: With the mission to help readers grasp more comprehensively about the method we conducted and wrote the dissertation, this chapter will discuss more in detail about our Topic selection, Search strategy, and Theoretical frameworks selection. Followed by, each step in data collection will be presented in a logical way before writers introduce elaborate plans to analyze effectively the results, and limitations that they confronted and had to resolve in the execution time of this dissertation.

2.1. Topic selection

Originally, the plan for studying this topic was nurtured from the time we were attending lectures of Professor Tomohiko Sakao, in Integrated Product Service Engineering (IPSE) course at Linkoping University. Namely, the course introduced PSS - one of new efficient approaches that provide numerous benefits for manufacturers in innovative production, generating more profit for Companies as well as creating significant value for customers, alleviating environmental impacts.

In addition, with consultancy of Prof. Tomohiko Sakao, we knew about this exciting topic, which has been a part of research collaboration project between Linkoping University and Cranfield University in England. Despite of the fact that there are a large number of valuable researches conducted and published in this area by well-known scholars, quite few papers propose a holistic uncertainty management framework that is helpful for PSS Companies in the product planning, design and development phases. Thereby, this is a fruitful and interesting researching domain. Even though we perceive completely how challengeable and demanding it is, because we are part of creating a unique research contributing to the topic PSS field. However, the challenges are accepted, and we strongly believe that our outcomes from this dissertation would be helpful and applicable to PSS Companies in managing uncertainties to some extents.

2.2. Theoretical framework selection

As mentioned, in PSS domain there have been few studies conducted about uncertainty management framework. So far, we found that ‘An Integrated Lifecycle Model of PSS’ proposed by Hepperle et al., (2010) was a valuable reference to help us find the various uncertainty factors in product development, and construct an effective uncertainty management framework in PSS plan, design and development.
In order to categorize the PSS products, we realized there were numerous classifications created and most of them make a distinction among three main categories: Product-oriented, Use-oriented and Result-oriented. However, PSS classification (Tukker, 2004) which had been mentioned and discussed in other literature (e.g. Tan & McAloone, 2006) caught our attention by its logic, clarity and comprehensiveness. Thereby, the uncertainties would be investigated easier in a logical way based on this PSS product taxonomy.

Regarding uncertainty management, in countless academic papers there are generally four major steps, which consist of Risk Identification, Risk Assessment, Risk Prioritization and Risk Response. Among them, we chose Active Risk Management methodology created by Intel to provide a standard way to identify, assess, prioritize and manage potential risks. There are two reasons for that selection. First, Intel is a gigantic corporation with high level of reputation in Information Technology and it has “a world-class risk management methodology” (Goodman et al., 2007). Second, Six Steps Active Risk Management process was developed and verified by Intel in the past few years. Currently, they have achieved considerable successes in the risk management domain.

2.3. Data Collection

In this part, Data Collection is described in detail to let readers grasp how we gathered related information and knowledge to construct the framework and support arguments. Technically, there are two types of Data Collection: Primary and Secondary data.

2.3.1. Secondary data collection:

Secondary data is available data collected by other researchers before. Namely, it consists of statistical raw data, archival records, photos, TV, newspapers, journal articles, official documents etc. In our case, we mainly exploited the database constructed previously by PSS researchers in Linköping University & Cranfield University. Many valuable PSS literatures were shared by Prof. Tomohiko Sakao via Dropbox (a sharing data application on Internet). Moreover, the related outcomes of the preceding surveys and researches could be applicable for our dissertation. Nonetheless, bearing in mind that it was necessary to check the coherency of this data before utilizing it in order to increase the authenticity of this report.

In addition, we also reviewed the PSS literature, articles relevant to this topic. To find them, we implemented the search strategy, which is described elaborately in the following text:

- To search quickly and effectively related papers in the field of study, the common searching key words are Uncertainty, Risk, Opportunity, Planning and Design, Product Development, and PSS.
Methodology

- We targeted to academic and official source of data such as journals, articles in LiU library webpage\(^3\) and other websites: Scopus\(^4\) and Science Direct\(^5\). Furthermore, IPSE website\(^6\) is also considered as a fruitful resource to exploit relevant literature about PSS.
- Accumulated knowledge from the lectures and notes of IPSE course contributed significantly to the theoretical foundation of this dissertation.

### Table 1 Investigation summary

<table>
<thead>
<tr>
<th>Company</th>
<th>Participant 's position</th>
<th>Product sector</th>
<th>Investigation Method</th>
<th>Date</th>
<th>Duration (minutes)</th>
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<td>Electronics</td>
<td>Online survey &amp; telephone</td>
<td>20/05/2011</td>
<td>34</td>
</tr>
<tr>
<td>B</td>
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<td>Engine and power systems</td>
<td>Online survey &amp; telephone</td>
<td>24/05/2011</td>
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<td>Construction Machines</td>
<td>Online survey &amp; telephone</td>
<td>30/5/2011</td>
<td>45</td>
</tr>
<tr>
<td>D</td>
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<td>Energy Sector</td>
<td>Online survey &amp; telephone</td>
<td>1/6/2011</td>
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<td>Large Size Vehicles</td>
<td>Online survey &amp; telephone</td>
<td>27/05/2011</td>
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<td>7/6/2011</td>
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<td>Medium Size Vehicles</td>
<td>Online survey &amp; telephone</td>
<td>10/6/2011</td>
<td>52</td>
</tr>
</tbody>
</table>

2.3.2. Primary data collection

The Primary data is data gathered directly by researchers through surveys, interviews or observation. In the case of this dissertation, in order to obtain valuable empirical data, a general survey and an intensive interview were delivered. The questions in the investigation were created, based on our accumulated knowledge and working experience, as well as insights into secondary data collected and the consultancy from our supervisor. The structure of the investigation consisted of two parts: an online survey and a short interview. Under the guideline of The Survey System's Tutorial created by Creative Research System website\(^7\), a survey was built elaborately with ten relevant questions categorized into three different domains: uncertainty factor, opportunity in PSS and risk management. To facilitate the delivery, we used a common online survey application named SurveyMonkey. The interview, which included four questions, aimed to investigate intensively specific situations of Trade-off, Active/Passive risk responses

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\(^3\) [http://www.bibl.liu.se/?l=en](http://www.bibl.liu.se/?l=en)
\(^4\) [http://www-scopus-com-lt-ltag-bibl-liu-se/home-url](http://www-scopus-com-lt-ltag-bibl-liu-se/home-url)
\(^6\) [http://www.ipse.se/](http://www.ipse.se/)
\(^7\) [http://www.surveysystem.com/sdesign.htm](http://www.surveysystem.com/sdesign.htm)
Methodology

and Communication barriers. The whole investigation was executed via telephone, and expected to last a maximum of 45 minutes (includes 25 minutes for the online survey and 20 minutes for the interview).

Target group of our investigation is managers who are working either for marketing, planning, or design and development departments of PSS Companies in Sweden. The Companies are medium or large enterprises, operating in various industries with high level of technological complexity. Since there have been quite a few Companies operating in PSS domain, so we were just able to send the investigation request to 17 contacts working for 14 Companies. Some belong to our supervisor’s past research contacts, others replied directly to our investigation invitation email. Since not all of them are working in the investigated domain, they either refused the request or recommended us to the “right person” in their Companies. In response, seven contacts agreed to participate fully the investigation (accounted for 41 %), one just had time to fill in the online survey. Technically, there were eight PSS Companies joined our investigation as summarized in Table 1.

2.4. Analysis planning

In this paper, we aimed to use mainly qualitative and semi-quantitative methods to clarify the discussed problems due to the limitation of PSS Companies in Sweden. After reviewing secondary data, initial assumptions were carried out as a foundation to construct a uncertainty management framework prototype, which would be verified in the practical contexts through primary data collection. Furthermore, numerous Research Questions (RQs) were initially formed to reach the thesis statement. However, due to the scope and limitation of this dissertation, the authors narrowed down to three comprehensive RQs as mentioned in the Introduction chapter. In the following part, analysis methods will be depicted in detail for each RQ.

2.4.1. Method for the first RQ:

RQ1: What are key factors leading to uncertainty in PSS design and development?

This research question was addressed through a survey matrix table. In the table, we synergized all the most common uncertainty factors that PSS Companies may confront in the design and development phases. The proposed factors are based on insights of numerous PSS literatures reviewed, our own learning knowledge and accumulated working experience. The survey respondents were required to score each factor from one to five in term of Probability and Consequence. By multiplying these two dimensions, we were able to elicit which factors are the most critical leading to uncertainties in PSS design and development. Due to the limited number of respondents and the variety of Company background/ industry, the uncertainty perspective of
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Companies may vary and lead to slightly different meaning of the scores. Therefore, the authors decided to normalize the rating in order to increase the rationality of the results to some extent and facilitate the analysis process.

2.4.2. Method for the second RQ:

**RQ2**: From the provider’s perspective, how much reliability of a PSS designed product is expected in order to fulfill customer satisfaction, whilst continuously creating opportunities/profit for the company in the usage phase?

This question was resolved mainly by practical information gathered from interviews with PSS Companies. However, it does not mean that we neglected the important role of theoretical reviewing. It inspired us in creating ideas and shaping the relevant questions, which contributed to the success of interviews.

2.4.3. Method for the third RQ:

**RQ3**: How will Active risk management be beneficial in the proposed framework, in order to overcome the uncertainties involved in planning/ designing and developing of PSS?

In the scope of this dissertation, to answer this question we relied on theoretical foundations, valuable and constructive information gathered from the survey and interviews. The answer is a result of a synergy between critical analysis and elaborated assessments, based on primary and secondary data collected.

2.5. Limitation

Apparently, PSS is considered as a new competitive concept in product development and being studied by scholars in the last 10 years. As a result, there are a few literatures available in terms of uncertainty management which definitely being beneficial to our study.

Moreover, due to the time limitation and a small number of PSS Companies operating in Sweden, we did not expect to receive a large quantity of responses from the primary data collection to validate more critically the results. Consequently, the research methods for this dissertation mainly are qualitative and semi-quantitative as mentioned above.
3. Literature Review

Chapter 3: This chapter deals with in depth literature review of our topic within PSS design/development and risk management tools for an assortment of uncertainties involved in PSS. Various arguments raised by different researchers are noted in this chapter. The relevant concepts are summarized to form the basis of our analysis in the proceeding chapters.

3.1. PSS overview

3.1.1. Definitions and perspectives:

PSS (Product/Service System) as known by the other name as ‘function-oriented business model’ is developed in academia aimed at providing sustainability of production and consumption together (Cooka et al., 2006). In more than a decade of development, there are numerous PSS definitions defined by well-known scholars and practitioners working in this field of expertise. In general, the most highlighted features of PSS description are the harmonious combination between physical products and services, the efficient fulfillment of customer’s needs, changes in ownership structure of PSS, and the environmental impact reduction.

In term of ownership determination, instead of selling physical products and transferring the ownership to customers as tradition, PSS has a tendency to operate under the new ownership pattern. It means by leasing, renting or pooling, the artifact remains in the ownership of the manufacturers. This policy is argued to help providers obtain advantages since the disposal phase and remanufacturing issues are easier to handle in the end of PSS life cycle (Lindahl et al., 2008).

Regarding environmental perspective, numerous scholars highlighted the important role of PSS in reducing environmental impacts and helping the society dematerialize (Lindahl et al., 2008; Sakao et al., 2009; Roy and Cheruvu, 2009). However, there are two-way perspectives about this controversial issue. Although PSS is considered as a potential approach for “de-linking economic growth” when providers are switching from selling products to provide services instead (Mont, 2004), the improvements in environment are incremental or even barely visible. Some scholars argue that by transmitting to focus on service and extending the utilization phase of products, the production of physical products will decrease significantly in the near future. Apparently, this reflects changes in the consumption pattern when the utilization of natural resource reduces gradually and the production becomes more efficient. Nonetheless, Tukker (2004) claims that leasing model in PSS may result in negative environmental effects when there are not many incentives for leasers to use the product in the careful way. In addition, product renting, sharing
or pooling probably have minor environmental benefits if the burden is unrelated to the artifact production, since the same product is not shared and used in an intensive way.

Despite being a state of the art and efficient business model, PSS is not applicable effectively to all kinds of artifacts in different industries. In Sakao (2009), he referred to a list of product conditions proposed by Tukker & Tischner (2006) in which if any of them apply, the PSS approach will achieve the highest effectiveness:

- Products with high costs to operate and/or maintain;
- Complex products that require special competencies to design, operate, manage and/or maintain;
- Products with considerable consequences or costs if not used correctly or appropriately;
- Products where operational failure or downtime is not tolerated;
- Products with long life; or
- Products with only a few major customers on the market.

Concerning content of PSS, according to Lindahl et al. (2008) three main parts of the offer seem to be physical products, maintenances, and repairs. It is worth to note that when conducting maintenances and repairs, apparently there is a consumption of subsidiary products and physical products. These statements were resulted from outcomes of large survey conducted among 34 PSS Companies of different industries in Sweden, Japan, Germany, and Italy (Lindahl et al., 2008). Furthermore, it illustrated that the main actors in development of PSS are marketing, product development and after sale departments. In which, the two first actors were overwhelming in Germany and Italy meanwhile in Sweden and Japan, after sale department was the majority (Figure 1).

![Figure 1 Department related with PSS (Lindahl et al., 2008)]
In line with PSS concept, there are other concepts mentioned in the past few years such as IPSO (Integrated Product Service Offering), IPSE (Integrated Product Service Engineering) or Functional Sales. The relationship between PSS, IPSE, and IPSO is that IPSE and IPSO are two perspectives of PSS. IPSE is the methodology or development process activities of PSS, whilst IPSO is the offering or result of PSS. Regarding Functional Sales, this is a new business concept, “in Functional Sales, a function is delivered to the customer” (Lindahl & Ölundh, 2001).

3.1.2. Driving forces:
A large number of PSS papers indicated that the main incentives for industrial companies to implement PSS originated from changes in consumption behavior and business advantages, which PSS offers in terms of profit generation, customer satisfaction, competitive competence and environmental impact.

The initial move to PSS was partly motivated by the awareness of higher profit generation of product-services combination compared to the products alone (Mont & Lindhqvist, 2003). Therefore, faced with shrinking markets and increased commoditization of their products, numerous companies saw service provision as a new path towards profits and growth (Tukker & Tischner, 2006).

![Figure 2 Driving forces for PSS providers (Lindahl et al., 2008)]
Besides, the result from survey conducted by Lindahl et al. (2008) indicated that the main incentives for PSS Companies were connected with customers. Namely, PSS is an effective approach which helps companies build longer relationships and closer contacts with clients, thereby fulfilling better on the specific customer’s needs by allowing high level of customization, and delivering efficiently added value to the end-users.

As can be seen in the Figure 2, Customer Demands and Customer Connection were the two major driving forces for PSS, following by Increased Competition and Secure the Aftermarket. There is no doubt that achieving high-level satisfaction from clients is a competitive edge for producers against other rivals in the increasing global competition. Moreover, PSS helps manufacturing companies control their artifacts’ life cycle better due to special contract patterns between companies and their clients. These patterns enable producers to retain their product ownership and not transfer it to the end-users. These results are partly in line with assumptions of McAlone & Andreasen (2002) for the industrial companies. By building a strong relationship with customers, PSS companies are able to innovate faster, maintain the contract longer, offer value added services such as maintenance, upgrading or realize new ownership patterns (leasing, service contracts), enhance competitiveness and achieve greater market share.

3.1.3. Classification:

In previous researches, various classifications of PSS were proposed and most of them make a distinction between three main categories: product-oriented service, use-oriented service and result-oriented service. However, to let reader have a holistic view about types of PSS, Tukker (2004) referred to the elaborated typology proposed by Tukker & Van Hallen (2003), in which PSS was identified in eight specific categories (Table 2).

**Product-Oriented Service**: This is a PSS in which, the ownership of tangible product is transferred to the consumer. Although the business still gears mainly towards sales of products, additional services are provided such as installation, maintenance or upgrade.

**Use-Oriented Service**: This is a type of PSS in which, provider retains the ownership of tangible products while selling the functions of artifacts throughout the modified distribution and payment systems. In principle, this manner is more cost effective, except for lower profit margin (compare car sharing with car selling).
result-oriented service: in this type of pss, physical products are replaced by intangible services. moreover, there is an agreement between client and the provider on a result without any involvement of pre-determined products (e.g. voicemail is replacing answering machines). this type of pss is more effective and opens the door for fully new function fulfillment. however, result-oriented service requires totally new capabilities. namely, it has worse cash flow properties and all risk lies with the provider. in addition, the offering is probably difficult to specify because of its intangibleness.

