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MULTI-ACTOR DESIGN AND RISK ASSESSMENT OF PRODUCT-SERVICE SYSTEM (PSS) IN FURNITURE INDUSTRY

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ABSTRACT

The competition within furniture industry is getting more intense shown by the high competition and changing trend in the society. In Indonesia, based on the data from the Ministry of Industry, the export of national furniture is rising from the past two years (2016-2017) and expected to increase in the following year. The sales are targeted to hit US $5 billion by 2019. Therefore, a different and innovative strategy should be implemented, so a company can be distinguished in the market with many competitors. One of the strategies is to apply different business models such as Product-Service System (PSS). Through its integration on product and service, PSS can be used to give solution for the company and answer the question about consumer's need. The proposed business model is use-oriented service which provide furniture renting. However, before adopting this new business model, the company needs to do planning to set the right strategy in developing the furniture business. The needs of manufacturer is obtained from the previous research. While for service providers, there are 10 criterion, which are cost, management, performance, empathy, customization, deliver, company readiness, policy, and company reputation. On the other hand, customer requires 13 criterion which are affordable rental rate, easy to purchase, product information, good service, ease of delivery and return on rented furniture, multifunctional, customization, low maintenance, easy to use, durability, policy, anticipation of unexpected events, and environmentally-friendly. By using Fuzzy-AHP and multi-layer QFD, it is found that providing consultation service, insurance service, and online apps are the most appropriate technical responses to answer the need of all actor. The result is used to create a PSS blueprint. However, new business model can be risky. Therefore, an assessment of risk is done using House of Risk. From HOR1, 8 of 15 risk agents were chosen because of its cumulative of occurrence reach 80%. Then, HOR2 was constructed to determine what preventive actions that can decrease the occurrence of risk agents for all actors.

Keywords: PSS, Multi-actor QFD, Risk Evaluation, House of Risk

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Surabaya, July 2018

Author

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CHAPTER 1
INTRODUCTION

This chapter contains the background of the research, problem formulations, research objectives, research benefits, research scope, as well as the outline of the report to give the big picture.

1.1 Background

The competition in furniture and home furnishings market indicates an escalation in the number of business players and brands (Porter, 2008). Over the past five years, the compound growth rate has been 4.1% heading to $96.57 billion in 2016 in the U.S. As shown in Figure 1.1., the trend of furniture and furnishing is growing over years. This shows a promising business for the industry.

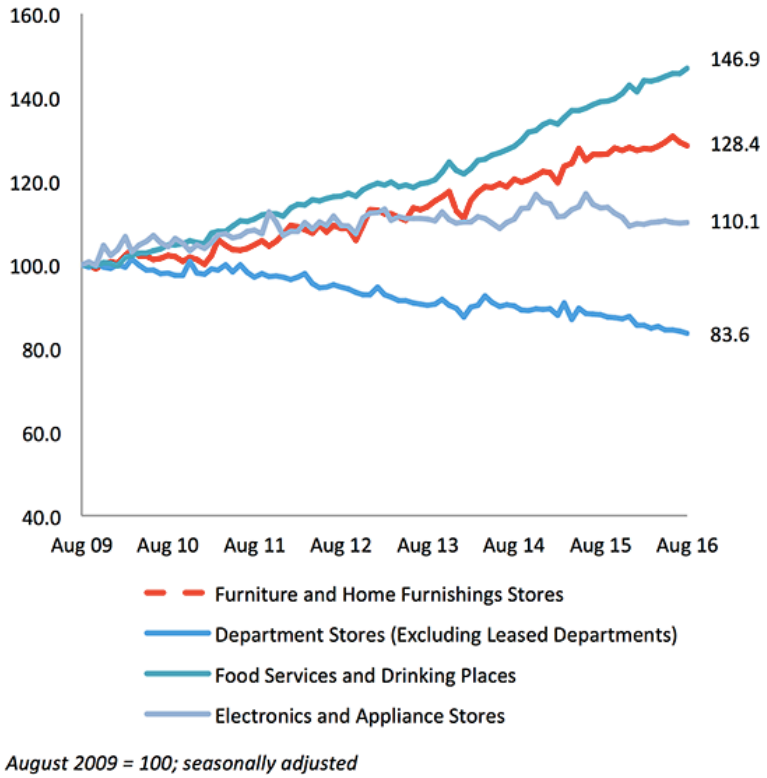


Figure 1.1 US Furniture Sales vs. Other Retail Sectors Index
(Coresight Research, 2016)

While in Indonesia, based on the data from the Ministry of Industry, from January to November 2017, the export of national furniture is worth US $1.489 billion. In the same period, in the preceding year, the export was worth US $1.465 billion. The rate is expected to increase in the following year, targeting sales of US $5 billion by 2019. Even more, according to the chief of HIMKI (Indonesian Association for Furniture Industry and Craft), the furniture industry is predicted to grow at the rate of 12-16% in 2018 (Rini, 2018). Reflecting on this occurrence, furniture manufacturer should have a new planning because the competition within the industry is getting more intense shown by the high competition. A different and innovative strategy should be implemented, so a company can be distinguished in the market with many competitors.

One of the strategies is to apply different business models such as Product-Service System (PSS) which is a business model that integrates product and service. PSS has an objective to increase competitiveness, customer value, and to reduce the negative impact on the environment (Geng et al., 2010; Kim et al., 2012). Rather than just producing a large volume of products that meets specification and standard, this business model concerns more on the capability for continuous innovation, improving design and quality, and create customized goods that lead to product differentiation. It is also found that integrating products and services is a growing trend among companies in today's globally competitive business environment (Mont, 2002; Tan, 2010).

PSS is discovered to be able to develop companies and to gain a competitive advantage (Manzini and Vezzoli, 2003). It is also a way to offer product and service that has the potential to improve efficiency, which can lead to positive economic and environmental effects for industry and society (Mont and Tukker, 2006). As an additional value, PSS is also a supporting action towards sustainability. The concept is based on the fundamental of triple bottom lines where it is actually concern about people, planet, and profit as shown in Figure 1.2.

Figure 1.2 Sustainability
(BNAC Environmental Solutions, 2016)

The nature of a business is to gain profit, it is very reasonable when a company wants to earn income as much as it can (profit). Along with this action, when a company uses the resources wisely to give less impact on waste, energy footprint, and protect the environment then the process will be environmental friendly (planet). Since the production happens in a company and how the product will be used in society is a form of social preferable (people), a company that supports sustainability will give economic benefit to clients' operations full benefit from many aspects.