3.1.4. challenges
switching from traditional economy to a new service approach pss that includes numerous domains involved regularly poses numerous challenges for industrial producers. the challenges vary and depend on different field of industry, the size of pss companies and their production capability. the internal challenges for pss companies were categorized into human side, organizational resistance to change, product/service integration and cost related. meanwhile, the external challenges are related to new way of cost thinking, conflicts from external actors and aftermarket control.
**Internal challenges**

First, the PSS implementation requires the involvement of several business domains and departments inside a PSS producer. As a result, the inter-department cross-communication and individual collaboration efficiency play crucial roles in the success of PSS development. Moreover, the interaction among departments regularly challenges the organizational management tasks like negotiation and coordination. Since the collaboration in different competencies becomes more and more complicated. Besides, switching to PSS from traditional production, manufacturers and stakeholders have to keep in mind that instead of selling products, they mostly offer customer services and generate revenues from delivering added value to their customers. For “PSS development to become successful and sustainable as a practice, a changed mindset is necessary about the roles and practices of product development.” (McAloone & Andreasen, 2002).

Second, PSS requires considerable changes in organizational principle, structure and operation, which are new to many manufacturers. Transforming to a new business model always poses difficulties for companies in running their production (Steven & Richter in Sakao et al., 2010). This statement is in line with findings of Sakao et al. (2008), in which they assumed that abundant hindrances of PSS originated from the preparation of human resource, and organizational structure modifications. In large enterprises, the resource relocation that facilitates PSS development is often negotiated easier than that in SMEs (Small & Medium Enterprises) due to the availability of their diverse resources. Furthermore, their flow of academic knowledge also transfers much faster than SMEs’ (Lindahl et al., 2008). Besides, switching to PSS means a new business model is adopted and in order to work effectively with this, the organizational structure or even culture is inevitably modified to some extent. These changes extremely challenge large manufactures, who have built up a stable organizational structure which working well with a specific collection of values, norms shared among people or groups in the companies. This collection probably stands for organizational culture and controls the way employees interact with other stakeholders. Therefore, the more constant organizational structure and culture are established, the more difficult to transform them into a new organizational pattern.

Third, PSS is a combination of complex architectures with different layers in design. When “offering customized solutions to the customers, PSSs require a systematic design of product-service portfolio as well as a systematic planning of resources needed to meet further market demands” (Schuh et al., 2010). These are definitely tremendous challenges for every PSS providers. The results from many PSS studies show that the development of PSS has been separated by tradition. This means the physical product development is processed independently with the service part. Therefore, the difficulty here is to achieve efficient integrated development between product and service that are to be included in their PSS (Sundin et al., 2009). Moreover, Mannweiler et al. (2010) stated that physical product configuration is completely different to the configuration of PSS. For instance, when the PSS is configured, it is necessary to attach the
individual needs resulted from customer specific product life cycle in the process, and the existing interaction of physical and non-physical components has to be focused seriously.

Last but not least, another important barrier for producers in developing PSS is related to barriers in the cash flow. The top managers have to be fully aware that PSS stems the flow “from the change over from short-term profit generation at the point-of-sale to medium-and long-term amortization periods in service-oriented solutions based on leasing contracts” (Mont, 2002). This may result in unexpected modifications in the business and investment strategy of the companies.

### External challenges

Study about PSS manufacturers, Sundin et al. (2009) found that successfully marketing PSS offerings is a challenge not only to the company group, but to their dealers, customers and/or users as well. Both providers and their customers find it hard to differentiate between PSS business logic and the traditional product selling-based logic. Namely, customers have problems validating PSS offerings, since many PSS offerings cover the usage, the disposal phase in the product life cycle and the costs generated there. Therefore, this new approach needs a life cycle, cost-thinking approach from both manufacturer and customer to understand fully the business logic.

Sakao et al. (2008) indicated the other obstacle for PSS customers might be the initial investment, even though after the payback time, they are able to earn excess revenue compared to their investment. Customers prefer purchasing products with “prices originating cost-based calculation by the company (Eg. dislike value-based prices) due to a psychological reason” (Sakao et al., 2008). Therefore, indentifying the appropriate contract patterns to satisfy both customers and providers is an effective solution to overcome this barrier. Apparently setting the price of the PSS offerings is always a tricky part for PSS providers. The price of the PSS needs to be balanced with the values delivered to their customers, and creates a feeling of making a good deal between PSS producers and customers (Sundin et al., 2009).

Moreover, the conflict interest between PSS Companies who aim to lower the sale volume of material products and traditional interest of retailers to sell more products is always a challenge for relationship of external actors (Mont, 2002). In addition, lacks of environmental awareness from public and relatively low price of resources (the recycling products have not yet been profitable due to cheap raw material cost) are hindrances against the development of PSS. Besides, in remanufacturing and disposal phase, convincing the customers that quality of remanufacturing products is the same as original, finding new ways to salvage more components, or control the second market are always the common challenges that PSS providers are confronting (Walsh, 2010).

These internal and external challenges are believed to be roots of uncertainties in PSS design and development stages. The connection among them will be clarified in the next chapter, when ten
main uncertainty factors are identified and discussed elaborately before conducting the empirical investigation.

3.2. Life cycle of PSS

Hepperle et al. (2010) argued that planning of future PSS in an integrated way, where separate product lifecycle and service lifecycle outlook is not adequate. Hence, they proposed an interrelated lifecycle with a level of granularity which can be used in the planning phase for future PSS development. In order to set up PSS which fulfills customer needs in the lifecycle, the PSS provider needs to anticipate changes by foreseeing the potentials and constraints, and also fit it in the process and possibilities of the PSS. These different customer specific lifecycle characteristics affect the life cycle cost. This life cycle characterize the intensity of the usage of the product, the overall life span of the physical product core and the environmental impact of the utilization (Mannweiler et al., 2010).

The aggregated PSS lifecycle contain three parts PSS Planning; PSS Development; PSS production, delivery and decomposition. In the first step, the PSS potential and ideas are evaluated with company and environment potentials. Then the requirements of both the products and services are collected which are then updated during the design process. A good communication is required between the product development and service design team. After passing the market test, the PSS product is available, and the service implementation is prepared with supporting tools (Hepperle et al., 2010).

These services provide flexibility in product development as well as value added functions or activities in the life cycle of products (Moon et al., 2010). In Service evaluation- Requirement-oriented service improvements are re-analyzed, and re-identification of the customer needs lead to modified and radically improved services (Akasaka et al., 2010). This integrated lifecycle gives an overview of singular phases PSS runs through with strong emphasis on interaction and integration needed in PSS (see Fig 3) (Hepperle et al., 2010).
Figure 3 Overview of Integrated PSS Lifecycle Model (Hepperle et al., 2010)
3.2.1. Comparison normal product development Vs PSS development process:

Since PSS development also has different stages from the time of PSS conception till the delivery stages, we will see how PSS development varies with normal product development. Table 3 gives a comparison of the main differences.

**Table 3 Compare Product Development Vs. PSS Development**

<table>
<thead>
<tr>
<th>Normal Product Development (Ulrich and Eppinger, 2008) Fig.4</th>
<th>PSS Product Development (Kimita et al., 2010) Fig.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Planning phase</strong></td>
<td>PSS development consists mainly of value analysis and design phase. Process initiates with customer analysis followed by conceptual design.</td>
</tr>
<tr>
<td><strong>Concept Development phase</strong></td>
<td><strong>Conceptual design</strong>, designers first develop functional structure, it facilitates in fulfilling the requirements derived from customer analysis. <strong>Functional structure-</strong> designers determine the service activities, product behaviors and attributes of entities</td>
</tr>
<tr>
<td><strong>System-level Design phase</strong></td>
<td><strong>Embodyment design phase</strong>, the attributes determined of the actual entities in the conceptual stage are followed up by the designers</td>
</tr>
<tr>
<td><strong>Detail design</strong></td>
<td><strong>Detailed design phase</strong>, the tasks to be performed in the transition phase of the life cycle is developed by the designers</td>
</tr>
<tr>
<td><strong>Testing and Refinement phase</strong></td>
<td></td>
</tr>
</tbody>
</table>
3.2.2. PSS Design and Development:

PSS design and development is viewed as an enabler in fostering innovation, as well as being environmentally friendly with respect to sustainability. The provider has an advantage over a normal product manufacturer, by designing a multiple product platform increasing the sustainability of the PSS, in terms of product life cycle. Having new ownership pattern and provides flexibility to the end user who pays only for the functionality of the product. This is the opportunity where the provider can redefine core business and create new business opportunities by exploring new markets. This development requires new competencies as the product development becomes more complex (McAlone & Andreasen, 2002). The characteristic of PSS design has three dimensions, first, involving the customer-provider relationship, which provides interaction in the whole product life phases (Matzen et al., 2005), the second being organizational boundaries between customer and provider, being transcended through the development phases. Thirdly, by implementing PSS solutions, the business opportunities become apparent through its development. (Tan and McAloone, 2006)

The main tool used to for systematic development for PSS conceptualizing and providing the solution concepts between the customer and the provider is activity modeling cycle (Matzen and McAloone, 2006). The necessity of having such design tools assist the designers to comprehend and conceptualize the PSS life phase systems and communicate these concepts to its team and their stakeholders.
Morelli (2006), proposes to extend traditional designers domain in PSS, by introducing value proposition, market analysis and product-service definition. This is followed by the use case analysis, tentative architecture, test and final definition. The overall implication is that they should focus on the most needed design perspective, whereas previously they focused on increasing the number of design parameters. Aurich et al. (2006) propose about process modularization, where the elementary building blocks of products and service design process are enabled through a library, which can be used by network partners to have an easier assembly process when required.

3.3. Risk Management in Product Development

Risk Management is defined as “Systematic process where organizations methodologically address the risks attaching to their activities with the goal of achieving sustained benefit within each activity and across portfolio of all activities.” (Luoma et al., 2009; IRM (UK), 2002)

According to Sakao et al. (2009), we can define Risk, Uncertainty and Opportunity as

Risk: “Negative effect of uncertainty on objectives. Risk can be expressed in terms of combination of the consequence of an event and their likelihood.”

Uncertainty: “State of deficiency of information related to a future event.”

Opportunity: “Positive effect of uncertainty on objectives.”

Risk assessment plays a vital part in each project and helps the common goals and objectives to be reached smoothly in execution stage. Via risk assessment in business idea planning, one is able to avoid, transfer or mitigate negative impacts of risk effectively. According to Bo Tonnquist (2008), Risk identification is referred as a first step in risk management, in which brainstorming and SWOT analysis are excellent techniques to come up with initial risk identification process. The author presents another way of risk/uncertainty identification for project execution in which he propose four main categories:

In Technique risks, where uncertainties like the change in technical platform, arrival of new technologies or setting of unrealistic goals are few identifiable uncertainties in this category. Management risks face uncertainties like allocation of resource management, weak management decisions. Organizational risks encounter uncertainties like financing, lack of prioritization, change in structure of organization. External risks usually are change in laws with respect to environment and labor, external competitive forces and union disputes.

With no previous extensive research carried in detail other than notably Sakao et al. (2009) ‘Addressing uncertainty as a key for successful integrated product and service offerings’ and Erkoyuncu et al. (2010) ‘Impact of Uncertainty on Industrial Product/Service System Delivery’
into the uncertainty management for PSS Companies. More research into uncertainty management framework will provide a further base for PSS Companies to analyze and execute the right type of risk management. Identifying major uncertainty factors and opportunities from these factors can be exploited for business purposes. Normal product development has many existing risk management framework unlike PSS development, making it vital for more research needed in this area. We will see in detail about the uncertainty factors management for PSS in chapter 4.

3.3.1. Strategy for risk response planning:
Identifying the major risks that will impact the design, are assessed whether to be mitigated depending on the category of risk. A typical risk response should be adequate for the risk level, be cost efficient, transpire at the right time, be realistic, be accepted and approved and finally be executed by an responsible person or team. Below are common strategies for risk responses;

Table 4 Strategy for risk response

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoid risk</td>
<td>The plan or design of product is changed to eliminate or protect the product from the risk impact (Hasting and McManus, 2004).</td>
</tr>
<tr>
<td>Transfer risk</td>
<td>The risk is transferred to a third party, E.g. insurance company, or solution provider who is willing to take this uncertainties and deal with them, since he is able to tackle better than his customers with his profound knowledge and capabilities in this field (Roy and Cheruvu, 2009).</td>
</tr>
<tr>
<td>Mitigate risk</td>
<td>The probability of the identified risk is reduced by introducing measured response in order to alleviate the consequences of that risk (Hasting and McManus, 2004).</td>
</tr>
<tr>
<td>Accept risk</td>
<td>The design and plan is not changed in spite of the identified and residual risk (Tonnquist, 2008).</td>
</tr>
</tbody>
</table>

**Flexibility in Risk Management:** Uncertainty increase in strategic planning has lead to introduction of more flexibility for successful coordination, as later changes can be made in business plan in the scope of strategic planning.

Uncertainties can occur from change in customer behavior during operation phase, as well as due to future technological developmental change. Flexibility offers options for suppliers to react to appropriate change in request (Steven and Richter, 2010). Ford and Sobek in Moon et al., (2010) suggest that uncertainty can be managed in product development through flexible project behavior, performance and value.
3.3.2. Tools used in Risk Management:

In order to overcome risks in product development, there are many useful engineering tools to identify, assess and prioritize the risks like FMEA (Failure Modes and Effects Analysis) and FMECA (Failure Modes, and Effects Criticality Analysis), FTA (Fault Tree Analysis), Ishikawa diagram (Fishbone diagram), Pareto approach (80-20 rule) or Mini Risk Method as mentioned above.

In order to assess the level of risk impact and come up with reasonable risk responses, Bo Tonnquist introduces a method called ‘Mini Risk Method in which the level of risk probability and impact is represented in a scale of 1 to 5 (1 being the lowest, 5 being the highest). Namely, the risk value is calculated by multiplying “probability” with “impact”, and the method applies to measure the influence of risks overall production. Any constraint with risk value which is above 10 should be mitigated by offering appropriate risk responses to tackle critical constraints (Tonnquist, 2008).

**Table 5 Mini Risk Method example (Tonnquist, 2008)**

<table>
<thead>
<tr>
<th>Risk</th>
<th>Probability</th>
<th>Impact</th>
<th>Risk value (P.I)</th>
<th>Risk response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>Keeping safety lead time</td>
</tr>
<tr>
<td>Complexity of equipment</td>
<td>2</td>
<td>4</td>
<td>8</td>
<td>Subcontracting</td>
</tr>
<tr>
<td>Labor efficiency</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>Accept-no response</td>
</tr>
<tr>
<td>Customer requirement</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>Accept-no response</td>
</tr>
<tr>
<td>Assembly</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>Outsource</td>
</tr>
<tr>
<td>Product disposal</td>
<td>3</td>
<td>5</td>
<td>15</td>
<td>Communication</td>
</tr>
<tr>
<td><strong>Sum total</strong></td>
<td></td>
<td></td>
<td><strong>51</strong></td>
<td></td>
</tr>
</tbody>
</table>

The other practical methodologies designed to identify and evaluate potential risks for product development process are FMEA and FMECA. The basic concept FMEA is to:

- Evaluate failure modes and their effects in product development and in processes.
- Help us identify how our process is most likely to fail.
- Point to process failures that are the most difficult to discover and adjust.
- Help us find failures in the early stages of design in the product development process.
The FMEA is based on qualitative approach, whilst FMECA focuses on the quantitative parameters for a criticality assigned to each probable failure mode. It can be stated that FMECA is an extension of FMEA. However, FMEA is utilized more universally by numerous companies due to its simple procedure. To conduct FMEA, the procedure needs to go through seven major steps as follow:

- For each process input, determine the failure mode (potential risk).
- For each failure mode, determine its effects and select a severity level for each effect (score 1-10, in which 10 represents for the highest severity level).
- Identify potential causes for each failure mode and select an occurrence level for each cause (score 1-10, in which 10 represents for the highest occurrence level).
- List current controls for each cause and select a detection level for each cause (score 1-10, in which 10 represents for the highest detection level).
- Calculate RPN (Risk Priority Number) with the formula:
  \[ RPN = \text{Severity} \times \text{Occurrence} \times \text{Detectability} \]
  
  - Prioritize high RPN : Give attention to severities with high rate.
  - Determine Actions/Plan: Based on the causes found, determine actions that will minimize the effect of each cause in priority order.

Table 6  FMEA illustration

<table>
<thead>
<tr>
<th>Failure mode</th>
<th>Specific Cause</th>
<th>Effect of Failure</th>
<th>Occurrence</th>
<th>Detectability of Failure</th>
<th>Severity of Failure</th>
<th>Risk Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Decrease of market segment</td>
<td>Obsolescent technology</td>
<td>Lower revenue generation</td>
<td>2</td>
<td>5</td>
<td>10</td>
<td>100</td>
</tr>
</tbody>
</table>
In addition to FMEA/FMECA, another practical inductive technique (bottom-up analysis), which starts with consequence and investigates causes is Ishikawa diagram or also called as Fishbone diagram.

![Ishikawa illustration](image)

**Figure 6 Ishikawa illustration (Russell, 2008)**

In contrast with inductive, a deductive technique (bottom-up analysis/ general to specific), in which FTA (Fault Tree Analysis) is the most famous tool to identify events (root causes) that can cause to undesirable event. Moreover, FTA provides practitioners efficient initiatives for Risk Assessment and Design Safety Assessment (Ericsson, 2000).

![FTA illustration](image)

**Figure 7 FTA illustration (Ericson, 2000)**
The other way to assess and prioritize risks is to use Pareto principle, which states that 80% of the consequence comes from 20% of root cause. Furthermore, Pareto helps researcher’s breaks a big problem down into small pieces, identify the most critical risk factors, and show where to focus efforts as well as allow better use of limited resources.

![Delay in Processing Credit Card Applications](image)

**Figure 8 Pareto illustration**

Other powerful tools like Multi-Attribute Tradespace Exploration (MATE) allow risk mitigation but also facilitates in exploring opportunities in an uncertain environment especially in conceptual design stage (Hasting and McManus, 2004). Other than the tools, project planning and management is considered important. Process engineers also play a vital role in manufacturing and assembling process. Process engineers minimize risk by leveraging existing processes and tooling designs (Templin, 2010).

If risk management practitioners are seeking for a holistic approach for Risk Management, Active Risk Management, which facilitates product development teams to mitigate new risks identified during the design/development stage, is recommended (Goodman et al., 2007). This new initiative for risk management will be explained in detail in the following chapter. Besides, ‘Process Service Channel’ is another tool to address customer uncertainty (Sakao et al., 2009).

There are doubtless numerous tools and approaches to efficiently manage risks in product development. The decision to choose the right initiative depends on the particular contexts and distinctive product features in each company.
4. Uncertainty factors identification in PSS

Chapter 4: Based on the literatures, the 10 major uncertainty factors are identified along with the opportunities they present to PSS Companies. These uncertainties are usually encountered at the planning and design/development phase. The new risk management called ‘Active Risk Management’ is also discussed in detail in this chapter.

Uncertainties are not a negative factor to be mitigated. Systems with robustness, versatility and flexibility not only mitigate uncertainty but they also provide value for the users. Uncertainty can be defined as ‘things not known or known only imprecisely’. While most of the uncertainties are measurable, others are not. Hence, there is no value judgment in declaring something that is uncertain, as it could be better or worse than expected (Hasting and McManus, 2004). Compared with product sales, PSS offerings have a different type of uncertainties. Looking from the design perspective, PSS actually presents more opportunities. A crucial impact of PSS offering on business originates from the shift to dynamic state from the static state. Hence, uncertainty becomes a critical factor to address PSS while designing/developing (Sakao et al., 2009).

The main classes of uncertainties for a designer in product development is

**Lack of Knowledge**: ‘Facts that not known and known only imprecisely’, this knowledge needs to be collected or needs to be created.

**Lack of Definition**: ‘Things about the system in question that has not been decided or specified’, the challenge is not to define too early in terms of defining over specifications or bad requirements.

**Risk and Opportunities**: Risk which is the consequence of uncertainty in design or system can be seen as potential opportunities, if the uncertainty is resolved in a favorable way. Risk are considered as negative effect, while opportunities are considered as a positive effect on uncertainty, there needs to be an integration of risk and opportunities for maximum benefits (Jabagchourian and Cvetko, 2002; Sakao et al.,2009). E.g., Market shifts can be seen as opportunity or bad for business, Need Shift where the function of the system is changed from the earlier design can be seen as harmful, but if the design is serendipitously corrected then the product can be seen a opportunity fulfilling the new needs of the user (Hasting and McManus, 2004). Another example is provider’s risk assessment on the preciseness of maintenance service leads to more profitability (Oliva and Kallenberg, 2003; Sakao et al., 2009).

The ten major uncertainty factors were ascertained by looking into the whole life cycle of PSS and all these factors were involved in the process from planning till design and development. The paper by Hepperle et al., (2010) was used as the basis, to come up with the most important factors mentioned below.
PSS planning phase uncertainty factors:

4.1. Market Analysis

Most of the products available at the market today are conventional, and become PSS by adding services to their already existing products. As manufacturers are slowly realizing that adding services improves their market share and acceptance in the global competitive market (Sakao and Lindahl, 2009).

When having different competencies in an organization, like the marketing team and product development team, there could be a lack of using different termini or foci, which need to be complemented by the business model and technical solution. The customer needs have to be identified and clarified in the market analysis. The quality of the identified needs is relevant by the quality of the market studies done (Muller et al., 2009). In other words, this stage can be called market sensing, where the existing and potential customers are scanned along with installed base, business networks and competitors. This is executed before addressing the idea in the development stage till the sales and delivery of the offering (Edvardsson 1997 in Kowalkowski and Kindstrom., 2009).

There are more opportunities in terms of economy in the after-market, as exemplified by the automobile industry (Sundin, 2010). The two directions for companies to look for opportunities in the market are 1) Along product’s life value chain, i.e. installation, operation, maintenance etc. 2) Along Customer activity chain. i.e. financing, designing, managing, resale, training etc. Hence the opportunity to utilize the product and support the activities here is the greatest (Tan et al., 2009).

The tools used for overcoming this uncertainty are done using SWOT analysis. There is no quantitative tool to assess market uncertainty and these tools lack description for PSS design concepts (Komoto and Tomiyama., 2009).

Therefore, the change in needs of customer value, defining the correct requirements, quality of market analysis and sustainability of the market needs have to be regarded as crucial uncertainties in the planning phase for market analysis.

4.2. Company Analysis

PSS leads to complex organizational structure with the involvement of multi-disciplinary teams from different departments and various stakeholders. This begins from the product planning to the development stage (Chirumalla et al., 2010). Lack of access to capital can be sometimes a barrier along with lack of information, knowledge or time (Thollander et al., 2010).
Theoretical Framework

PSS designer have to analyze the internal and external environment of the company. The various stakeholders are involved in this process. Tools such as Stakeholder System Mapping, Offering Diagram and Interaction Table illustrate the interaction among the stakeholders (Kim et al., 2010). The stakeholder’s collaboration is important for business strategy level throughout the product lifecycle (IGES 2007 in Muller and Sakao, 2010). As Mont and Kimita et al., 2010, exemplify that stakeholders roles and responsibility to the lifecycle is crucial to the success of PSS. However, lack of common objectives between different stakeholders can preclude the execution of PSS, due to conflict results from performance (Duarte & Davies., 2003). Many intricate and intermediate stakeholders are involved between a receiver and provider, Therefore forming a complex structure. The solution proposed was to set a definition at the design stage for each task components; hence, several stakeholders can work concurrently and avoid conflicts as much as possible (Kimita et al., 2010).

There seems to be an absence of closer cooperation from various stakeholders and employers within the company. In order for them to engage in discussion, web based solution like Blog, Wikis, Tagging, RSS feeds have played a role in bridging the gap between the stakeholders, employers and PSS designers. This helps in decision making between organizations and knowledge sharing (Chirumalla et al., 2010).

The various uncertainties can therefore be derived to be lack of definition in terms of objectives, barriers in communication and lack of knowledge (also, lack of understanding- Erkoyuncu et al., 2010) for both internal and external stakeholders of the company.

4.3. Environmental Analysis

The advent of new technology which is more complex in technical point of view carries higher risk and uncertainty. This may affect the customer too, who might not be able to perceive the new features and value the performance (Herzenstein et al., 2007, Peters, 2006 in Rese et al., 2010). Investment into new technologies may also be a barrier for a company (Thollander et al., 2010).

With sustainability issue, technology change is relevant with full lifecycle of the product taken into consideration. The technology is built in a way which results in long life. This PSS approach can be boon or bane for the provider (Thompson et al., 2010). But PSS also provides opportunities for example; Swepac Soil Compactors were able to change the technology on floor care without violating the contract (Sundin et al., 2010).

In a competitive environment, emergence of new technologies make the existing technology obsolete, hence the planning phase of PSS is important in terms of innovation and anticipating along the lifecycle the potentials and constraints (Hepperle et al., 2010). The product development design team is technology driven and is responsible for design of the hardware,
while the knowledge development team is responsible for the definition of the best practices and verifies if the company has enough knowledge to carry on the operation (Bertoni & Ericson., 2010).

Mitigation strategies used for technology change uncertainty is implemented by using technology roadmap, to evaluate Evolution of technology – first by looking at the ‘Maturity of technology’ and then doing a ‘Technology Stability Assessment’ (Identifying potential changes in the future) (Romero et al., 2010). Research remains the main core for technology driven innovation and is automatically associated with technology change (Sbordone, 2010). Regular innovation is a strategy which lowers risk for technology becoming obsolete by building firms established knowledge base.

Usual trend has been that new or radical technology otherwise termed as disruptive innovation, performs worse than established technology when introduced to the market. But opportunity wise, innovative companies can become a strong competitor in the market by addressing untapped customer needs (Wenngren et al., 2010).

Hence the uncertainty is mainly focusing on change in technology and lack of knowledge in the environmental analysis.

**PSS Design and development phase uncertainty factors:**

4.4. **Reliability/Robustness**

Consumers demand high quality products and reliability is the crucial element for continuous quality improvement. Customers also tend to value more the products with high quality and reliability, which is backed by process-oriented services preventing breakdowns (Thomas and Richard, 2006; Tan et al., 2009, chapter 10).

Reliability can be stated as probability of an item surviving over time and expressed in percentage for not failing or in categories like low, moderate and high. The process of reliability allocation is to achieve overall system specification translating the reliability of each system component (Thomas and Richard, 2006). According to Shu & Flowers, (1988) and Guide & Jayaraman, (2000) in Sundin, (2009), Reliability can be the expected life cycle of a product and is important to last at-least one life cycle.

The provider has complete responsibility of the reliability of the product and its operation. Customers attribute the performance and reliability, and demand these criteria as a prerequisite for investment (Ericsson & Larsson., 2009, chapter 11).

Another major factor correlated to reliability is the warranty period/contract offered by the providers. The warranties signal the accurate reliability of the product and hence the benefits are
economic incentive to reduce the warranty claims, which is accomplished by making reliable products (Wiener, 1985).

One method to overcome the reliability uncertainties is to collect statistical data on the modes of failure outside the warranty. By looking at the patterns and having improved product failure knowledge, gives manufactures or remanufactures advantage to design out the defects in the original product design, and therefore use it as a selling point. Lean manufacturing also improves the reliability by having standardized technique (Walsh, 2010).

A recent example of a reliability is cited to exemplify this issue; Toyota motor sales\(^8\), USA had to make a voluntary safety recall, so that they could change the ‘electric power steering pinion shaft nuts’ of approximately 52000 Prius models. This was on top of 106,000 cars recalled globally by TMC (Toyota Motor Corporation). This example demonstrates that even Toyota which is renowned for its high quality and reliability, faced reliability issues which in turn had huge cost implication for the provider (TMC).

Reliability can be an uncertainty factor mainly based on its life time cycle, warranty contracts and life expectancy of the PSS product.

### 4.5. Product function

The main challenge in PSS is to redesign Product function as Service function (Baines et al., 2007 in Hosono et al.,2010). The definition of each product function, working component, elements and their structure is essential for continuous updating of requirements of the product (Hepperle et al., 2010).

Though sometimes the product functions do not change, the structure of the product might be changed to facilitate addition of new service activities (Hara & Arai, 2010). By focusing on function level and have modularization, product function is combined with customer needs to have monolithic product architecture. These different functions can be identified by their product modules compared to the product platform (Lee et al., 2010).

QFD (Quality Function Deployment) tool is used for translating customer needs into product functionality and attributes (Sakao and Shimomuro, 2006). CAD systems are mainly used for product function for designing product but not much for designing of services (Sakao et al., 2009). Therefore product function uncertainties arise mainly from the lack of definition for functionality, addition of services function and platform strategy.

4.6. Innovative Service

Innovative service is the innovations developed in service, which are provided for customers in the utilization period. The Service innovation is likely developed either during the product development or during the usage phase. Service innovation is a key driver of success in many PSS Companies, and contributes significantly to the revenues improvements. According to Fischer et al., in Sakao and Lindahl (2009), in giant enterprise such as IBM, General Electric, the service revenue probably accounts for more than 50% of total revenue. Moreover, service innovation becomes a competitive edge for PSS Companies, and helps differentiate their offerings in the market place. Getting closer relationship with customers and encouraging their loyalty to the companies are other potential benefits of service innovation.

The priority of industrial companies, however, is mainly on product innovations meanwhile the resources devoted to service innovation are inadequate to some extent. As a result, in PSS domain where the balance between product and service developments is important, many companies face challenges (uncertainties) in implementing service innovation. Furthermore, the uncertainties in service innovation may lead to tremendous impacts on the success of PSS development, due to its enormous influences on the profitability, competitiveness and customer relationship. The service innovation not being able to match the customer’s requirements or resistant with the product innovations, services are not billed or high development cost (Fischer et al. in Sakao and Lindahl (2009) are some uncertainties which get the PSS development off the track.

To overcome these uncertainties, Witel, L., in Sakao et al. 2010 found that a deliberate strategy to transform intra-organizational services to end-users is often implemented by many organizations. Thereby, the developed service innovations bases on the discussions with customers reflecting fully their needs. In addition, by aligning the way to develop service innovation with the existing Product/Service System and service strategy, the causes to those problems can be eliminated (Fischer et al. in Sakao and Lindahl (2009)).

4.7. Product/Service System integration

The aim of PSS integration is to integrate physical product and service components in order to create intended value. According to (Witel, L., in Sakao et al., 2010), the reason for developing product and service separately is to make the PSS development more structured. Furthermore, many companies find it challenging to develop products and services in the same project development, even though it increases the collaboration among individuals. Therefore, the integration among physical products and services plays a vital role in the development of PSS. It enhances the functionality and implements new function of PSS products.
Since the product-service combination is considered as a core business to differentiate offerings of many PSS manufacturers, this process is always focused and prepared intensively in the planning phase. However, to be successful in integrating product and services (result, process and resources), the companies have to resolve numerous challenges which occurs in the execution time. The integration requires intensive collaboration between the development teams of physical product and services. Particularly the higher the degree of integration is, more complex and difficult its adjustment might be (Steven & Richter in Sakao et al., 2010).

Therefore, it is likely to assume that the integration phase leaves many spaces for uncertainty appearances. For instance, service malfunctions that occur in the integration process are not compatible with the existing product function; or services, which are customized by end-users and are not feasible with the product platform integration.

### 4.8. Supplier Coordination

Supplier coordination refers to the collaboration between PSS providers and their suppliers in terms of components delivery, service-design development supply. With hundreds of suppliers available in a field of industry, it is essential to match PSS customers with the supplier that is most capable of delivering the expected results. In supplier coordination, the collaboration of human side among PSS providers, customers and suppliers is a key element leading to the success of the coordination. However, “Human element provides the biggest source of uncertainty” (Alonso-Rasgado et al., 2004). Therefore, the probability of supplier coordination uncertainty is probably one of the biggest factors compared to the others. Moreover, the consequence of this uncertainty factor is considered as a high influence due to its interaction with numerous actors in PSS development.

Along with the common uncertainties, which exist in the traditional product development such as delays or low quality delivery, errors in specification interpretation, there are other distinctive supplier coordination uncertainties that only emerge in PSS domain. Suppliers lack of PSS understanding, or unable to tailor the right PSS offering for every customer may lead to obstacles in consolidation of the PSS offering. Close relationship with suppliers, increase supplier engagement to the development process with transparent contract patterns help PSS producers constrain uncertainties emerge in the coordination.

### 4.9. Communication

Communication represents for knowledge sharing inside a company (internal communication) or with their external stakeholders such as suppliers, consumers (external communication). The communication of a PSS company across departments is often standardized in the early phase of
product development process (planning phase). This standardization can be motivated by some techniques like ICT (Information communication techniques), SysML (System Modeling language), which “provides standardized language for design and traceability of requirements and the support for communication among PSS collaborators during development and delivery phases” (Durango et al. in Sakao et al., 2010). In some companies, the internal communication among individuals is developed and harmonized with the organizational culture, under a common language. Therefore, there is a limited space for conflict occurrence between the physical product and service design teams in the integration process.

Misunderstandings with outsourcing partners (providers) in the light of design specification interpretation due to their PSS knowledge limitation; or problems in customer communication would be potential uncertainties. As consequence, this uncertainty factor may result in a deep impact on the PSS development since it is able to break the interactive relationship of stakeholders, and hinders the flow of knowledge sharing and transferring process among them.

4.10. Remanufacturing

From the definition synergy of Walsh in Sakao et al., 2010, “Remanufacturing is defined as a returning used product, via a manufacturing-type process, to at least its original performance with a warranty that is equivalent or better than that of a new manufactured product”. This approach not only increases the revenue for producers by extending the life cycle of their products, also helps them secure the supply of spare and replacement parts (Sundin, 2004). Furthermore, with the efficient resources usage, remanufacturing has considered as an effective initiative to reduce the environmental impacts compared to other business models.