PSS shifts the strategic focus from a pure product to an integrated product-service strategy. According to Baines et al. (2007), PSS can be seen as a new proposition that broadens the traditional use of a product through the integration with service so it is the function to deliver. There have been various attempts to classify the diverse types of PSS which are product-oriented, use-oriented, and result-oriented service. An example of PSS adoption is renting and leasing that has

become widely used to help customers obtain certain products with the help of service provider as a third party.

The majority of past studies have consistently concluded that PSS has a positive effect on company performance, customer satisfaction, and competitive advantage. There are several journals discuss the implementation of PSS on furniture, but the amount is still limited. Furniture renting can already be found in some countries around the world, including Indonesia. Presently, the implementation of renting home furniture has not become a lifestyle, but the trend of renting is already there. As seen in Figure 1.3, baby's product such as stroller, carrier, and baby walker are already provided and ready to borrow via website. With a similar purpose, tokorental.com also creates a website to serve leasing transaction for more products like gadget, gaming, sound system, car, and even for house. From these two websites, it can be seen that actually renting or use-oriented business model is not a completely new system in Indonesia.

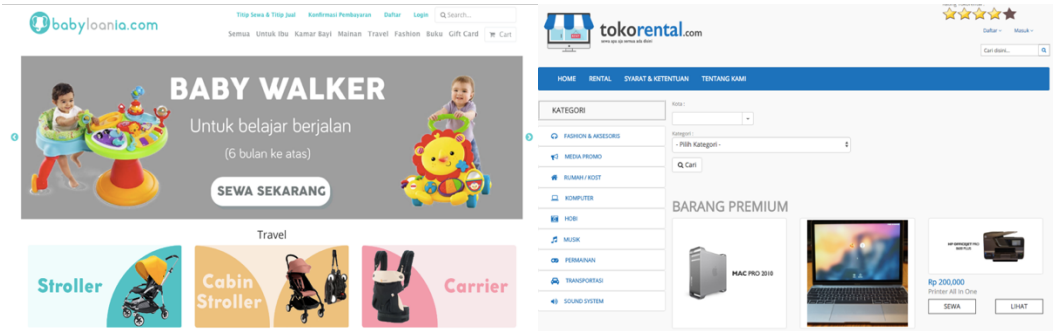


Figure 1.3 Baby Product and General Product Renting Website (Babyloania, 2018; Toko Rental, 2018)

Currently, there are also some websites that already provide furniture rental as the company's service either for home interior, store decoration, or even corporation as shown in Figure 1.4. Arbor & Troy and The Mahogany are two examples of companies that implement the business model.

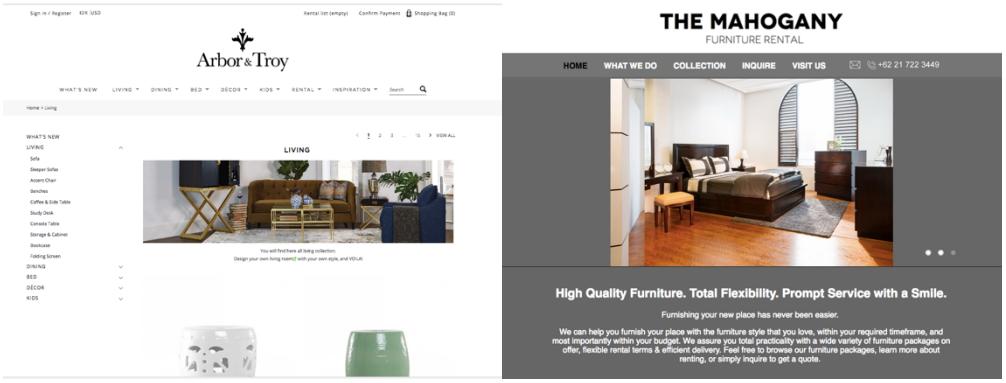


Figure 1.4 Furniture Renting Website
(Arbor & Troy, 2018; The Mahogany, 2018)

However, before adopting this new business model of PSS, the company needs to do planning to set the right strategy in developing the furniture business. Even though it is for the company's purposes, in this case the manufacturer, the company is not the only party should be focused on. Customer and service provider also take roles in determining how successful the new business model will be. Thus, Multi-Actor PSS is designed. Data will be gathered and utilized to list the general needs of each party. By using Fuzzy-AHP and multi-layer QFD, PSS can be constructed involving all three actors (manufacturer, customer, and service provider).

Since implementing new business model is a risky footstep, where the implementation does not always succeed, therefore assessing risk is necessary. By identifying all risks that might occur, an assessment can be done through the identification with Risk Breakdown Structure, Aggregate Risk Priority and HOR analysis, and mitigation.

Currently, the newly carried out research in the furniture industry in Indonesia was still limited to multi-actor PSS design with two actors involving only customers and manufacturer (Afiatna, 2016). On the other hand, there is no further research discusses the risk management of PSS implementation in Indonesia's furniture industry. To completely adopt the system and get the big picture, more study is required. Therefore, research in multi-actor PSS design involving service provider and risk assessment in the furniture industry is required.

Following the new-carried out research by Afiatna (2016), the case study in this research will be conducted at PT Exigo. PT Exigo is a furniture producer and also engages in interior design service for house interior to public space and mass production. PT Exigo has been focusing on creating great design since 2003 by being selective on material selection, careful supervision of production process, and manage the time scheduling to deliver them qualify product on time. The company's mission is committed to being the best partner of its customer in creating their interior space and striving to serve them as optimally as possible, by providing the best design and quality in the product. Customer satisfaction and easiness in are the company's goal. After years, the company wants to expand the furniture business by not only being product-oriented but integrate product and service to meet customer needs with use-oriented business model. For that reason, this research is aimed to design an appropriate PSS model for PT Exigo as an example of the furniture industry in general and assess the risk of its implementation from multi-actor perspective.

1.2 Problem Formulation

This research is to fill the gap in the existing research which has not considered the service provider in the current design of PSS business model of furniture industry and the risk assessment on how it will affect the manufacturer, service provider, and customer in term of risk.

1.3 Research Objectives

Formed on the research background and problem formulation, the objectives of this research are:

1. To involve service provider in the multi-actor design of Use-oriented Service PSS for furniture industry.
2. To assess the risk in adopting Product Service System concept using the House of Risk (HOR) in multi-actor point of view.