However, to implement successfully remanufacturing, PSS producers have to overcome different obstacles, which mostly emerge in the usage and disposal phases of industrial product life cycle. Technological problems in the design and development to manufacturing, customer’s doubts regarding remanufacturing products quality, cheap raw materials may reduce the cost-effectiveness of remanufacturing are some of the potential uncertainties against remanufacturing and makes this approach unprofitable for some PSS Companies (Fishbein, Mc Garryetal et al., in Mont, 2002).

Moreover, according to Mont (2002), the common uncertainties for companies who do remanufacturing activities are the return flow of product, worries about the market dominance by third party manufacturers acquiring knowledge in reverse engineering. It implies that there are various probabilities of remanufacturing uncertainty and its consequences vary, depend on each practical context of PSS Companies.
4.11. **Active Risk Management**

Risk management is used to lessen the negative factors associated with the environment in product development. One of the methods to manage risk in product development is through Active risk management. Active risk management uses common processes and tools, which results in increased communication across different platform development teams. Furthermore this approach accelerates product launches, by running simulations like Monte Carlo which improves the predictability of time-to-market of the platform to be launched. Intel used High Speed Database-Risk as a central risk database to provide a standard way to identify, assess, prioritize and plan to prevent risk.

The standard risk methodology used by Intel in 2001 contains six steps:

1. Risk management: planning where the approach is decided on how to conduct risk activities.
2. Risk identification: where they clearly identify, describe and document uncertainties which have an impact on the projects while taking into account the triple constraints like Time, Cost and Scope. A matrix table with ‘known’ versus ‘unknown’ helps in determining ‘known risks’ and ‘unknown risks’ where majority of the risk are found in known risks quadrant. Project Managers are encouraged to read old reports and documents to learn from different projects in order that other unknown risks are placed in the known risk column.
3. Risk assessment and prioritization where Time-to-Action shows the effective response of the team to the probability/impact of risks.
4. Risk quantification is the statistical technique to quantify risk impact.
5. Risk response planning shows the response strategy both proactive and reactive. The other commonly used strategies are Prevention (which attacks probability), Mitigation (which attacks impact) and Contingency (when the risk has occurred).
6. Risk tracking and control is the periodically and continuously monitoring of risk in order to see if any risk occurrence takes place and the appropriate response plan is executed (Goodman et al., 2007).

From this literature, we could define Active and Passive Risk Response as:

**Active Risk Response**: “If a new uncertainty is identified in a design/development process, the uncertainty is addressed ‘concurrently so that risk/opportunity out of the uncertainty is managed in design/development or afterward.”.

**Passive Risk Response**: “The product development process is made robust, which improves the capability of the product functions under the different risks identified”.

Active Risk management is a worth attaining goal, with cost increasing in product development. The six step Active risk management process and tool can provide an approach to measure risk and have a coherent language in the process. This tool provides visibility between platforms and many-to-many relationship. Active risk management can also be seen as a tool to enhance inter-team communication which proactively avoids costly risk events (Goodman et al., 2007).
5. Empirical Data

Chapter 5: The chapter includes the results from our survey and interview excerpts with the PSS Companies.

5.1. Interviewed Swedish PSS Companies' background

A total of 8 PSS Companies were sampled for the survey and interview, though one company participated only for the survey. The name of the Companies would not be disclosed due to agreement of anonymous clause. We will try to classify the Companies as Company A, Company B and henceforth in order to distinguish and analyze the data collected. The selected Companies are all B2B (Business to Business) where their customers are primary target Companies or whole sale buyers.

The sampled field was from medium size to large scale multi-national Companies. The technology factor scale is from medium to high technology type of Companies. All these Companies are located in Sweden.

5.1.1. Type of PSS Companies:

The Companies were asked to identify themselves based on our definition of three types of PSS. The Companies then stated what their services offer and what types of products they designed and develop. It is to be noted that Company C is no longer using Use Oriented Services but since they have experience in using this type of offering, we considered their evaluation to ascertain their rating in uncertainty factors. Also, Company H is using Use oriented services but in the survey the manager just chose product oriented services. This fact is verified in the one to one interview. See Table 16 (appendix) for each Companies PSS type offer. Based on their answer, we have classified the Companies to the respective types of PSS (Table 7) and for easier comprehension; we class Group I as Companies using only P.O.S and Group II as Companies using U.O.S, R.O.S or P.O.S.

Table 7 Companies Service Category based on types of PSS

<table>
<thead>
<tr>
<th>Type of PSS</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Oriented Service</td>
<td>7</td>
</tr>
<tr>
<td>Use Oriented Service</td>
<td>4</td>
</tr>
<tr>
<td>Result Oriented Service</td>
<td>2</td>
</tr>
</tbody>
</table>
The most commonly used PSS type offering is ‘Product Oriented Service’. A total of 4 Companies are implementing only Product Oriented Service, who mainly offer after sales services like maintenance and repair. Only one Company E is using Use Oriented Service. There are two Companies G and F, which use all three types of PSS (Product Oriented Service, Use Oriented Service and Result Oriented Service). And Company H is using both ‘Product Oriented Service’ and ‘Use Oriented Service’.

![Figure 9 Types of PSS Companies](image)

For Company F, the reason is that they have various service models which enable them to use all three types of PSS. Whereas, Company G has a wide range of products and product families, that they need to offer broad portfolio of services to cover their various products usability.

5.1.2. Product Lifecycle and Service Contract in Average:

The Companies were asked to give the life cycle of their product before the first call back for upgrade or remanufacturing. Since most Companies as seen in Table 7, are into high technology or large-scale products, the lifecycle period of their products is also more than 10 years. Products of Companies C, G H have 5-10 years lifecycle, as their products range is from low to medium technology. Company A has its product lifecycle range from 1-5 years, as their industry experiences a constant change in technology every few years. The Company sees no reason in building products with longer lifecycle as the current technology would become obsolete or there would be change in regulation in the market.
### Table 8 Product Lifecycle and Service Contract Periods

<table>
<thead>
<tr>
<th></th>
<th>Company A GI</th>
<th>Company B GI</th>
<th>Company C GI</th>
<th>Company D GI</th>
<th>Company E GII</th>
<th>Company F GII</th>
<th>Company G GII</th>
<th>Company H GII</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product Lifecycle</strong></td>
<td>1.0-5.0 years</td>
<td>&gt;10 years</td>
<td>5.0-10.0 years</td>
<td>&gt;10 years</td>
<td>&gt;10 years</td>
<td>&gt;10 years</td>
<td>5.0-10.0 years</td>
<td>5.0-10.0 years</td>
</tr>
<tr>
<td><strong>Service Contract</strong></td>
<td>2.0-5.0 years</td>
<td>2.0-5.0 years</td>
<td>&gt;5 Years</td>
<td>&gt;5 Years</td>
<td>2.0-5.0 years</td>
<td>2.0-5.0 years</td>
<td>&gt;5 Years</td>
<td></td>
</tr>
</tbody>
</table>

The service contract also varies a lot depending on the lifecycle of the products. A 2-5 years service contract period is seen to be a safe bet in terms of minimizing risks in reliability. It is noted that Company B did not offer any services in specific, but only offer 3 years guarantee for their product. Company D used to have service contracts up to 15 years due to the high technical complexity and cost of the product, but even they have reduced their service contracts to 5-10 years now due to the constant change in customer demands.

### 5.2. Results of Uncertainty factors

The survey contained 10 most significant uncertainty factors that we identified from the literatures. The uncertainly factors covered both the planning and design/development stages of PSS. The planning phase uncertainty factors are market analysis, company analysis and environmental analysis. The design and development uncertainty factors consist of reliability, product function, innovative services, Product/Service System integration, supplier coordination, communication and remanufacturing.

These ten uncertainty factors were listed in a matrix table. The Companies were asked to rate each uncertainty factor based on the probability of the event happening and the effect on the company by its consequence. The risk (R) is calculated by the overall multiplication of the probability (P) and consequence (C) i.e. $R = P \times C$. 
Empirical Data

5.2.1. Critical uncertainty factors for the Companies:
Here we will observe each uncertainty factor and why the Companies rated them high. We will also see what influence these factors play in their planning and design/development stage. The whole result is shown in the form of graph seen in Figure 10 below.

Market Analysis:
The uncertainty in market analysis is related to changes in customer needs and market segmentation. Figure 10 indicates that market analysis has high uncertainty among Company A, Company B, Company F, Company D and Company H. This is mainly due to the fact that these Companies are always searching for changes in customer need in order to remain competitive in the market.

Company Analysis:
The uncertainty raised in the company analysis was to do with stakeholders, human resources, capital, and production capability. As observed, it is not much of an uncertainty factor as most Companies were quite in control of their own environment. However, Company E and Company D scored them relatively high. The main reason was the organizational structural change was taking place, and hence the higher uncertainty involvement in that process.

Environmental Analysis:
Environmental analysis means the change in technology and market shift. This factor is also a major concern for Company A, Company B and Company F. These Companies, as most of the other Companies, which took part in the interview, dealt with medium to high technology products. For some Companies change in technology happens very seldom, hence the low score for this uncertainty. However, others have quite a quick rate of technology change and hence have constant concern about market fluctuations. Furthermore, it is noted that some Companies have to adapt to new legislations introduced by the European Union.

Reliability:
The reliability uncertainty involves breakdown of product during the contract or warranty period, which could implicate extra burden on the provider in terms of financial penalty. Most Companies acknowledge the consequence is always high if this uncertainty occurs. However, due to the high quality standards in the high technology industries today, the probability is most often very low. Company A and Company F deem it still critical in their process of design and development.
Figure 10 Major Uncertainties for PSS Companies
**Product Function:**

The uncertainty in product function is adding variable functions, which can be modified, upgraded or removed in the future to meet the new changes in technology or customer needs. The Companies, which are running their design process based on platform strategy are quite confident of overcoming this uncertainty. Company A, Company F and Company D rated them still high. For Company A, the issue is since their products are one-dimensional, the variance of adding new features does not arise while designing their products. Hence, they overcome it by bringing out new products. For Company F, despite having a sophisticated product platform, they acknowledge the fact the while most effort is spent in R&D, hence getting it wrong in research and development could inversely affect their product function flexibility. The same is with Company D who develop high-end technology products. Therefore getting it wrong could lead to high consequence for them.

**Innovative Services:**

Addition to new services could lead to uncertainty in this factor. Company D, Company F and Company A rated this uncertainty very high. Company D is implementing PSS to their Company’s business model; hence, they deem it to be of high uncertainty. Company F is using all three types of PSS – product oriented service, use oriented services and result oriented service. Therefore, they also consider the diverse services offered for the benefit of revenue generation for their company, would lead to high uncertainty for this factor. Company A considers being as a service company supplying to a large company, so they try to offer suitable innovative services. Otherwise, the Company may face high consequence in terms of business revenue lost.

**Product/Service System Integration:**

This uncertainty arises when integrating product and service to create the intended value for the end users or customers. Company A, Company B, Company F and Company F all rate this factor high. As mentioned in innovative service, Company D is newly using PSS approach, rate Product/Service System integration uncertainty very high. Company F, which is offering three types of PSS, need this factor to be well coordinated or the consequence would be huge for them. As both the previous Companies are into high-end technology, the degree of integration can become more complex. Company A and Company B offer services on a guarantee level and this uncertainty factor is also rated critical. Since they feel it could affect their business significantly, if their services are not compatible with their products offer.

**Supplier Coordination:**

The lack of cooperation could lead to uncertainty in design/development stage for PSS Companies. Company A and Company B rated this factor very high as this affects the design and development of their products. Any compromise probably leads to high risk in the project, influencing the failure in the product development process. Other Companies consider this factor moderately high. However, all Companies have very close coordination with their suppliers. As
one manager said that, their supplier have become like a part of their Company. This negates the high level of uncertainty in the design/development stage.

Communication:

The uncertainty could arise due to lack of proper knowledge sharing and break in communication between internal or external stakeholders. Company A said this is high priority for them. Most Companies have a process in place to coordinate the communication in the right channels, and therefore negate the effect of this uncertainty. More details would be provided later in this chapter as communication is important factor for implementing active risk management successfully.

Remanufacturing:

This uncertainty factor involves in the re-usage of materials, or reconditioning from their original products. The other scenario where this factor could become uncertainty is when third party manufacturers get market dominance on remanufacturing by acquiring knowledge in reverse engineering. Since most Companies have not involved much in actual remanufacturing, they have not seen it as a major uncertainty factor. Even for Companies using remanufacturing like Company H and Company C, they do not consider this uncertainty to be a concern affecting their company.

Table 9 Summary of Highest and Lowest Uncertainty Factors for each Company

<table>
<thead>
<tr>
<th>Company</th>
<th>High Uncertainty Factor</th>
<th>Low Uncertainty Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Supplier Coordination, Communication</td>
<td>Remanufacturing</td>
</tr>
<tr>
<td>B</td>
<td>Market Analysis, Environmental Analysis</td>
<td>Reliability</td>
</tr>
<tr>
<td>C</td>
<td>Supplier Coordination</td>
<td>Company Analysis</td>
</tr>
<tr>
<td>D</td>
<td>Innovative Services</td>
<td>Remanufacturing</td>
</tr>
<tr>
<td>E</td>
<td>Company Analysis</td>
<td>Market Analysis</td>
</tr>
<tr>
<td>F</td>
<td>Market Analysis</td>
<td>Supplier Coordination</td>
</tr>
<tr>
<td>G</td>
<td>Supplier Coordination</td>
<td>Product Function</td>
</tr>
<tr>
<td>H</td>
<td>Market Analysis</td>
<td>Innovative Services</td>
</tr>
</tbody>
</table>

Table 9 shows the highest rated uncertainty factor for each Company and the lowest rated uncertainty factor. The majority of the Companies rated market analysis and supplier coordination as their highest uncertainty factor. Market analysis is pointed out to be the most crucial factor in the planning stage for many Companies. In order to overcome this uncertainty in design/development stage, the Companies have to be clear about defining the specification; investment needed and interpret the right customer needs into the product design.
In Figure 11, we can see the overall score of the ten uncertainty factors. Market analysis is the highest followed closely second by supplier coordination, and then by innovative services. Product service integration, environmental analysis and communication are other major uncertainties which all the Companies gave high score in terms of uncertainties involved.

With our topic PSS in mind, we note that Companies are still wary about the uncertainties involved in innovative services and integration of their existing product to new types of PSS services. Although only Company D rated these two factors as major uncertainties, the overall score from all Companies makes these two factors ‘Innovative Services’ and ‘Product/Service System Integration’ crucial for Companies to plan, analyze their product platform along with their service platform in the design/development stage.

5.3. Risk Response (Active or Passive)

After rating each uncertainty factor based on the probability and consequence, we asked the Companies to select what type of risk response they prefer or already used when such a situation arises. The given options were active risk response, passive risk response or both (if they used both types of responses depending on the circumstances). The interviewees were given the basic definition of active and passive risk response which is found in chapter 3 under active risk management;
Empirical Data

Answers to risk response for all the 10 factors, from Company A to Company H can be seen in Appendix (Table 14). Below, we mention the active risk response for certain highlighted uncertainty factors for each Company.

Company-A thinks market analysis is crucial factor to their company in order for them to stay ahead of the competition. There are two fronts in the analysis, one is customer and the other is keeping abreast of new technology. They use business intelligence companies to enable them to be updated. Their sales force and marketing team also plays a vital role in gathering data which is compared with the business intelligence data for future active planning.

When is the uncertainty addressed: ‘Design and Development Stage’

Table 10 Risk Response and Uncertainty Addressed for Major Uncertainties Factors

<table>
<thead>
<tr>
<th>Company</th>
<th>Major Uncertainty</th>
<th>Risk Response</th>
<th>Addressed in which stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Company A</td>
<td>Supplier Coordination</td>
<td>Active</td>
<td>Planning</td>
</tr>
<tr>
<td>Company B</td>
<td>Market Analysis, Environmental</td>
<td>Both</td>
<td>Design/Development, and Planning</td>
</tr>
<tr>
<td></td>
<td>Environmental Analysis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Company C</td>
<td>Supplier Coordination</td>
<td>Both</td>
<td>Planning</td>
</tr>
<tr>
<td>Company D</td>
<td>Innovative Services</td>
<td>Active</td>
<td>Design and Development</td>
</tr>
<tr>
<td>Company E</td>
<td>Company Analysis</td>
<td>Both</td>
<td>Aftermarket</td>
</tr>
<tr>
<td>Company F</td>
<td>Market Analysis</td>
<td>Both</td>
<td>Planning</td>
</tr>
<tr>
<td>Company G</td>
<td>Supplier Coordination</td>
<td>Active</td>
<td>Delivery</td>
</tr>
<tr>
<td>Company H</td>
<td>Market Analysis</td>
<td>Active</td>
<td>Design and Development</td>
</tr>
</tbody>
</table>

Company-B uses active risk response for supplier coordination. They have suppliers delivering components during the design stage and any defects or change in quality could seriously affect their customer satisfaction.

When is the uncertainty addressed: ‘Design and Development Stage’

Company-C stated reliability uncertainty is being responded actively in order to maintain their quality and reliability standards high.

When is the uncertainty addressed: ‘Design and development Stage’

Company-D use active risk response for all the uncertainties but the time of when they address the uncertainty varies. Their highest uncertainty factor is innovative services and PSS integration.

When is the uncertainty addressed: Both factors were addressed in ‘Design and development Stage’
**Empirical Data**

*Company-E*, we could not ascertain an example of how they use active risk response as they took part only in the survey. But they answered about using active risk response for supplier coordination which is a major uncertainty, while both active and passive risk responses are utilized for another major uncertainty factor ‘Innovative services’.

When is the uncertainty addressed: Addressed in the ‘*Delivery Stage*’ for supplier coordination and ‘*Design and Development Stage*’ for innovative service.

*Company-F* stated environmental analysis as their main uncertainty and uses active risk response to stay updated and implement the latest technology change or tries to comply with the change in technology or when new laws are brought by EU. They use passive response for innovative services though they have rated it also high among uncertainty factors. While they use both ‘active’ and ‘passive’ responses for market analysis which is the highest uncertainty factor among all for this company.

When is the uncertainty addressed: ‘*Planning Stage*’

*Company-G* takes active response for supplier coordination and innovative services uncertainty. They involve suppliers more in the production stage to execute the process efficiently. Therefore they actively respond to this uncertainty.

When is the uncertainty addressed: ‘Supplier coordination’ is addressed in the ‘*Delivery stage*’ while ‘Innovative services’ is addressed in the ‘*Planning Stage*’

*Company-H* actively relates the market analysis to the customer needs and implementing the change which will have a positive effect. They use passive response for innovative services and Product/Service System integration as they feel their process can withstand the uncertainties which the company might face.

When is the uncertainty addressed: ‘*Design and development Stage*’
### Empirical Data

#### Table 11 Summary of interview results (Part-I)

<table>
<thead>
<tr>
<th>Companies</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opportunities</strong></td>
<td>Market analysis, Environmental analysis</td>
<td>N/A</td>
<td>Remanufacturing</td>
<td>Market analysis; Environmental analysis; Product function; Innovative services</td>
</tr>
<tr>
<td><strong>Opportunity exploitation</strong></td>
<td>Scanning business intelligence provided by supplier; Keeping in the fore-front of technology development, participating in standard committees.</td>
<td>“Soft” projects; Look at the other divisions; Strong IT development to facilitate customer co-creation process.</td>
<td>Take back the products and reconditioning to the new achiness</td>
<td>Redesign with efficiency improvement and significant life-cycle products compared to competitors’; Environmental legislation supports; Continuous upgrade and extending the functionality of products; Looking for new technology and keeping track.</td>
</tr>
<tr>
<td><strong>Tools/ approaches to indentify &amp; prioritize risks</strong></td>
<td>Nokia 7 [A Root Cause Analysis]</td>
<td>FMEA; caWeb: Listing of identified risks in a project. APQP (GPI-057): Used for Risk Transfer to suppliers;</td>
<td>Long time experience</td>
<td>FMEA; FMECA; LoA [Root cause analysis]</td>
</tr>
<tr>
<td><strong>Tracking and control the risks in the future</strong></td>
<td>Documentation</td>
<td>Documentation in “white book”; Risk Management Macro Process Standard STD 105-0006;</td>
<td>Knowledge documentation</td>
<td>Product development process include functionality testing during the design and test weeks; Validation with continuous feedback to the design team; Product Integrity Process or Eight Steps Process for continuous product improvement; Documentation: Databases for our processes.</td>
</tr>
<tr>
<td><strong>Inter-department communication barriers</strong></td>
<td>NO (Due to small size of the company)</td>
<td>YES</td>
<td>NO (due to the small size of company)</td>
<td>YES (Not many)</td>
</tr>
<tr>
<td><strong>Solutions for communication barriers</strong></td>
<td>Flat Structure: Direct communication between personals from different departments. Lot of close contact between developers and suppliers.</td>
<td>Chase system in which all kind of problems can be reported.</td>
<td>Direct communication between departments at all levels.</td>
<td>There are many channels to increase the flow of knowledge sharing and break through the communication barriers: Continuous meetings during strategic planning; Special database: Fault report System communication with the customers.</td>
</tr>
<tr>
<td><strong>Supplier coordination in resolving uncertainties</strong></td>
<td>Close contacts with suppliers to be able to see how road map will develop together; Have good forecast and sales planning to be able to source material for production.</td>
<td>Close collaboration process to prevent malfunctions from happening; get close relationship with them;</td>
<td>Open and direct communication; Involved in R&amp;D and Product development.</td>
<td>Supply chain management; Continuous collaborating with suppliers on verification and validation; Control quality continuously.</td>
</tr>
</tbody>
</table>
Table 12 Summary of interview results (part-11)

<table>
<thead>
<tr>
<th>Companies</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Opportunities</strong></td>
<td>N/A</td>
<td>Market analysis; Environmental analysis; Reliability/ Robustness; Product function; Innovative service</td>
<td>Market analysis; Environmental analysis; Reliability; Product service integration</td>
<td>Market analysis; Reliability; Production function</td>
</tr>
<tr>
<td><strong>Opportunity exploitation</strong></td>
<td>N/A</td>
<td>Detect changes in customer need as soon as possible; Rigorous testing, so malfunction do not happen in the warranty period; Customer co-creation in the R&amp;D process</td>
<td>Market and customer need analysis; Research and Development; New sales channels.</td>
<td>Strong IT development and keep updating products to meet changes in customer need; Providing high quality for products and Services to satisfy customers and build a long-term relationship;</td>
</tr>
<tr>
<td><strong>Tools/ approaches to identify &amp; prioritize risks</strong></td>
<td>Long time experience</td>
<td>Many different tools depending on the type of risk (financial, technical, etc); Long time experience; Operational Factors – Calculation based method.</td>
<td>Long time experience. Product development concept selection: to filter out products based on cost and risks.</td>
<td>PULSE concept: Handling deviations and risks.</td>
</tr>
<tr>
<td><strong>Tracking and control the risks in the future</strong></td>
<td>Documentation</td>
<td>Documentation: Feedback from customer directly to R&amp;D. Web Arrow Process: A special task force within the R&amp;D, which work with deviations and give solutions quickly.</td>
<td>Documentation</td>
<td>Documentation: Practice Engineering and Guideline System to explain how you design what should be done next, with texts and pictures</td>
</tr>
<tr>
<td><strong>Inter-department communication barriers</strong></td>
<td>N/A</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Solutions for communication barriers</strong></td>
<td>N/A</td>
<td>Cross functional teams: Have more cross functional meetings in aftermarket phase or in R&amp;D process. Work environment like a small company and a lot of people know each other.</td>
<td>Common language in use is English; Knowledge sharing: Company culture;</td>
<td>Project model based on line organization; Core team in projects to interact with members from different departments; Establish common information channels between departments.</td>
</tr>
<tr>
<td><strong>Supplier coordination in resolving uncertainties</strong></td>
<td>N/A</td>
<td>Single supplier: Integrated in R&amp;D process and production process; ‘View the supplier as part of the company’</td>
<td>Close contact with suppliers on different level;</td>
<td>Development Agreement; Integrated with suppliers: Design team collaborate tightly with suppliers and working with specification approval</td>
</tr>
</tbody>
</table>

---
5.3.1. Exploitation of opportunities derived from the uncertainties factors:

The results (Table 11 & Table 12) indicate that most of Companies investigated consider uncertainty factors such as Market analysis, Environmental analysis, Reliability/Robustness, Product function, Innovative services and Remanufacturing are potential business opportunities with the aim of increasing profitability, and achieving significant value for the company. The exploitation initiatives vary, depending on each enterprise and their special context. For instance, to achieve opportunities in Market analysis, Company A is utilizing business intelligence scanning. Meanwhile, with a strong IT development and updating products to meet changes of customer need, Company H takes important advantages over their competitors and achieves a larger market segment.

5.3.2. Risk Management Tools and Approaches:

Regarding approaches to identify and prioritize risks in planning, design and develop PSS, with the tools already mentioned in the literature review (Mini Risk method, FMEA, FMECA and so on), the findings refer to other interesting risk management approaches which are used by the Companies, including LoA (Limit of Authority), PULSE concept, caWeb, Nokia 7. In which Nokia 7 is a root cause analysis approach similar to FMEA, FTA or Ishikawa diagram. The process for Nokia 7 is first defining the potential risk, evaluating them and finally prioritizing the risk in terms of their cost or other influential factor. PULSE concept is a visual method, where deviations and risks are posted on a white board and handled out to responsible people. They meet on a weekly basic to follow up the progress in handling and eliminating risks. This concept is widely used in many organizations; the application of R&D department in Siemens can be an illustration, as seen in Figure 12.

Figure 12 Review board in R&D (Fazlalipour, 2010)
On this board, there are responsible department and the problems/risk names, which are stuck on the Y and X axes representatively, and the different color dots represent for different level or risk severity. For instance, the reds are critical risks which need to be resolved immediately, the yellows stand for ordinary or less serious risks that can be treated later, and the greens are eliminated risks or minor problems existing parallel in the product development process. Due to the flexibility of Pulse, this concept is implemented in numerous Companies under various adaptations. However, the core function remains as a visualization method for risk assessment.

To track and control the risks in the future, most interviewees suggested ‘Documenting Knowledge and Experience’ under different support applications (Table 11 & 12).

5.4. Communication Barriers and Supplier Coordination

In implementing Active Risk Management, the barriers in communication between departments occur and become increasingly obvious with large Companies due to their complicated organizational structure. In which, a product development project gets involvement of many members from different departments, divisions, countries or even regions in the world. The solutions for overcoming communication barriers used by various Companies are to conduct frequent meetings and workshops, build common information and have knowledge sharing channels through all parts of the organization. With SMEs (small and medium enterprises), the intercommunication barriers seldom exist due to their simple organizational structure. Direct communications, Fika (coffee meetings) are initiatives for treating the problem occurrence. In order to collaborate efficiently with suppliers in resolving uncertainties, most of the investigated Companies claimed that by having close relationship with suppliers, letting them be a part of company in the product development process, it is enable the Companies to have less uncertainty involving suppliers.

5.5. Reliability—The Threshold Factor

Regarding the questions about determining threshold factors in quality with respect to each PSS life cycle and the main influences, all interviewees emphasized the vital role of producing high quality products in their business strategy and organizational philosophy. To gain significant revenues, there is no need to shorten the life cycle of artifacts. Particularly, with continuously changing technology products (e.g. mobile phone industry), customers are motivated to purchase new products because of technology change. With the traditional products, providers keep testing and verifying the prototype in design and development phases in order to make sure fewer defects or malfunctions happen in the warranty period. After that period, with the aim to increase profitability for Companies and provide add value for the customers, extra services such as
maintenance, repair agreements are offered with different reliability guarantee. If the customers have no service agreement, they can just purchase spare parts from the providers.

To determine the quality threshold, marketing department of the PSS Companies look at their competitors products and also get feedback from the customers in the aftermarket phase which is passed on to the R&D department. Moreover, the product life cycle is also defined by what the customers expects the minimum life term of the product to be. By doing this, providers are able to prepare maintenance activities and have appropriate action plan, which can be implemented during the operation or in use phase without affecting the uptime for the customer. E.g. Company F used Replacement Programs where the Company acquired the ‘knowledge for the failure rate’ of each part in their products. The Company gained an advantage by giving them headway in changing the particular part before it fails. This practice also adds value to the customer by not interrupting their usage phase usually caused by breakdowns.

For PSS Companies trading with rental partners such as Company C, the product life-cycle is normally shorter than usual (5-7 years compared to 10-15 years used by end-users for instance). If producers want to lower the extra cost for maintenance and repair in the warranty period, they have to make sure that their products should last a little bit more than 7 years while being utilized continuously.
6. Analysis

Chapter 6: The analysis part strives to answer the research questions created in the beginning. In which, all the critical uncertainty factors derived from the empirical data interpretation will be analyzed elaborately, based on the theoretical foundations. The factors which may be exploited as opportunities are discussed before the final framework for uncertainty management is proposed for PSS planning, design and development.

6.1. Critical uncertainty factors

From the results presented in the Finding chapter, the authors realized that due to the small number investigated Companies and the variety in terms of Company’s size, industry, and interviewees, the interviewees’ perception of rating scale (1-5) could be different. For instance, in a same factor of uncertainty, Company A’s 3 may not be equivalent to Company E’s 3. However, in the scope of this thesis, we decided to normalize this scale to bring conformance in the rating process and the critical uncertainty evaluation.

<table>
<thead>
<tr>
<th>PHASES</th>
<th>UNCERTAINTY FACTORS DEFINED IN PSS PRODUCTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Analysis</td>
<td></td>
</tr>
<tr>
<td>Company Analysis</td>
<td></td>
</tr>
<tr>
<td>Environmental Analysis</td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td></td>
</tr>
<tr>
<td>Product Function</td>
<td></td>
</tr>
<tr>
<td>Innovative Services</td>
<td></td>
</tr>
<tr>
<td>PSS integration</td>
<td></td>
</tr>
<tr>
<td>Supplier Coordination</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td></td>
</tr>
<tr>
<td>Remanufacturing</td>
<td></td>
</tr>
</tbody>
</table>
Regarding the uncertainty factors proposed in the beginning of this dissertation, from 10 factors indentified, the authors elicited the most six critical ones from the empirical investigation (highlights in bold in Table 13).

6.1.1. Planning stage:
In the planning stage of PSS implementation process, two of three factors, which are considered as critical, are Market Analysis and Environmental Analysis.

Market Analysis
Apparently, in every kind of product development process, the Market Analysis plays a vital role in identifying the customer target and market segmentation, orienting the product development process. In PSS, the Market Analysis along with Company Analysis and Environmental Analysis results are reference foundations for developing PSS potential ideas (Hepperle et al., 2010). Due to study of variables such as changes in customer need, market trend, the rivalry among existing competitors or threat of new entrants, threat of substitution products or services (Porter, 2008). Market Analysis itself is regarded as a critical uncertainty factor in planning PSS. This is also validated by the information of the empirical data, when many investigated Companies rated this as the most critical factor. The reason behind is that the Companies are continuously monitoring changes in consumer behavior and market segmentation in order to remain competitive, and take advantages in competitions with their rivals.

Company D manager supporting stated “Market analysis is done continuously and is our mandatory process.”

The level of severity of this factor is assumed much higher with SMEs. These Companies are definitely more vulnerable and sensitive with fluctuations in the market, due to their limitations in terms of finance, resources and competences compared to giant enterprises.

Environmental Analysis
Similar to Market Analysis, Environmental Analysis, which studies about technological changes, market shifts or even legislation modifications, is deduced as a moderately critical uncertainty factor. All the Companies in the investigation are producing medium or high level of innovative products. In fact, the radical innovation or incremental innovation result in technology changes (Wenngren et al., 2010). In a fierce market, possessing a strong R&D and remaining in forefront of technology change always generate huge competitive advantages for PSS Companies. Such motivations encourage them to keep improving, even changing technologies applied in their products. However, there are still some manufacturers, who are providing medium technology outcomes; therefore, the uncertainty in technology is considered low. Hence, for these Companies, the major concerns in environmental analysis are new legislation implementations.
As in an investigated electronic communication device manufacturing company, if they had not reacted successfully to the modifications of transmission trend and new legislation introduction from European Union (all analog transmission must be switched off by 2012 to digital), the Company would have suffered a lot from this uncertainty. By having a good sense of the environment, and creating a strategic roadmap for this conversion in the production, the Company has occupied a large European segmentation in their field and taken significant advantages over the other competitors who anticipated this much slower.

**Company Analysis**

Regarding Company Analysis in which organizational structure, stakeholders, resources and competence are analyzed to assess the feasibility of designing and developing a new PSS product. Because PSS leads to complex organizational structure with the involvement of multi-disciplinary teams from different department and various stakeholders (Chirumalla et al., 2010), this uncertainty factor was expected to be critical. However, the results from the findings indicate that the level of uncertainty in Company analysis is moderate, even quite small for a few Companies, due to some particular reasons. First, most of Companies participated in the investigation are medium or large enterprises, which have qualified competence and adequate resources allocated to new PSS development. Second, their organizational structure is not only stable, but also flexible enough to integrate thoroughly diverse expertise and resources from different departments into a new PSS development project. Moreover, their transparent and efficient management system facilitates the analysis team in delivering an accurate report of the Company’s status, in which all potential uncertainties are covered in detail. Therefore, the uncertainties that may occur become predictable events for the Companies. Finally, closer cooperation between various stakeholders with employers within the Company increases the knowledge sharing process, crosses the communication barriers and reaches a consensus on PSS design and development easier with the support from stakeholders.