1.4 Research Benefits

In reference to the research objectives, the benefits will be obtained by the company are:

1. The PSS that has been designed can be made as a reference in making business development model. The analysis can help to give consideration to the implementation of PSS as a part of its competitiveness, which is expected to open the opportunity in doing the strategy.
2. Company can take the right action to prevent and avoid risks that might occur in PSS implementation.

1.5 Research Scope

The scope of the research is bounded by some limitations used while conducting this research as listed below:

1. The PSS business models used for the design is Use-oriented Service because this is the most approaching business model for manufacturing product. For Use-oriented Service, product renting in furniture industry will be analyzed.
2. The sample of customers is active customers in Surabaya.

1.6 Report Outline

In pursuit of understanding the big picture of this research, the following is the outline of the research report.

- CHAPTER I – PREFACE

  This chapter contains the background of the research, problem formulation, research objectives, research benefits, and research scope.
- CHAPTER II – LITERATURE REVIEW

  This chapter elaborates the theoretical base used to conduct this research related to the concepts which are Product-Service System (PSS), Fuzzy-AHP, Multi-layer QFD, Risk Management, Use-Oriented Business Model Application, and review of previous research.

- CHAPTER III – RESEARCH METHODOLOGY

  This chapter defines the methodology and its explanation to guide the research process in becoming a systematic and clearly directed research. The phases are classified into two phases which are preliminary stage, PSS design, and risk management.
- CHAPTER IV – MULTI-ACTOR PSS DESIGN

  This chapter contains the information of the object of observation, the process of creating use-oriented service (UoS) design , and multi-layer QFD.
- CHAPTER V – RISK ASSESSMENT

  This chapter contains the preliminary study for risk assessment, risk identification, risk analysis, HOR 1, HOR 2, and risk evaluation.
- CHAPTER VI – ANALYSIS AND INTERPRETATION

  This chapter contains the analysis and interpretation of multi-actor PSS Design and risk assessment in the two previous chapter.
- CHAPTER VII – CONCLUSION AND SUGGESTION

  This chapter consists of the conclusion of the research and the suggestions offered to the company to solve the identified problem in PT Exigo

CHAPTER 2
LITERATURE REVIEW

This chapter elaborates the theoretical base used to conduct this research related to the concept and works of literatures that support researcher's comprehension, which are Product-Service System (PSS), Multi-Actor Design, Risk Management, and review of previous research.

2.1 Product-Service System (PSS)

Triggered by the need for a more effective and sustainable way of planet's wealth usage, research on PSS field acknowledge the great possibility for balancing economic, social, and environmental interest (Mont, 2002; Tukker, 2004). Tukker and Tischner (2006) define PSS as 'a mix of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling final customer needs'. On the other hand, Mont (2002) focuses on the purpose of fulfilling customers' needs and being competitive. Goedkoop, Mark J; Halen, Cees JG van; Riele, Harry RM te; Rommens (1999) declares that PSS is a marketable set of products and services that have what it takes to cooperatively giving what the purchasers ask for. However, the first definition that ties in PSS with sustainability was stated by Mont (2002) "a system of products, services, supporting networks and infrastructure that is designed to be competitive, satisfy customer needs and have a lower environmental impact than traditional business models". Thus, it can be summarized that PSS is a business model that specifies its target toward the procurement of marketable collection of products and services, managed to be money-saving, socially and environmentally sustainable, with the final intention of fulfilling what customer needs (Annarelli et al., 2016).

The concept of the system shows that product and service in PSS shouldn't be on one's own but it can be simply put together. Both terms establish an offering where boundary lies between physical and non-physical elements are blurred (Meier et al., 2010; Tukker, 2004). PSS business model might be the critical factor that tell apart PSS with positive results in terms of eco-efficiency and sustainability

from other business models that has not yet included the aspect of environment into the business (Ceschin, 2013). Bocken et al. (2014) emphasized the importance and difficulties of developing sustainable business models that can make it on three essential components called triple bottom line which is environmental, economic, and social levels. (Lee et al., 2012).

2.1.1. Classification of Product-Service System (PSS)

PSS is categorized into three main parts, namely product-oriented, use-oriented, and result-oriented service. These parts will be divided into some subcategories for more details as shown in Figure 2.1.

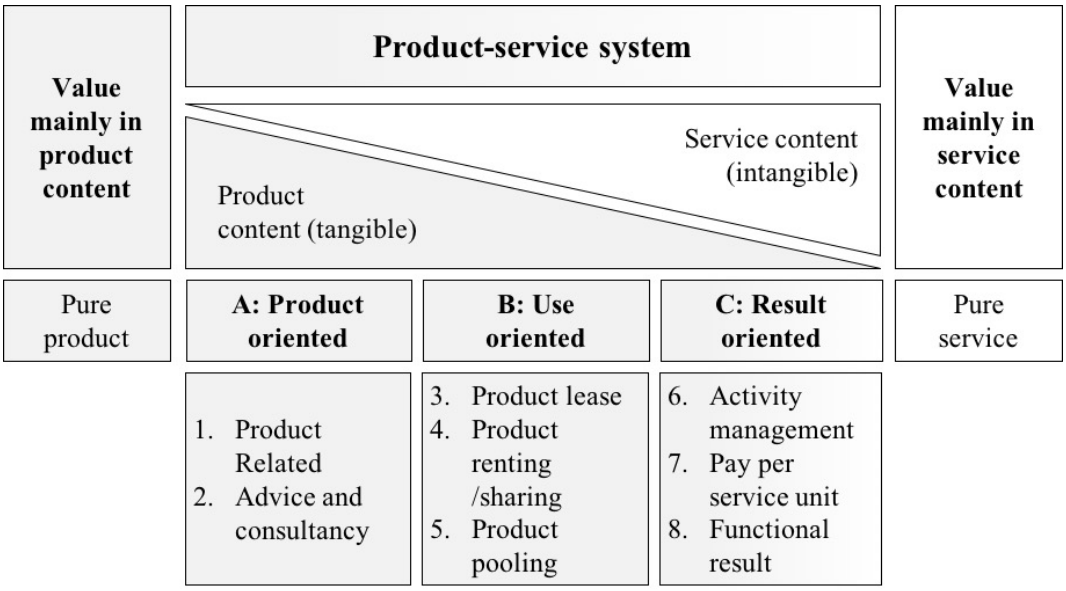


Figure 2.1 Categories of PSS
(Tukker, 2004)

In the Product-oriented Service (PoS) category of PSS business models, a provider not only sells its product. Delivering service related to the product is also a part of the duty one has to commit to (Tukker, 2004). PoS is divided into two subcategories which are product-related service and advice and consultancy. The first one, product-related service, is where a provider does not only offer the product but also some service that may be needed during the product life cycle. Here, the material ownership of the product being sold is transferred to the customer and

services such as warranties and maintenance are presented in order to ensure the utility of the product. While the second one, advice and consultancy, gives some suggestion to optimize the product usage.

In the Use-oriented Service (UoS) category of PSS business models, instead of selling a physical product, a provider opens the opportunity of leasing agreement and makes it available for rental (Tukker, 2004). The provider still run a production but shifts its process into selling the function of the product. In this model, service provider takes part in retaining the ownership of the material and as the party that the customer pays for since the product is used over a period of time or units of service. The first UoS is product lease where the ownership of the product is still owned by the provider and customer pays for the use of the product and own unlimited access to the product. The second one is product renting or sharing where customer also makes payments for the function of product, but this time customer does not own the privileges of access and access is limited. In this model, product can be used more than one customer at different times. The last but least is product pooling where a product is more simultaneously used by different customers (Gaiardelli et al., 2014).

While in the Result-oriented Service (RoS) category of PSS business models, a provider agrees to provide the customer with a certain result or outcome rather than a specific product or service (Tukker, 2004). The service provider, as in UoS, also keeps the ownership rights of the product. The difference is that customer does not make expenditure for the use of the product, but rather purchase an expected outcome. The first subcategory in RoS is activity management or outsourcing that use third party to do the company's activity. The next one is pay per service unit where customer pays based on the output resulted by a product. While in functional result, the company has the most flexibility to deliver the products' output.

A company's business model explains the design or architecture of the company's mechanisms to create, deliver, and capture value (Teece, 2010; Osterwalder and Pigneur, 2010). In Table 2.1, each model has its own value based on creation, delivery, and capturing that differentiate one to another.

Table 2.1 Comparison of Business Model Categories

	Product-oriented Service (PoS)	Use-oriented Service (UoS)	Result-oriented Service (RoS)
Value creation	Provider takes responsibility for the contracted services.	Provider is responsible for the usability of product and service.	Provider is responsible for delivering results.
Value delivery	Provider sells and services the product sale and service. (e.g., maintenance or recycling)	Provider assures the usability of the physical product along with service.	Provider actually delivery result.
Value Capturing	Customer pays for physical product and performed service.	Customer can make continuous payments over time (e.g., leasing)	Customer payments are based on outcome unit.

Source: Reim et al., 2015

From each model, Kim makes guidance as a reference to design PSS business model in order to solve the needs of consumers in general. Table 2.2 is the PSS business model based on the category that has been identified.

Table 2.2 PSS Model Elaboration

PSS Category	PSS Model	Description
Product-oriented PSS	Recycle service	Reuse service, recondition or re-manufacture
	Maintenance service	Repair and maintenance service
	Capital budgeting service	Financial budgeting service for product procurement
	Diagnose service	Monitor and diagnose product condition which used by customer
	Information service	Required information by customer regarding the product
	Consultation service	Provide consultation service for optimum usage of product
	Education service	Provide knowledge to customer regarding product usage
	Installation service	Product installation or assembly

Table 2.2 PSS Model Elaboration (con't)

PSS Category	PSS Model	Description
Product-oriented PSS	Agency service	Service to represent customer job
	Trial Service	Provide trial version of product/service
	Life cycle service	Provide product service during product life cycle
	Total package solution	Provide one-stop package solution
	Customized solution	Provide custom product/service based on customer order
	Sale by component	Provide spare parts for repair or upgrade activity
	Expansion of access	Offer and make new method for customer to access the product/service
Use-oriented PSS	Self-service	Service provided for customer who wants to serve themselves
	Sharing	Product/service sharing with another customer
	Leasing and renting	Leasing or renting product or service rather than buying them
	Endowment of right to use	Provide member or reservation system for customer to use product/service
Result-oriented PSS	Guarantee of result	Guarantee of the product/service
	Pay-per-use payment	Customer pay the product/service based on their usage

Source: Kim et al., 2012

2.1.2. Benefits of PSS Implementation

Based on 62% of articles, the most frequently recognized benefit of PSS is how effective it is to create reduction of environmental impact, which is the why and wherefore PSS is developed and implemented (Goedkoop et al., 1999; Williams, 2006) sometimes this benefit is also known as the conjunction with "Image Improvement" (Gelbmann and Hammerl, 2015; Wagner, 2013). Being different is also an important benefit, as stated that PSS is recognized to be able to provide strategic market opportunities and be an option for standardization and mass production. It is an advancement in giving total value to customers through adding service elements (Baines et al., 2007).

PSS can bring products closer to the customers and allow them to customize to a larger extent than traditional products. PSS can thus create a more personalized

experience and increase the added value received through these offerings (Gebauer et al., 2005; Penttinen and Palmer, 2007).

Another important benefit is that PSS implements “Locking-in customers” that is related to customer engagement, which was recognized first by Vandermerwe and Rada (1988) and Wise and Baumgartner (1999). The end goal has shifted from gaining the largest share of customers into obtaining the strongest relationship with the most profitable customers. As it is locking-in the customer, it is also locking out the competitors. The innovation created through the business model makes it harder to be imitated by others.

Consumption efficiency and production efficiency, which are always cited together (Cook et al., 2006) are two of other PSS benefits. It allows better exploitation of resources, produce less waste, and have better product lifecycle and utility. Moreover, joining service together with product may also introduce advantages from the producer's frame of reference, through the application of reuse & recycling policies because reused components could be remanufactured, reutilized and recycled into new products. This life cycle clearly gives more sustainable production system than creating from scratch. From customer’s point of view, continued lifespan of products points to greater efficiency during the consumption phase.

More advantage from applying PSS business model is cost reduction (Goedkoop et al., 1999; Heiskanen and Jalas, 2003). Simultaneously, it can lead to the increase of revenue gained by provider. Furthermore, the government can also gain some advantages since the company can help constructing policies to promote sustainable patterns of consumption. A wider chance is opened to develop new market opportunities for companies (Manzini et al., 2001).