### 6.1.2. Design and development stage:

In this stage, four of seven defined uncertainty factors get a serious concern from the PSS providers and assumed to be critical issues. As illustrated in the Table 13, they are *Product Function, Innovative Service, PSS Integration* and *Supplier Coordination*.

**Product Function**

Most of interviewed PSS Companies are offering Product Oriented Service, in which the main offerings are still physical products with integrated basic extra services such as maintenance, upgrade or repair. In this case, the product function uncertainty derives mostly from the product platform. In order to fulfill customization requirements and apply innovative changes of technology, new product functions can be added, upgraded or modified. In some cases, the functions often do not change; the structure of the product might be changed to facilitate addition
of new service activities (Hara & Arai, 2010). The common uncertainty here could be incompatibility between new product functions and the existing platform strategy. For some Companies who are providing PSS products based on a flexible product platform with incremental technology innovation, the uncertainty of this factor is quite low. For others, especially who are offering Use Oriented Service/ Result Oriented Service and their revenue mainly comes from the integration of physical product-service offerings, this uncertainty factor is considered as critical. Since the integration is a sophisticated process which require diverse expertise and advanced technology to integrate efficiently the offerings of the service into product platform.

**Innovative Service & PSS Integration**

The core concept of PSS product is to develop a combination of physical product and intangible service with the aim to fulfill efficiently the customer needs on the market. As a part of PSS, there is no doubt that the services play an important role in the success of PSS product development process. Particularly, Innovative Services provide more business opportunities, competitive edges for the PSS Companies and helps them to get strong commitment from their customers.

*Company F manager noted about innovative services “We are planning new technologies as we are working with disruptive technology.”*

Nonetheless, as mentioned above, the innovation leads to technology changes (Wenngren et al., 2010) and consequently, generates uncertainties. Furthermore, the probability of lacking resource allocation for innovative services is frequent in many cases since the Companies get used to focusing on product innovations (Fischer et al., 2009). This routine poses many challenges for them in relocating resources and implementing PSS efficiently. Besides, the product-service integration is considered as a core business to differentiate offerings of many PSS manufacturers in the fierce market. However, according to Steven & Richter (2010), the higher the degree of integration is, more complex and difficult its adjustment might be. Some of the studied PSS providers are working with disruptive technology; thereby they assess PSS integration being extremely critical. For instance, if the design does not support well the services like maintenance then many questions come with safety issue and could affect the environment, the down time and the cost of PSS production. The service requires regular inspection, but due to product being in constant use, leaves the provider less option to provide high quality service leading to serious safety concern. This was complimented by Company F manager;

*“If the design is not supporting the services like maintenance then a lot of questions can come with safety issue, the quality is not safe, it could affect the environment, the down time and the cost.”*
The others mainly provide Product Oriented Service with a few basic extra services integrated in the physical product, therefore the level of uncertainty in this factor is quite moderate for them due to their simple integration between product and service.

**Supplier Coordination**

Regarding Supplier Coordination, it refers to the collaboration between providers and suppliers in the PSS design and development. The collaboration is perceived mainly as human interactions in communication, along with coordination in production and component delivery processes.

“If suppliers make changes or deceive in quality that we are not aware about, then we find out the defects. It is really tricky to take care of it, it is very extremely costly and embarrassing sometimes, so I think we should chase them out” quoted Company B manager.

According to Alonso-Rasgado et al., (2004), the human element creates the biggest source of uncertainty. To validate this statement, the findings indicate that the uncertainty in Supplier Coordination is moderately critical in most of the investigated Companies. When collaborating with a new supplier, the technology roadmap of PSS supplier may be different with the roadmap of their supplier; the others have to confront with the product quality deception or resolve wrong delivery from their suppliers due to misunderstandings in the specifications interpretation or communication. To eliminate the risks, which are derived from the supplier collaboration, each PSS Companies have their own solutions. Generally, building a strong and closer relationship, long-term commitment with suppliers is chosen as an optimal initiative. Few Companies even consider the supplier as a part of the Company and let them involve in the R&D process. By doing that, the PSS providers are able to support their suppliers when they meet difficulties or get off track. The product quality is under control by being followed up continuously. Besides, certain demands and transparent contracts, which are offered to PSS suppliers, are effective methods to manage and remove uncertainties in Supplier Coordination.

**Reliability/ Robustness**

Reliability can be the expected life cycle of a product and it is important to last at-least one life cycle (stated by Guide & Jayaraman, 2000 in Sundin, 2009). The reliability uncertainty is probably perceived as breakdown of product during the contract or warranty period, which could carry extra burden for the provider in terms of financial penalty, reputation and credit decrease. The finding results indicate that all Companies acknowledge completely the severity of this factor if the uncertainty happens. However, they are all strongly confident with their own quality management system and believe that the uncertainty probability is very low.

Nonetheless, as Company F manager pointed out “As all Companies do, in the warrantee year, we want zero defects, if we look from an internal perspective. But we still do have some defects.....The quality that we can deliver is the up time that we can provide for our customers... and up time is what we try to measure,”
Analysis

This is complemented by testing artifacts elaborately in the production time, collecting and analyzing statistical data on the modes of failure outside the warranty, and implementing the effective quality control methods such as Lean production, Six Sigma or TQM (Total Quality Management) and so on, the PSS providers are able to deliver superior quality products and satisfy completely their customers.

Communication

The uncertainty in communication among internal and external stakeholders was argued to be moderate, or even low in some cases before. In fact, with SMEs in which the relationship of inter-departments, individuals is quite close, the communication is more direct and open, even with their suppliers. There is almost no space for misunderstanding or communication barriers in this case.

*Company H manager stated that “we have the communication often from design team and our suppliers when development agreement has been signed”*

However, in large enterprises, which are operating under the line organizational structure, there are more challenges in communication since the communication network cross the divisions, countries or even regions is more complicated. However, in each Company they have their own communication system with several efficient channels (frequent meetings, workshops, common database) to motivate the knowledge sharing process and improve efficiency in communication.

Remanufacturing

The remanufacturing uncertainty involves in the re-usage of materials and reconditioning the original products. This was argued quite critical due to worries about the product return flow process, market dominance by third party manufacturers, and so on (Mont, 2002). However since most investigated Companies have not involved much in remanufacturing process, this has not been seen as a major uncertainty factor in this investigation.

6.1.3. Differences between Group I and Group II Companies in terms of critical uncertainty factors:

Among eight Companies investigated, the authors grouped Companies who are providing purely Product Oriented Services (P.O.S) compared to the rest ones, who offering either Use Oriented Services (U.O.S), Result Oriented Services (R.O.S) or all three types of PSS products. Moreover, some interesting trends in terms of critical uncertainty factors among them encouraged us to classify the Companies into two groups: Group I consists of A, B, C, D Companies and E, F, G H Companies belong to Group II. At first glance in Table 17 (appendix), it is easy to note that in all critical uncertainty factors, the number of Companies who rated the factor as critical in Group I was higher than that in Group II (as mentioned before, the factor in which the total score is above 10 is considered as critical). For instance in PSS Integration, three Companies (A, B, D) of
group I rated these uncertainties as critical. In contrast, three out of four Companies in group II scored this factor very low. As a result, the average score of group I is higher than that in group II. Particularly in Product Function, these scores are 12.25 and 5.5 respectively. This may elicit that for physical products integrated extra service producers (Group I), they have to confront with more uncertainties in PSS design and development than enterprises who providing more serviceable or high flexible PSS products (Group II). The other differences between Group I and Group II in terms of opportunity and risk response will be discussed elaborately in the following parts.

Analysis

6.2. Uncertainty factors viewed as Opportunities for exploitation

Before we analyze the different factors which are perceived to be opportunities by the PSS Companies, we will first have a look at why other uncertainty factors are not considered to be opportunities. Company analysis factor is regarded to be internal and has less consequence as an uncertainty and provides almost no opportunity. As basic organization of a company needs to be well functioning in order to be efficient and productive. And most Companies have already great experience in cross functional teams and structures (Chirumalla et al., 2010). The same is for communication and supplier coordination uncertainty factors, with almost no Companies considering them as opportunities due to the internal nature of the uncertainty and its scope to influence the external competition/environment in giving them due advantage. PSS integration does not much come in the radar of the Companies either, with the exception of Company F who had complex product platform which enabled them to view this factor as an opportunity.

The main opportunities from the uncertainty factors are:-

The Market uncertainty factor with the highest uncertainty overall score from all Companies is also seen as a major opportunity. One reason is that with greater uncertainties involved, it enforces the Companies to explore many new ways to exploit this uncertainty. With changing customer demands, a company who could be behind their competitors, can catch up or overtake the competition by foreseeing a new customer need and be the first in market9 (Trott, 2005).

“We need to keep in forefront of what is happening in the markets” Company A manager stated.

To exploit this uncertainty, Companies were scanning the market utilizing ‘business intelligence’ or in academic terms known as market sensing (Edvardsson 1997 in Kowalkowski and Kindstrom, 2009). This is the more efficient way for Companies, who can’t spend resources on their marketing department in terms of global outreach. In addition Companies look at the customer activity chain (Tan et al., 2009) to provide training to customers to make use of their

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products and utilize their support activities more efficiently. Companies also stated strong IT development to facilitate co-creation with customers as a prerequisite to exploit this opportunity.

Looking for Environmental uncertainty opportunities, in terms of technology change is very crucial. Not evaluating the new technologies that makes an entry into the market can be a major risk and in turn lead to loss of market share and profits. Company D manager quoted environmental analysis “also as an opportunity to come with redesign with efficiency improvement and significant life”. Major emphasis was put by certain Companies to invest more in their R&D to come up with new innovation (Wenngren et al., 2010) and one of the means was using customer co-creation. As we observed Company F, who taking the initiative to connect their R&D department to get direct feedback from their customer, fostering them to bring out new innovative solutions.

**Product Function** uncertainty provides opportunity to Companies to evolve their product platform. Companies see flexibility in terms of how the product can be evolved and add new function in the future. This gives the Companies advantage for increasing the life cycle (McAlonee & Andreasen, 2003) of the product considerably through multiple product platforms and facilitates changing the structure to add new service activities (Hara & Arai, 2010). Product platform gives cost reduction benefit where redevelopment of components for multiple use is achieved (Trott, 2005).

Company H manager complemented this view “It is important to introduce new products to the market. Then, we should be able to make more changes to add more value to the customer. We have a good product platform to build from.” Although very few Companies interviewed use sophisticated product platform, we didn’t find any Company using process modularization as stated by Aurich et al., (2004, 2006).

When we observe Innovative Services, Companies see this uncertainty factor as an opportunity in differentiating themselves from competitors enabling them to get closer contact with their customers (Fischer et al., 2009). This enhances the Company’s evaluation of their customer’s current needs being re-analyzed (Akasaka et al., 2010) with the purpose to provide new modified and innovative services. Bringing new innovative services also boosts the revenue to the provider by introducing different warranty contracts which accompany the type of service. In doing so, it gives flexibility (Moon et al., 2010) for the customers in selecting of the type services they prefer based on their requirements.

**Reliability** as an uncertainty factor is viewed by Companies to provide real opportunities in terms of evaluating their products life cycle. This gives the providers to map out the service contracts and warranty periods more accurately. In PSS, this is more crucial as the Companies can now derive more revenue and try to minimize the loss of profits due to malfunctioning or break down of products in the usage phase as ascertained from the interviews with Companies. Customers also gain more by having high reliable products which also benefits the providers to have the customer’s loyalty and long term commitments.
Analysis

Company H manager view was “It is important to achieve high quality since the products can be used for the next decade by the customer. Another effect is that we can offer better rental agreements, which is beneficial for both the customer and us.”

Remanufacturing, though it is the least among the uncertainty factors, is seen as a business opportunity. This implies that remanufacturing can be seen as a future business opportunity with less risks involved in terms of third party acquiring knowledge through reverse engineering (Mont, 2002). Regarding cost benefit and third party usage scheme, Company C manager stated

“Another thing is that we try to reduce the cost when remanufacturing the machines, because the rental Companies exchange the machines every 5 years so we have to calculate the cost of machine and the service, compared what they get with the rental.”

Although product function, quality (reliability) and technology (environmental uncertainty) indirectly influences this factor, remanufacturing gives providers advantage by increasing the life cycle of their product (Sundin, 2004).

6.2.1. Differences between Group I and Group II in terms of Opportunities:

From Table 20 (appendix), it is interesting to note that while comparing group I Companies (P.O.S) and Group II Companies (U.O.S, R.O.S or P.O.S), the factors like market analysis, environmental analysis, product function and Innovative services are commonly viewed as opportunities. And as stated above in our finding, we also found that these factors to be high in terms of uncertainties involved. From Group I, the exception is Company C who stated remanufacturing factor to be an opportunity for them. While Company C does not use U.O.S anymore, they still term remanufacturing to be an opportunity with less uncertainty involved. From Group II, Company G stated product/service integration to be an opportunity. This again is due to the fact that they have such a wide range of products; they see integration of product and services as an opportunity which can give them greater market revenue. Product/service integration uncertainty factor is scored low by Company G therefore making this factor to be a viable opportunity for business.

The main significant highlight between the two group’s differences is the Reliability uncertainty factor. While three Companies (Company F, G, H) from Group II see this factor as an opportunity, no Companies in Group I see this uncertainty factor as an opportunity. By analyzing, we find that this is mainly due to the various service offerings Group II Companies provide. Though the scoring for this uncertainty factor is low by all Companies except for Company F, this factor gives Companies an opportunity to use their different service offering and capitalize based on these offering. This means having shorter life cycles but having high reliability with minimizing defects to almost zero during the usage phase. The service offering also gives the Companies flexibility (McAloone & Andreasen, 2002; Moon et al., 2010) on the product life cycle; one principle reason is Companies have greater access to the product during
the usage phase. Company F uses live telemetry transmission to keep themselves updated on their customer usage of their product. Therefore, before the product becomes unreliable, the Company replaces the particular part in the product or takes back the whole product and replaces them with another similar product (e.g. Company H through their rental program), therefore maintaining high reliability of the product and customer satisfaction at a high level. Group I did not see this factor as an opportunity as they just rely on the after service sales of their product and manufacture the product with very high reliability. Hence, they had less flexibility in terms of how they can use P.O.S offering to their advantage unlike their counterpart Group II Companies did with their U.O.S or R.O.S.

6.3. Reliability – ‘The Companies’ perceptions of determining the threshold between profits and quality

Most Companies focus on maintaining high quality standards of their products, that the chance of failure of their product malfunctioning or breaking down is extremely low. However, the risk of reliability failure is always persistent in spite of all the checks and preventive measures taken in reliability testing phase by designers (Ulrich and Eppinger, 2008). This leaves room for uncertainty to be still moderately high. As seen from Company F’s viewpoint, their products are made up of thousands of components, which means the complexity of their overall product integration increases.

In essence we can say from our main research question on reliability, we wanted to investigate in depth on how the Company decides the minimum guarantee period when designing their product. How do they make the customer satisfied with the quality of the product designed? And do Companies need to shorten the life cycle of the product in order to sell more products and benefit from aftermarket services?

As stated from our findings, all Companies do want their products to be reliable with high quality, but in terms of making revenue from services, there needs to be a clear distinction of how long the product life cycle should last. It was almost unanimous from all the Companies answer that ‘Customer is the king’!

“It is the customer who judges us on what level (quality and reliability) we are on.” Company F Senior Manager

Thomson and Richard, 2006 also had the same view that customer demand was on high quality and value the products more with high quality and reliability. All Companies during their design and development stage, take feedback from the customers on how the customers perceives the quality of the product and what the customer still expects from the provider. For example if the customer feels 5 years of product reliability is good enough for their business and makes the customer to the rate their product satisfaction high, then the providers design their product to
have at least minimum of 1-2 year of zero defects reliability with a follow up of minimum maintenance service.

Since PSS is all about offering customers high standard services, the majority of profit revenue made by the Companies comes from aftermarket services. Most Companies have contracts based on guarantees to their customers. The failure of product during this contract period makes the provider to bear all the cost (Ericsson & Larsson, 2009) of replacing and repairing the defunct product. Nevertheless, this uncertainty is also seen as a business opportunity by Companies to make revenue from the various PSS types of service offerings. Companies F ‘Replacement program’ of collecting statistical data (Walsh, 2010) is an example of positive use of converting reliability issue into a business opportunity. Offering different types of contracts to the customers also gives flexibility to the customer to choose which benefit the customer wants. The more benefits the customer gets from the provider, the higher premium the customer pays.

The other major influence on reliability threshold is the ‘competitors benchmarking’. All the Companies base their product’s initial design on what is the competitor’s reliability of their product in the market. This benchmarking is crucial for Companies remaining competitive in the market.

    Company D manager stated this view “Competitors are the main and we know what their reliability is and then we know what the customer expectation is, as it comes to us as a request.”

One Company stated that they used ‘Toyota Way’\textsuperscript{10} to reduce waste and implement lean production in their system process, to increase efficiency and reliability. Walsh, (2010) also stated that lean manufacturing enables improvement in reliability.