2.2 Multi-Actor Design

In this research, the actor involved in the making of PSS design is more than one. Manufacturer, service provider, and customers are the three actors needed to be considered. Thus, a multi-actor design is applied in developing multi-layer QFD and Fuzzy-AHP.

2.2.1 Multi-layer QFD

Customer satisfaction is the main goal or priority of studying quality. Among the various approaches, Quality Function Deployment (QFD) is one that exclusive and also object-oriented in the quality control science. In the beginning of assessment, this method should be occupied in order to increase the process of manufacture and service. Moreover, this ensures the customer satisfaction. QFD was first developed by Yoji Akao in 1966 and created to assess based on customer inputs. According to Subagyo, (2000), QFD is a way to develop the quality of goods or services by understanding what the consumers need then link it with technical provision to produce goods or services at each stage.

According to Warwick (2016), the aims of using QFD are to get higher quality of products to market faster and at a lower cost; to create products that meet customer expectation; to provide tracking system for future development. By carrying QFD, there are some advantages that user wants to achieve:

- Better understanding of customer needs
- More advance organization on development projects
- Improved introduction to production
- Less changes in design in the development project
- Less issues related to manufacturing start-up
- Gain the product with quality reputation
- Increased business
- Documented product definition based on customer requirements.

QFD is commonly interpreted as a matrix within a form of a house, called House of Quality (HoQ). HoQ matrix is known as the tool and can be described as shown in Figure 2.2.

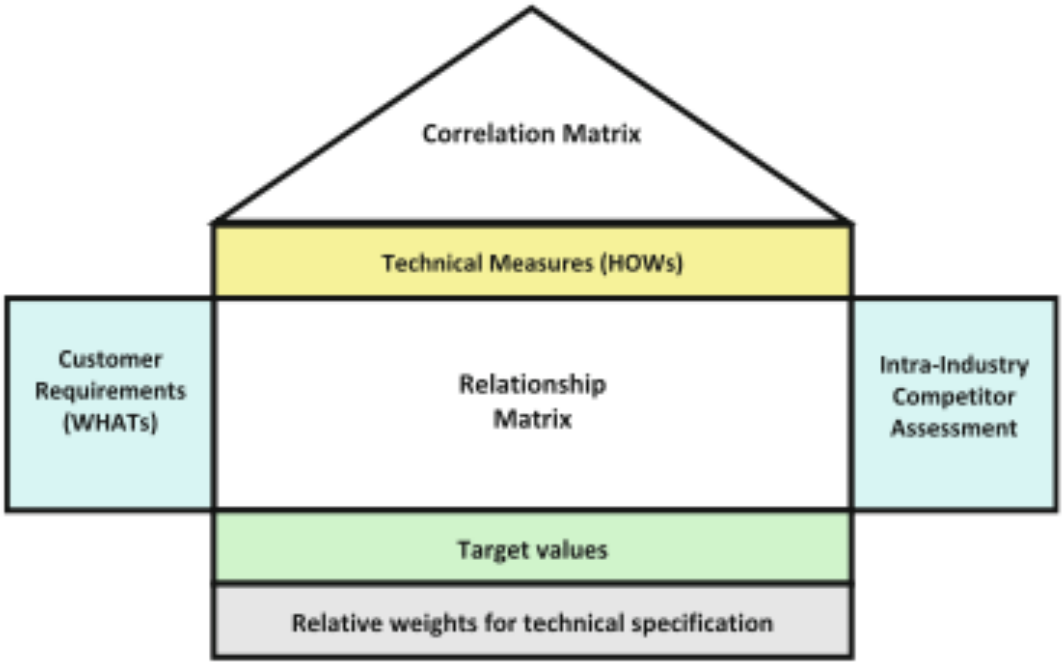


Figure 2.2 Traditional HoQ
(Duru, et al., 2011)

In general, there are six main components in HoQ. There are (Tan &Pawitra, 2001; Wijaya, 2011, Tjiptono, 2003; Rampersard, 2003; Marimin, 2004; Yuri and Nurcahya, 2013):

1. Customer Requirement Matrix (WHATs), is a matrix that lists the needs and wants of consumers;
2. Intra-Industry Competitor Assessment (WHYs), is a matrix that describes the perceptions of the observed customer based on survey or research. This is used to translate customer needs into strategy to meet those needs;
3. Technical Response Priorities Matrix (HOWs), is a matrix that contains company's responses or answers to meet fulfill requirements;
4. Relationship Matrix, is a matrix that describes the QFD team's perception of the relationship between the response technique and the customer requirement. Table 2.3 shows the symbol used in showing the relationship.

Table 2.3 Symbol of Relationship Matrix

Symbol	Description
■	Strong Relationship
▲	Moderate Relationship
●	Low Relationship
∅	No Relationship

5. Technical Correlation (Roof) Matrix, is a matrix used to identify where technical responses support or interfere with each other in product design. Table 2.4 shows the symbol used in correlation matrix.

Table 2.4 Symbol of Correlation Matrix

Symbol	Description
++	Strong Positive Correlation
+	Positive Correlation
-	Negative Correlation
--	Strong Negative Correlation
∅	No Correlation

6. Technical Response Priorities (Floor) Matrix, is a matrix used to record the priorities of the technical response matrix.

2.2.2 Multi-layer QFD Framework

In traditional QFD, it only consists of two layers or dimensions. While in Multi-layer QFD, it is a three-dimensional HoQ as shown in Figure 2.3.

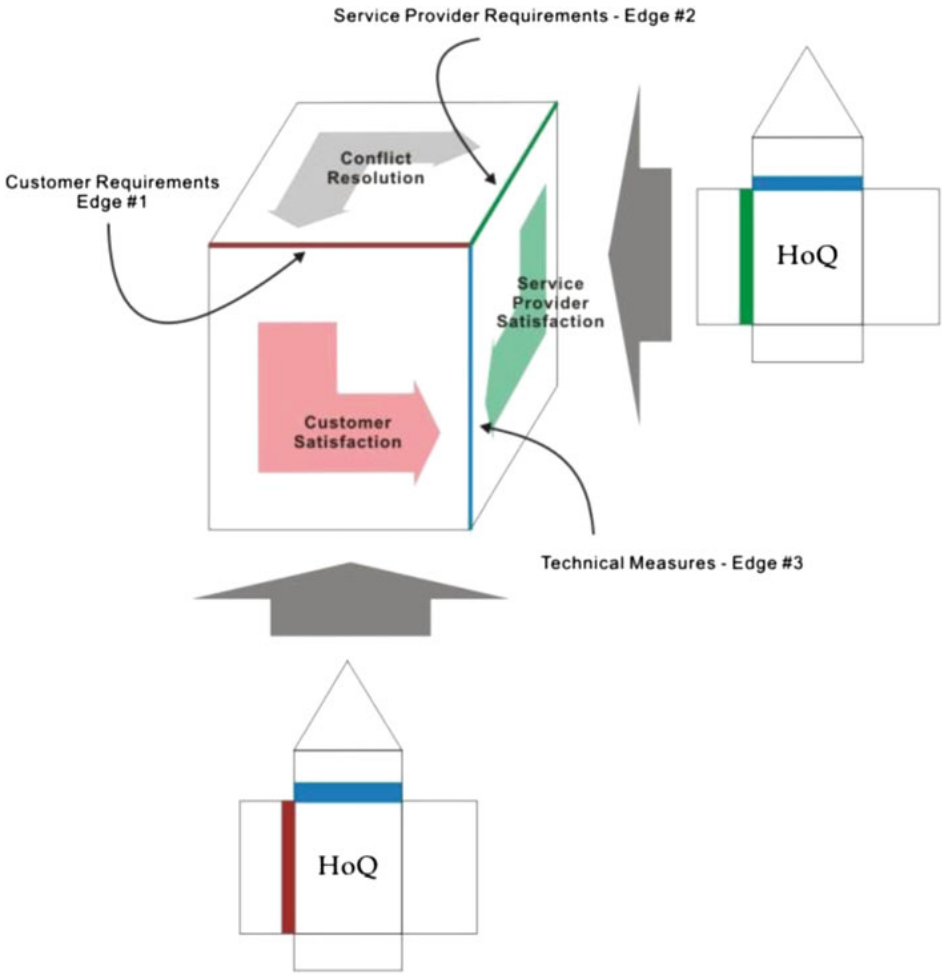


Figure 2.3 Multi-layer QFD
(Surjani et al., 2015)

From the illustration, the anterior surface of the cubical shows the traditional HoQ which is customer-oriented (customer satisfaction face). On the other side, the right-hand side of the cubical indicates the service provider oriented HoQ matrix. Both matrices will have the technical response indicator on edge #3. Even though both of the matrices are identical, the requirements are not the same.

On edge #1 and edge #2, the requirement of customer and service provider or manufacturer are indicated respectively. The top side shows the cross-synthesis matrix for conflict resolution and the size depends on the requirement from both parties, which is based on the needs of service providers and companies. The value of the company's needs and service providers is obtained from interviews and analyzed with Fuzzy-AHP. After cross synthesis analysis, the relative weight to be

studied will be obtained. Then, HoQ is combined with matrix in which there is relative weight that can be used for the preparation of the concept design.

2.2.3 Cross-Synthesis

The cross-synthesis analysis is a part of the multi-layer QFD framework to solve the conflict of interest between customer and service provider (or manufacturer). Each party defines one's intention and rate the importance which will be formulated into relationship matrix to show how each of them correlated and support or against each other.

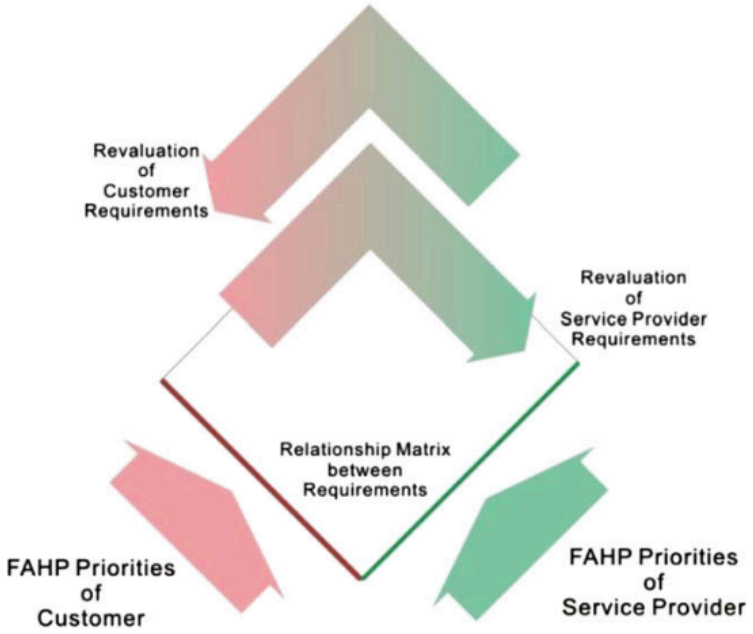


Figure 2.4 Conflict Resolution Layer for Cross-Synthesis Analysis (Duru et al., 2013)

Figure 2.4 shows the resolution layer for cross-synthesis analysis. By using priority assessment of Fuzzy-AHP method, the relative importance of the requirements is identified. The next step is to gain estimation of the implied relative importance from the perspective of the counterparty which is obtained from the product of relationship matrix and the relative importance of the counterparty. The synthesis can be accomplished by finding the average of relative importance of a party and the implied relative importance of the counterparty.

2.2.4 Fuzzy-AHP

The Analytic Hierarchy Process or known as AHP is a measurement with general theory. It transforms discrete and continuous paired comparisons to develop ratio scales. These comparisons may be referred to actual measurement or fundamental scale that indicate certain relative strength of preference and feeling (Saaty, 1987). The common AHP is known to be a nonlinear framework for executing both deductive and inductive thinking without using instance form of reasoning by taking several factors into consideration and allowing for dependence and feedback, then construct numerical arrangement to build a conclusion. This method is developed by Thomas L Saaty in 1971-1975. The differences between AHP and other methods is the data input. Instead of using quantitative data as the input, AHP can process qualitative data. The use of its hierarchy eases the grouping of unstructured issues. Moreover, traditional method creates decision defines priorities among different criterion and rank all alternatives while AHP will come out with the best choice of existing alternatives and process multi-criteria issues into a hierarchical model. The steps to execute AHP are divided into some steps:

1. Outline the decision issue into hierarchical form. The top level of hierarchy serves as the overall objective of the decision problem, the intermediate level serves as the criteria and sub-criteria influencing the decision, and the bottom level serves as the possible choices.
2. By using pair-wise comparison, measure the relative importance weights of decision criteria in each level of the hierarchy. The fundamental scale or weight used is between 1 (equal importance) and 9 (extreme importance) to score the priority for each pair in the same level as stated by Saaty. Then, for each criterion in normalization, calculate the average weight.
3. Assess the decision alternatives by considering the weight from decision criterion. Combine alternative scores with criterion weights to have the result of overall score for each option.