The influences stated above prove that Companies do not need to shorten the life cycle of their product in order to make revenue from aftermarket, as that can be counterproductive. Companies still make a win-win situation by making it mutually beneficial for the customer and provider by;

- Providing high quality products which are very reliable to make the customer satisfied.
- Establish loyal customer following who will buy future products from the Company and continue to use their services.

6.4. Uncertainty management framework

The proposed framework for uncertainty management is the synergy of theoretical insights, valuable empirical findings with convincing and logical arguments above. The framework was developed and applied as a part of Active Risk Management structure, which was created by Intel and implemented successfully in the last few years. The goal of framework is to identify critical uncertainty factors, focus on implied business opportunities, evaluate and control the potential risks in PSS design and development. The uncertainty management framework consists of two main parts: the left side is identified critical uncertainties factors and opportunities, the right side is the holistic risk management process proposed. Figure 13 below shows the proposed framework.
Figure 13 Uncertainty Management Framework (Hepperle et al. (2010), Goodman et al., (2007), Hasting and McManus, (2004))
6.4.1. Risk Management Planning:

This step plans and decides how to conduct the Risk Management activities in details. The expected outcome is Risk Management plan generated by using a standard template. The benefit of this process is to improve quality of the product and overcome ‘last minute fire fighting response’

Risk Identification

This step is to identify potential uncertainties, describing and documenting the risks, which have negative or positive impacts on the PSS development. This is executed mainly based on the long-time experience of the risk management team and internal risk documentation, which are fruitful sources to exploit efficiently in this step. In addition, a support visualization method named PULSE concept could facilitate risk practitioners to identify risks.

Risk Assessment & Prioritization

The goal of this step is to determine the risk probability and its impact on the whole PSS production. The most common tools used by PSS Companies in this step are FMEA, FMECA, and Mini Risk Method. Furthermore, in order to assess efficiently the potential risks and discover the root causes, other analysis approaches such as FTA, Ishikawa diagram or Pareto chart, NOKIA 7 are highly recommended. The selection of appropriate method depends on particular context of each PSS Companies. The combination of several methods could be applicable in some cases.

Risk Quantification

This is the process of using statistical analysis to quantify the risk impact. In Active Risk Management, it is an optional step. In the empirical data collection, the authors observe that all the investigated Companies are using qualitative tools to analyze risks. Quantitative approach is unfamiliar with them and there is no enthusiasm to study about that. Since the qualitative approach is apparently easier, faster and more intuitive than quantitative one. However, if the risk practitioners desire to apply a quantitative tool in the risk management process, Monte Carlo simulation is recommended as an effective technique to quantify risks (Goodman et al., 2007).

Risk Response Planning

As explained to us in the interview with an example, by one of the Company’s senior managers about ‘Facit’11, a world leader in mechanical calculators from Sweden did not react to the new electronic calculators from Japan and therefore went bankrupt. Therefore remaining passive can have very high consequence for Companies in today’s rapid shifting environment and market.

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Almost all Companies stated to take active risk response mainly at the design and development stage. This exemplifies that Companies want to remain proactive in taking action (Goodman et al., 2007) with the intention to prevent or overcome the risks identified for all the major uncertainty factors. Companies want supplier coordination factor to be under active response as this factor required constant communication and cooperation in the design/development stage. Environmental and market analysis require more active response for Companies to remain vigilant to the constant change in the industry. When we see the above quoted example, Companies do not want to commit similar mistakes; hereby they try to remain proactive in either bringing disruptive technology themselves, or adapt quickly to change in new technology and regulations. Even reliability risks are acted upon actively to maintain the quality of the product to the conformance of the industry or customer requirements.

Such strategy of using active response can be classified as ‘Avoid risk’ where design of the product is changed to eliminate or protect from the identified risk. In addition, the other one is ‘Mitigate risk’ where a measured response is introduced to alleviate the risk (Tonnquist, 2008).

Some Companies emphasize that they will respond using both risk response ‘active and passive’ for uncertainty factors like Product-service integration and Innovative Services. We term this as using flexibility in risk management (Steven and Richter, 2010). Since these factors involve many variables in terms of designing product and services in the design/development stage, Companies are usually using active risk response. But Companies applying the aftermarket feedback to come up with new improved services or adding new functionality to their product use passive response at the design and development stage. I.e. waiting for the aftermarket to determine or affirm the change needed, for the risks identified in the initial design stage. Hence, Companies will have to use both proactive and reactive responses depending on the circumstance. The same can be said for product function and communication, where Companies need to be flexible when dealing with identified risk and take the appropriate response.

**Risk Response based on Group I and Group II Companies**

Looking at the risk response based on the group segregation, the pattern indicates that Group II Companies take more active response for risks. But as observed from Table 15 (appendix), Company D from Group I take active risk response for all the uncertainty factors. This makes the overall active risk response between Group I and Group II to be equal. The interesting point is Group II Companies take more passive risk response compared to Group I Companies. While Group I Companies take both (active and passive) risk response depending on the circumstances more than Group II Companies. It is surprising that Companies using various service offering are taking more passive risk response, considering the fact that active risk response gives more flexibility in decision making. One would deliberate that this flexibility in risk management (Steven and Richter, 2010) through active risk management should correspond directly to the flexibility in service offering which Group II Companies offer.
As this data in Table 15 (appendix) doesn’t correlate to the theory, we deliberated further and noticed that all the passive risk response by Group II Companies for the uncertainty factor was scored very low, making the decision process insignificant to use active risk response. This is the same case for the passive risk response by few Group I Companies who selected this type of response for the listed uncertainty factors. But as exemplified by Company D, using active risk response for all uncertainties enables Company to stay ahead of competition and respond to changes immediately in the market.

**Risk Tracking and Control**

In this step, risks are expected to be monitored periodically and continuously in order to ensure that the risk responses are executed efficiently. Goodman et al., (2007) recommend all the risk practitioners to involve in the weekly meetings, in order to review the risks and track the risk management process. Besides, to facilitate the risk control in the future, most of investigated Companies suggest ‘Documenting Knowledge and Experience’ along with different support applications (risk handbooks, risk guideline systems) as effective instructions for risk management. For instance, Intel uses HSD-Risk, to share a common platform, for exchanging and mitigating risks. Some Companies use common database mainly for communication purposes and sharing knowledge. This database platform can be used for further development to implement active risk management as in Intel.

### 6.4.2. Communication - Key to Active Risk Management:

The success for Active risk management depends on how the Company is able to communicate both internally and externally in an efficient manner. With all the Companies we interviewed, the pattern is that small sized Companies were able to have high level of communication between personals and inter departments much faster (Lindahl et al., 2008). This is mainly because the work environments are small; the employees have more direct communication. The big Companies rely on their Company culture to get inter departments to have lots of cross-functional meeting. Since cross communication (Hepperle et al., 2010) aided by cross-functional teams helps in transfer of information more. Companies prefer to base themselves as a flat structure organization. Having ‘English’ as common spoken language aids Companies communicating to departments or branches located in different parts of the world.

Companies heavily rely on knowledge sharing process to get every employee updated on the latest event. Fault report system, Chase system and Common Access database are some tools used to overcome communication barriers. These are basic approaches used by most Companies and since not much literature in PSS contributes to communication processes, we cannot verify the ICT (Information communication techniques), SysML (System Modeling language) proposed by Durango et al., (2010).
7. Conclusion/Discussion

Chapter 7: This chapter is a prelude containing final summary of our findings, analysis and answers to the research questions raised in the beginning of our dissertation. The important finding is summarized in this chapter. The future research needed based on our study is also stated.

The authors started this research with the inquest to propose a new uncertainty management framework for PSS Companies. We set out with the objective to investigate the issues which were raised in the three research questions. Here we will summarize the final conclusions for our three research questions.

Research Question 1: What are key factors leading to uncertainty in PSS design and development and which uncertainty is considered as an opportunity?

From integrated PSS lifecycle (Hepperle et al., 2010), we derived ten uncertainty factors which were deemed important. In those, Market analysis and Environmental analysis are the major uncertainties faced by the Companies in the planning phase. Whereas in the design/development stage, Product function, Innovative Services, PSS integration and Supplier coordination are the major uncertainties.

In market analysis, Companies employ their marketing department resources or business scanning third party Companies (mainly utilized by SME’s), in constantly seeking to update on the altering market scene and customer needs. The primary reason is to remain competitive and have edge over rivals in the market domain. Being first in the market to come with product, which fulfilled the new customer needs, is seen as a major opportunity. Companies mainly concern about technology in environmental analysis. The Companies viewed that with new change in technology by either reacting or bringing in disruptive technology themselves led to more opportunities in exploiting this uncertainty. Being cautious of the need to be having the latest technology and ensuring they comply with the legislation, marks this factor very high among Companies in the planning stage. In design and development stage, supplier coordination is the most critical factor followed by innovative services. In supplier coordination, the collaboration between provider and supplier posed uncertainty elements like communication in terms of requirement specification and quality standard. Most of the uncertainty was overcome by involving the supplier into their design/development process, in so much that some suppliers became part of the company’s extension branch. Innovative services was rated high, as introducing new services with innovation is something novel and a challenge for most Companies to implement. Nonetheless, most Companies viewed this factor as an opportunity. As Companies felt with flexibility in offering new services can be exploited to benefit the Company’s new strategy of opening new avenues for income. Product service integration had a high uncertainty score, as high technology end Companies feel that higher degree of integration
Conclusion and Discussion

of product and services led to more complexity. Product Function uncertainty is incompatibility between new product functions and existing platform strategy. The same factor is an opportunity for Companies as this leads them to increase the life cycle of the product by utilizing multiple product platform strategies, reduction of costs and redevelopment of components for multiple uses.

Even though Remanufacturing is the least uncertainty factor, it is an important opportunity to Companies. They see the benefits of remanufacturing by increase in life cycle of product with less cost in manufacturing new products. Therefore, in terms of PSS, this potential factor can be explored in the future by the Companies.

In the comparison between Group I (P.O.S Companies) and Group II (U.O.S, R.O.S or P.O.S Companies), the noticeable difference in terms of critical uncertainty score let the authors assume that Group II Companies who offer more flexible and serviceable PSS products confront with less critical uncertainties then Group I Companies in designing and developing PSS. Besides, the two groups state market analysis, environmental analysis, product function and Innovative services as common opportunities from the ten uncertainty factors. The interesting fact is that the reliability factor is viewed as an opportunity by three out of four Group II Companies. The reason is underscored by the various service offerings that the Companies F, G, H offer. This allows them to have flexibility in controlling the product life cycle and have access to the product during the usage phase. This allowed the Companies to sustain high reliability as well as maintain high customer satisfaction. The only anomaly is remanufacturing which is seen as an opportunity by Company C from Group I, as they have been using Use Oriented Service before and this factor has low uncertainty for this Company. And in Group II Company G views product/service integration as an opportunity due to the various products families they have, which leads them to observe that integrating product and services will enable them greater revenue from the market.

Research Question 2: From the provider’s perspective, how much reliability of a PSS designed product is expected in order to fulfill customer satisfaction whilst continuously creating opportunities/profit for the company in the usage phase?

In today’s industry, Companies have high quality standards, which have lead to high reliability of the products. However, even with measures like reliability testing, there persists an uncertainty of failure for the products during the warranty phase. Moreover, though this factor was scaled moderately high in terms of uncertainty involved, this was mainly due to increase of product components presented more complexity in testing and integration. From our research perspective, Companies were unanimous in stating that customers determine what should be the threshold level in reliability. All Companies during the design/development phase get feedback from the customers about the minimum level of expectation the reliability of the product should
be. With PSS offering getting their profit revenue from aftermarket sales, the failure of product during the contract period makes the provider to bear the cost. Replacement program of collecting statistical data is a positive way of converting reliability issue into a business opportunity. The other major factor for setting the threshold is the competitors benchmarking. One of the tools for enabling improvement in reliability is lean manufacturing derived from Toyotas best practice ‘The Toyota way’.

**Research Question 3: How will Active risk management be beneficial in the proposed framework, in order to overcome the uncertainties involved in planning/designing and developing of PSS?**

The uncertainty management framework that we propose is a synergy of theoretical and empirical finding. The major emphasis is on Active Risk Management, which was firstly initiated by Intel. The left side of the framework contains the list of uncertainty factors identified. And the evaluation of opportunities from these uncertainties is carried out to find the potential factor for exploitation. The right side is the holistic active risk management process. The six step process of active risk management is initiated by risk management planning followed by risk identification, risk assessment and prioritization, risk quantification, risk response planning and risk tracking and control. The risk response planning output is either active or passive (see Figure 13).

Observing from our research at the pattern for differences between Group I and Group II Companies, we noted that both groups have identical active response score. But the fact that captured our attention was that Group II Companies used more passive risk response than Group I Companies for the uncertainties faced. As this did not correspond to the theory that flexibility in risk management would correlate to flexibility by Group II Companies various PSS offers. Further investigation showed these passive risk responses were selected for uncertainty factors, which had less significance in terms of probability and consequence, so they had less importance in the risk management decision making. The same pattern was noted for few Group I Companies that used passive risk response. As exemplified by Company F, who used active risk response for all the uncertainties, the authors of this dissertation would like all the Companies to take lead in such direction by using Active Risk Management, which benefits the Company to stay ahead of competition and react immediately to any changes in the market.

Active risk management brings coherent language and tools for approaches to measure risks. The tools provides visibility between platforms and many-to-many relationships. It also enhances the communication within teams to proactively avoid costly risk events. A common tool that Companies used for risk identification is from long time experience. PULSE concept facilitates the risk identification process. In addition, the authors found that the other interesting tools like Nokia 7 for root cause analysis. Mini risk method, FTA and FMEA are being used universally.
for risk assessment and prioritization in many Companies. Risk quantification is still an unfamiliar domain for most PSS Companies. We suggested tool called Monte Carlo, which is a simulation tool to be beneficial for Companies in quantifying risk. Documentation and using common accessible database are methods used by Companies to track and control risks effectively. As most Companies already had some sort of common database, the authors felt the Companies could develop this database further to implement HSD-Risk as Intel did to improve their risk management efficiency.

From our study, we found communication is a barrier for almost large Companies compared to the SME ones. This made the Companies rate the uncertainty in communication for both internal and external to be high. The success of Active risk management implementation depends on overcoming these communication barriers by having a supportive company culture, which encourages cross communication actively. Active risk management also provides flexibility in risk management, since numerous variables are involved in designing and development. Although, some circumstances or strategies involve using passive risk response, pace in technology and competition is continuously changing in today's market. This challenges Companies to be proactive in their response to uncertainties in order to stay ahead of risks beforehand, and the competition in bringing out innovative PSS offers.

Above all, this holistic framework allows Companies to identify the major uncertainties and have a risk follow up plan set up. This is conducted either by a risk management team or by appointing a member in the project team to look at the uncertainties and see which opportunities can be exploited. If the Company doesn’t have a special team for risk management, then proper training can be carried out for selected personals within the project team to be familiar with the methodology, process and tools. Frequent meeting needs to be scheduled to guarantee active participation of the members of the project team in order to be updated on the latest uncertainties the Company faces and come up with an action plan to respond. Thereby, it improves the inter-communication among departments and gives flexibility in decision-making process. Moreover, to deal with risks, the Companies can use the tools mentioned in this framework, which are the standard practices being utilized by PSS Companies, and develop a common database for risk management to provide greater efficiency and speed. It can be stated that this framework gives a standard active risk management template for Companies to follow and implement.
7.1. Special characteristics of PSS Companies uncertainties over Non-PSS Companies

To conclude, we are sure the reader of this dissertation would inquire ‘How is this study of uncertainty management for PSS Companies different from non-PSS Companies?’ The authors have compelling evidence from this study to exemplify the contrasts. As one has read from the analysis between Group I and Group II Companies in the previous chapter, we can state Group I Companies with just ‘Product oriented service’ as non PSS Companies who give regular services along with their product. Group II Companies on the other hand utilizing the ‘Use oriented service’ and ‘Result oriented service’ are the typical PSS type Companies.

One can observe from Table 20 that PSS Companies exhibit more flexibility in order to find more opportunity in uncertainties they encounter. As stated at the beginning of our report, uncertainty of an offering is the main highlight which differentiates PSS from normal products. The perception of uncertainty changes dramatically for Companies using PSS, as the various service offerings they provide to their customer, gives them advantage over their competitors to suit the customer demands more effectively. Hence, other than changes in market or environment uncertainties, the rest of the uncertainty factors have very little effect on PSS Companies risk management ratings. This gives PSS Companies a head start in terms of overcoming initial mitigation barriers to uncertainty factors.