The advantage of AHP over other multi-criteria methods are listed below:

1. Flexibility, intuitive appeal to the decision makers and its ability to test any inconsistencies (Ramanathan, 2001). Users discover that the pairwise comparison form of data input are straightforward and convenient.

2. It disintegrates a decision problem into parts that constituents and evolves hierarchies of criteria. Here, the importance of each element of criterion becomes clear (Macharis et al., 2004).
3. The ability to capture both subjective and objective evaluation measurement is also one of the strength. This leads to bias reducing in decision making while providing a useful mechanism for checking the consistency of the evaluation measures and alternatives.
4. By calculating the geometric mean of each pair comparison, AHP method supports group decision−making through consensus (Zahir, 1999).
5. The capability of deriving scales makes AHP in a uniquely positioned to help model situations of uncertainty and risk where ordinarily do not exist (Millet and Wedley, 2002).

Conventional AHP cannot adjust the ambiguity of the subjective assessment, so F-AHP is the solution to give more valid result. Fuzzy-AHP is an alternative method by using AHP combined with fuzzy logic to make the results more accurate. Fuzzy AHP uses linguistic assessment on pairwise comparisons that are represented by triangular fuzzy numbers. Furthermore, the results of paired pairwise comparisons and syntheses of alternative options are to be performed.

To select an alternative by using F-AHP, first, the hierarchy should be compiled from the problem, and specify the table showing the matched pair matrices using Triangular Fuzzy Number scale. Triangular Fuzzy Number or TFN is illustrated by 3 numbers (l, m, u) where l is for the lower (pessimistic), most likely, and upper (optimistic) to describe the fuzzy event. Table pairwise comparison can be seen in Table 2.5.

Table 2.5 Triangular Fuzzy Number and Inverse Scale

No	Fuzzy Scale	Inverse Scale	Definition of linguistic variable	Fuzzy Scale	Inverse Scale
1	1 = (1,1,3)	(1/3,1,1)	Two elements have the same interests	1 = (1,1,2)	(1/2,1,1)
2	3= (1,3,5)	(1/5,1/3,1)	One element is slightly more important than the other.	2 = (1,2,3)	(1/3,1/2,1)

Table 2.5 Triangular Fuzzy Number and Inverse Scale (con't)

No	Fuzzy Scale	Inverse Scale	Definition of linguistic variable	Fuzzy Scale	Inverse Scale
3	5 = (3,5,7)	(1/7,1/5,1/3)	One element is more important than the other.	3 = (2,3,4)	(1/4,1/3,1/2)
4	7 = (5,7,9)	(1/9,1/7,1/5)	One element is much more important than the other.	4 = (3,4,5)	(1/5,1/4,1/3)
5	9 = (7,9,9)	(1/9,1/9,1/7)	One element is absolutely more important than the other.	5 = (4,5,5)	(1/5,1/5,1/4)

Source: Forhad et al., 2014; Kusumawardani and Agintiara, 2015

The linear scale 1-9 is the standard scale proposed by Saaty. The limit for which the consistency ratio (CR) is allowed is 10%. If a pair of matched comparison matrices which are rated more than 10% are not accepted. A more 1-5 scale is proposed to minimize CR value and to reduce the scale too large.

The decision maker gives the value of several alternatives that exist with TFN numbers that have been spoken with linguistic variables. After the assessment is completed then the next step is to define the fuzzy value of the assessment results for each alternative on each criterion.

The steps in using the F-AHP method for alternative selection are as follows:

1. The decision maker provides a pairwise comparison value for each alternative, criteria, sub-criteria that have been expressed with linguistic variables using the TFN scale found in Table 2.3
2. Calculation of the mean fuzzy geometry values for each alternative, criterion, and sub-criterion. The average value of fuzzy geometry can be calculated by the following formula.

$$\check{r} = \left(\prod_{j=1}^{n} d_{ij} \right)^{\frac{1}{n}} \tag{2.1}$$

i = 1, 2, 3, ..., n

3. Calculation of fuzzy weight for each alternative, criterion, and sub-criterion with the following formula

$$\tilde{\omega} = r_i x (r_1 + r_2 + \cdots + r_n)^{-1} \quad (2.2)$$
$$= (l_{wi}, m_{wi}, u_{wi})$$

4. Perform defuzzification on the calculation result in step 3 with Center of Area (COA) method with the following formula

$$M_i = \frac{l_{wi}, m_{wi}, u_{wi}}{3} \quad (2.3)$$

5. Normalization of the M value obtained in step 4 with the following formula

$$N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \quad (2.4)$$

In this research, F-AHP is used for weighting to the questionnaire that has been filled by service providers. The use of F-AHP is expected to eliminate the shortcomings of the AHP method, namely the high level of subjectivity.

2.3 Risk Management

The adoption of PSS business model can be risky and need plans to prevent the undesired event. By doing risk management, the probability of these events can be reduced. Risk is defined in relation to the consequence of activity in the future with respect to something that valuable in human's point of view. Often, these values are mentioned as planned values and objectives, and the focus is normally on undesirable consequences (SRA, 2015a). According (Collier and Agyei-Ampomah, 2008), risk can be seen from more points of view:

- Risk as threat (downside risk): negative event occurrence that need to be prevented to reduce the probability of negative impacts.
- Risk as uncertainty: the variance between anticipated and actual outcomes of all possible outcomes.
- Risk as opportunity (upside risk): possible event that can be seen as a source of opportunity to business.

Therefore, an action of reducing the likeliness of risk should be done by doing risk management. Risk management is a central part of any organization's strategic management. The focus is to identify and give treatment to these risks so

it can add maximum sustainable value to the business activity, understand the potential upside and downside, increase the probability of success, and reduce the failure chances. Managing risk involves establishment of the context, risk identification, risk analysis, risk evaluation, risk treatment, communication and consultation, and monitoring and critical review.