This study is the first step in finding a real assessment of uncertainty management practiced by PSS Companies. And the authors of this dissertation hope further research on this topic of uncertainty management might strengthen the PSS concept, as not only as an environmental beneficial idea but also as a sound business concept.
7.2. Summary highlighting the interesting facts from this research

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<thead>
<tr>
<th>Research parameters</th>
<th>Interesting facts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main Uncertainty factors</strong></td>
<td></td>
</tr>
<tr>
<td>Market Analysis</td>
<td>Business scanning or extensive market research.</td>
</tr>
<tr>
<td>Environmental Analysis</td>
<td>Bring disruptive technology or be ready to react to new technology.</td>
</tr>
<tr>
<td>Product Function</td>
<td>Multiple product platforms give flexibility.</td>
</tr>
<tr>
<td>Innovative Services</td>
<td>Design services along with product design to give greater advantage in the offering.</td>
</tr>
<tr>
<td>Reliability</td>
<td>Maintain High quality to satisfy and maintain loyalty from the customer.</td>
</tr>
<tr>
<td>Remanufacturing</td>
<td>Re-usage of materials saves cost and benefits the environment giving the Company a green environmental friendly label.</td>
</tr>
<tr>
<td><strong>Business Opportunity</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Active Risk Management</strong></td>
<td>Being continuously active in risk management makes the Company stay abreast of uncertainties.</td>
</tr>
<tr>
<td>Risk identification &amp; Prioritize tools</td>
<td>Nokia 7, FMEA, caWeb, PULSE concept</td>
</tr>
<tr>
<td>Risk tracking and control tools</td>
<td>Common Database Documentation; Web Arrow process (special team within R&amp;D to track deviation); Guideline system (how to use), Practice Engineering (Checklist)</td>
</tr>
<tr>
<td>Communication tools</td>
<td>Flat Structure; Chase System; Cross functional teams; Project Based Organization</td>
</tr>
<tr>
<td>Reliability Tradeoff</td>
<td>Customer Feedback &amp; Competitors benchmarking</td>
</tr>
<tr>
<td></td>
<td>[Use of statistical tools to keep track of customer’s product usage. Helps foresee reliability issues and preemptive services can save money for the provider.]</td>
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</table>
Conclusion and Discussion

7.3. Future work based on this dissertation

- Separate study on Companies focusing on result oriented and use oriented services, to find their major uncertainty factor, as the result from our study cannot be generalized for Companies using such offers.

- Consider B2C Companies and conduct research among Companies in a same industry for more in depth analysis on uncertainty management.

- Study about quantitative risk management tools which could be beneficial for Companies in assessing and solving risks and investigate more tools used for risk identification.

- Validate the proposed framework from PSS Companies on the applicability for future use.
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Book:


**Websites and slides**

Appendix

Questions for the survey

1. What type of PSS does your Company provide? (Please select one by considering from the right option and stick to it in this survey.)
   □ Product Oriented Service  □ Use Oriented Service  □ Result Oriented Service

   **Product Oriented Service:** The product is owned by the customer and the value of the product is extended by providing additional services. *E.g. Upgrade, repair.*

   **Use Oriented Service:** The product is owned by the provider who sells function instead of products by means of modified distribution and payment systems. *E.g. Leasing.*

   **Result Oriented Service:** The service promises a certain result.
   *E.g. Virtual answering machine instead of an answering machine at home*

2. How long does the life cycle of your product last in average?
   □ 0-1.0 years  □ 1.0-5.0 years  □ 5.0-10.0 years  □ more than 10 years

3. How long does the service contract last? (Please select and stick to the longest one.)
   □ 0-1.0 years  □ 1.0-2.0 years  □ 2.0-5.0 years  □ more than 5 years

   **Uncertainty Definition:** Uncertainty is things known imprecisely or unknown.
   *(It can be worse or better expected and uncertainty often creates unexpected opportunities).*

   **“Active” Risk Response:** If a new uncertainty is identified in a design/development process, the uncertainty is addressed ‘concurrently’ so that risk/opportunity out of the uncertainty is managed in design/development or afterward.

   **“Passive” Risk Response:** Even if a new uncertainty is identified in a design/development process, the PSS is designed/developed with the uncertainties known prior to the design/development.
4. Score the level of Uncertainty with *Probability/Consequence* in the matrix below (regarding consequence, 1: *being the lowest effect for the provider*, 5: *the highest effect for the provider*) within the contract period for your PSS.

And select the preferred risk response correlated to the uncertainty for your Company as well as well as the phase that uncertainty is addressed.

[Active response example: After environmental analysis is conducted, an appearance of new technology during the design/development stage makes the Company take immediate steps to address it, and implement the change to their current design/development stage. Passive response example: New uncertainty discovered during the design/development stage for product function is accepted, and the process is carried on further without interruptions.]

When is uncertainty addressed? For example, regarding Market Analysis, the uncertainty related to customer target is mostly addressed in the Planning phase.

<table>
<thead>
<tr>
<th>Uncertainty</th>
<th>Probability (1-5)</th>
<th>Consequence (1-5)</th>
<th>Risk Response</th>
<th>When is the uncertainty addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PSS Planning Event (Examples)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. <strong>Market Analysis</strong> <em>(Customer target and market segmentation)</em></td>
<td></td>
<td></td>
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<tr>
<td>Customer preferences change over time, leading to new needs and value.</td>
<td></td>
<td></td>
<td>Active □</td>
<td></td>
</tr>
<tr>
<td>2. <strong>Company Analysis</strong> <em>(Stakeholders, human resource, capital, production capability)</em></td>
<td></td>
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</tr>
<tr>
<td>Expansion of Company or organizational structure change, leading to reallocation of resources.</td>
<td></td>
<td></td>
<td>Passive □</td>
<td>Both □</td>
</tr>
<tr>
<td>3. <strong>Environmental Analysis</strong> <em>(Analyzing the technology change and market shift)</em></td>
<td></td>
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<tr>
<td>New barriers in the market entry or laws which affect the competitiveness of the PSS.</td>
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<tr>
<td>PSS design and development</td>
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<td>-----------------------------------------------------------------</td>
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</tr>
<tr>
<td>4. Reliability / Robustness</td>
<td>The PSS product becomes unreliable (breakdown) before the warranty period expires. This can be overbearing by transferring the cost to the provider.</td>
<td></td>
<td></td>
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<tr>
<td>(Degree of fulfillment of a PSS product function)</td>
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<tr>
<td>5. Product function</td>
<td>Adding functions, which are partly incompatible with the product platform / technology.</td>
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<td></td>
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<tr>
<td>(Adding variable functions that can be modified, upgraded and removed in the future to meet customer needs)</td>
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</tr>
<tr>
<td>6. Innovative Service</td>
<td>Services developed (human/technical/financial resources) does not totally satisfy the customer requirements.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(Introducing innovative services)</td>
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</tr>
<tr>
<td>7. Product/Service System Integration</td>
<td>The higher the degree of integration, the more complex and difficult its adjustment might be. Malfunctions that occur in the integration process, such as services are not compatible with the product function.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>(Integrating physical product and service components to be able to create intended value)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8. Supplier Coordination</td>
<td>The supplier's lack of PSS understanding may</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Collaboration)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
with suppliers) lead to obstacles in consolidation of the PSS offering.

<table>
<thead>
<tr>
<th>9. Communication internal/external (Knowledge sharing inside a Company or with partners)</th>
<th>Conflicts occur between the physical product and service design teams in the integration process; misunderstandings with outsourcing partners regarding design specification interpretation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>10. Remanufacturing (Re-usage of materials, parts or products with reconditioning)</td>
<td>Third party manufacturers having market dominance on remanufacturing by acquiring knowledge in reverse engineering; In 6 years time, the particular PSS product remanufacturing would not be feasible due to the technology becoming obsolescent.</td>
</tr>
</tbody>
</table>

Others………………
………………

**Opportunity in PSS**
11. Which uncertainties within the list above does your Company consider as business opportunities?

...........................................................................................................................................................................................

12. How does your Company exploit those opportunities in order to achieve significant value and high revenue?
**Appendix**

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**Risk Management: Active and Passive**

13. What method is your Company using for Risk Assessment?  
*(Method to determine probability, consequence and characteristic of individual risk)*

---

14. What approach is your Company using for Risk Prioritization?

---

15. What are the *quantitative risk management tools* your Company is using? How would you rate the tool you are currently using? *(E.g. Monte Carlo simulation tool)*

---

16. After following the given risk response, what steps does your Company conduct to track and effectively control the risks in the future?  
*(Documentation, training, knowledge sharing interface)*

---

**Demographic questions:**

Name of Respondent:
Company Name:
Position in the organization:
Field of Expertise:
Phone Number:

*Thank you for taking your time filling in the Survey!*

***********************
Appendix

Interview questions addressing uncertainty management in PSS (Product/Service System)

Active/Passive responses

1. Having been presented the analysis results from the risk management team, what response plan would your Company prefer to follow?
   …………………………………………………………………………………………………………………
   …………………………………………………………………………………………………………………
   (Focusing on the most interesting uncertainty factors and why such (active/passive) response is preferable?)

Trade-off situational uncertainty

2. How does your Company determine the threshold factor in quality with respect to each PSS life cycle and what are the main influences?
   …………………………………………………………………………………………………………………
   …………………………………………………………………………………………………………………

Communication barriers

3. When implementing active risk response, what kind of inter-department cross-communication barriers exist need to be addressed?
   …………………………………………………………………………………………………………………
   …………………………………………………………………………………………………………………

4. What measures are coordinated with suppliers to resolve uncertainties in PSS development stage?
   (Transferring the guarantee obligation to suppliers in designing the assembly parts)
   …………………………………………………………………………………………………………………
   …………………………………………………………………………………………………………………

5. What is the profit margin in % (approx.) in average in your sector (not in your Company)?
   …………………………………………………………………………………………………………………

************************************************
**Company A** stated that *supplier coordination* and *communication* as the most critical uncertainty factors closely followed by the product function and innovative services. Remanufacturing was not much of a concern as the Company had effective control of the spare parts in the market.

![Company A - Uncertainty Factors](image)

**Figure 14 Company A Uncertainty Factors**

**Company B** assessed market analysis and environmental analysis as the major uncertainty factors followed closely by the supplier coordination and Product/Service System integration. This Company has products whose uncertainty were affected greatly by technology change, hence the need for having a strong market and environmental score. They are also in close coordination with the suppliers in order to design and develop their products. Therefore, communication uncertainty is low.

![Company B - Uncertainty Factors](image)

**Figure 15 Company B Uncertainty Factors**
Company-C noted supplier coordination, communication, innovative services and reliability as major uncertainties that affect their Company. Major uncertainties are involved in remanufacturing, as the Company is actively involved in remanufacturing of their products extensively. In addition, innovative services and reliability are other major uncertainties that the Company need to focus.

**Figure 16 Company C Uncertainty Factors**

Company-D rated a high probability and consequence for market analysis. The major uncertainty is innovative services, because they are applying PSS very recently to their Company’s business model. Therefore, the perceived risk is high in both probability and consequence of this uncertainty. They are planning new technologies with disruptive technologies and bringing in appropriate services to complement it. Therefore, the next major uncertainty PSS integration is also high due to the above mentioned reason.

**Figure 17 Company D Uncertainty Factors**
**Appendix**

*Company-E* evaluated Company analysis as main uncertainty factor due to internal changes within the Company followed by the supplier coordination, innovative services and reliability.

![Company E - Uncertainty Factors](image1.png)

**Figure 18 Company E Uncertainty Factors**

*Company-F* considered market analysis and environmental analysis as critical uncertainties faced by them. This Company has been using all three types of PSS to complement their high technical product platform. Hence getting the market and environmental analysis is important, because they have invested a lot in R&D. With the sophisticated product platform, they have less probability in uncertainty with product function, but if it occurs, then the consequence is high. This also leads to reliability being paramount with high quality, in order not to affect the service offers or contracts. PSS integration scored also high as the product platform has to be well coordinated with the service platform.

![Company F - Uncertainty Factors](image2.png)

**Figure 19 Company F Uncertainty Factors**
Company-G evaluated supplier coordination and communication as major uncertainties followed by innovative services and product service integration. Most of their planning phase uncertainties are very low as they are more into production of low to medium technologies and the market is stable in terms of change in technology and customer needs. More emphasis is given to communication breakdowns uncertainties, like having proper knowledge sharing process.

Figure 20 Company G Uncertainty Factors

Company-H had high uncertainty with market analysis, as change in customer needs would lead to negative effect on implementing changes. They have low uncertainty with product function, as they believe they have a very good product platform to develop and add new functions to their products. It goes the same with innovative services too, they have a good platform developing their services and this Company has been forefront in coming out with new PSS strategies over the years. PSS integration, supplier coordination and communication are other major uncertainties faced by this Company. Reliability uncertainty is also more concentrated on, as quality was paramount to their service type offer. However, since they have a good quality check system, the uncertainty is not high as others.

Figure 21 Company H Uncertainty Factors
# Appendix

## Overall Score of Uncertainty Factors

<table>
<thead>
<tr>
<th>Company</th>
<th>Market Analysis</th>
<th>Company Analysis</th>
<th>Environmental Analysis</th>
<th>Reliability</th>
<th>Product Function</th>
<th>Innovative Services</th>
<th>Product/Service System Integration</th>
<th>Supplier Coordination</th>
<th>Communication</th>
<th>Remanufacturing</th>
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<tbody>
<tr>
<td>Company A</td>
<td>12</td>
<td>4</td>
<td>15</td>
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<td>6</td>
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<td>15</td>
<td>6</td>
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<td>8</td>
<td>8</td>
<td>16</td>
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<td>86</td>
<td>78</td>
<td>87</td>
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<td>30</td>
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</table>
### Risk response for each uncertainty factor

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<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
<th>Company E</th>
<th>Company F</th>
<th>Company G</th>
<th>Company H</th>
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<td><strong>Group I (P.O.S)</strong></td>
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<td>Market Analysis</td>
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<td>Both</td>
<td>Active</td>
<td>Active</td>
<td>Both</td>
<td>Passive</td>
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<td>Product Function</td>
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<tr>
<td><strong>Group II (U.O.S, R.O.S or P.O.S)</strong></td>
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<td>Remanufacturing</td>
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</table>
## Type of PSS used by individual Companies

**Table 16 Type of PSS used by individual Companies**

<table>
<thead>
<tr>
<th>Company</th>
<th>Type of PSS</th>
</tr>
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<tbody>
<tr>
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<td>P.O.S</td>
</tr>
<tr>
<td>B</td>
<td>P.O.S</td>
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<td>G</td>
<td>P.O.S/U.O.S/R.O.S**</td>
</tr>
<tr>
<td>H</td>
<td>P.O.S/U.O.S</td>
</tr>
</tbody>
</table>

*Company C is not using Use Oriented Services anymore but had previously been using this business strategy for many years.*

**P.O.S – Product Oriented Service**

**U.O.S – Use Oriented Service**

**R.O.S- Result Oriented Service**
PSS Risk Score between Group I and Group II Companies

Table 17 PSS Risk Calculation

<table>
<thead>
<tr>
<th></th>
<th>Group I</th>
<th>Group II</th>
</tr>
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<tbody>
<tr>
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<td>Market Analysis</td>
<td>Company Analysis</td>
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<tr>
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<td>Company D</td>
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<td>Average GI</td>
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<table>
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<tr>
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<tr>
<td>Company F</td>
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<td>Company G</td>
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<td>4</td>
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<td>Average GII</td>
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<table>
<thead>
<tr>
<th>Ratio **</th>
<th>117%</th>
<th>80%</th>
<th>121%</th>
<th>100%</th>
<th>223%</th>
<th>161%</th>
<th>160%</th>
<th>200%</th>
<th>159%</th>
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</thead>
<tbody>
<tr>
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</table>

*Yellow color indicates the uncertainty factors with very high overall risk ratio.

**Ratio is between Group I and Group II Companies. (G1/G2)
### PSS Probability Score between Group I and Group II Companies

**Table 18 PSS Probability Calculation**

<table>
<thead>
<tr>
<th></th>
<th>Market Analysis</th>
<th>Company Analysis</th>
<th>Environmental Analysis</th>
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<th>Product Function</th>
<th>Innovative Services</th>
<th>Product Service System Integration</th>
<th>Supplier Coordination</th>
<th>Communication</th>
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</table>

*Yellow color indicates the uncertainty factors with very high probability ratio.

**Ratio is between Group I and Group II Companies. (G1/G2)**
# Appendix

## PSS Consequence Score between Group I and Group II Companies

### Table 19 PSS Consequence Calculation

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<tr>
<th></th>
<th>Market Analysis</th>
<th>Company Analysis</th>
<th>Environmental Analysis</th>
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<th>Product Function</th>
<th>Innovative Services</th>
<th>Product Service System Integration</th>
<th>Supplier Coordination</th>
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*Yellow color indicates the uncertainty factors with very high consequence ratio.*

**Ratio is between Group I and Group II Companies. (G1/G2)**
## PSS Opportunity between Group I and Group II Companies

### Table 20 PSS Opportunity Calculation

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*Purple color indicates the opportunities viewed by each Company in the list of uncertainty factors.  
*Yellow color indicated the highest total number of Companies viewing the particular uncertainty factor as an opportunity.