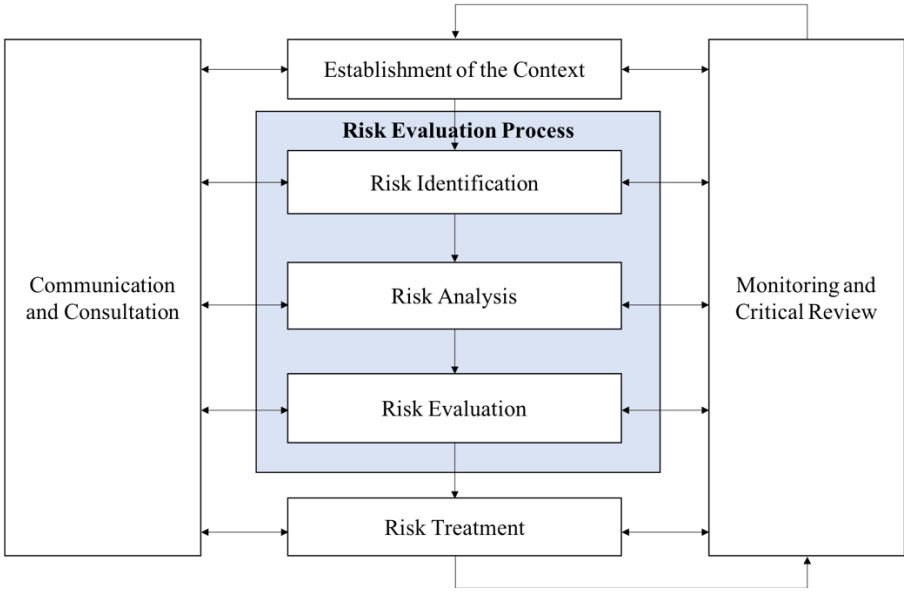


Figure 2.5 The Risk Management Process, adapted from ISO 31000:2009

The risk management process derived in ISO 31000:2009 is a generic model, as a basis to support organizations in developing and improving risk management system (ISO, 2009b) as shown in Figure 2.5.

2.3.1 Risk Identification

As the first step in evaluating risk, all the possible risks that might impact a project are generated. This usually happens during the planning phase and it is recommended to do it in group consists of the core team members and relevant stakeholders since it is proven that the judgments are more accurate that one mind does (Sniezek and Henry, 1989). The team conducts brainstorming sessions and other techniques to gather the information on potential issues. Participants need to be focused more on opportunity that can be value of the project and filter out unreasonable risks in the next stage of the process. The principal is to look at events

that can produce consequences and not on objectives. Solutions can be found if the participants keep focusing on actual events (Gray and Larson, 2014).

In identifying risk, the input should not be limited only to the core team members, so information can also be gathered from customers, sponsors, vendors, and other stakeholders. Information can be gathered through interview or active discussion. The final objective is to identify potential problems before it actually happens by doing proactive approach to risks (Gray and Larson, 2014).

2.3.2 Risk Analysis

The previous step produces a list of potential risk, however not all of them deserve the same attention. Therefore, a method needs to be applied in order to eliminate the inconsequential and highlight on larger risk. The process of analyzing risk requires clear definitions of different classification of risk probabilities and impacts. This definition might be varying depending on the project, but it must consider the need for the project.

There are three elements that can help identifying the risk which are likelihood, severity, and detection. The most common scales used are numeric rank (1-10, 1-5, etc.) and rank-order that with category of low, moderate, high, and very high (Gray and Larson, 2014).When a risk event has various likelihood, severity, and detection, then each severity also needs to be quantified. From the result, risk assessment matrix and risk mapping can be created. The example of risk assessment matrix is shown in Table 2.6 while Figure 2.6 presents the example of risk mapping.

Table 2.6 Example of Risk Assessment Matrix

Risk Event	Risk Number	Likelihood	Severity	Detection
Interface Problems	R1	4	4	4
System freezing	R2	2	5	5
User backlash	R3	4	3	3
Hardware malfunction	R4	1	5	5

Source: Gray and Larson, 2014

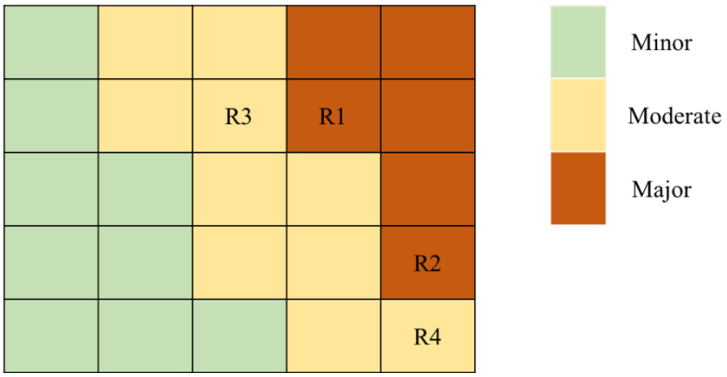


Figure 2.6 Example of Risk Mapping
(Gray and Larson, 2014)

For risk mapping, the determination of scale and area are decided by assessor and usually follow the company risk appetite. Risk appetite means the amount and risk type that a company is willing to take so that their strategic objectives can be achieved. If the company is a risk taker, then the minor or green part probably will take the bigger portion of all risks (Praxiom Research Group, 2017). The output is to have ranks and priority of the potential risk based on company risk appetite.

In order to continue the analysis, then assessment comes into the next stage which is House of Risk (HOR). HOR is divided into two phases. The first one or HOR 1 is used to rank each risk agent based on their aggregate risk potentials while HOR 2 aims to prioritize the proactive actions in dealing with the risk agent to maximize the cost-effectiveness. The output of HOR is to create Aggregate Risk Potential (ARP). ARP of risk agent j (ARPj) can be calculated as follows:

$$ARPj = O_i \sum_i S_i R_{ij} \quad (2.5)$$

Where: O_j = the probability of occurrence of risk agent j

S_i = the severity of impact if risk event i occurred

R_{ij} = the correlation between risk agent j and risk event i

ARP_j = the aggregate risk potential of risk agent j

2.3.2.1 House of Risk Phase 1 (HOR 1)

The objective of generating HOR1 is to determine the priority of risk agents in order to take the preventive actions by involving risk event and risk agent in the

process. Adapting House of Quality model, it is expected to connect requirements and responses that could address one or more requirement. Below are the process needs to be done in developing HOR 1 (Pujawan and Geraldin, 2009) and the example is shown in Table 2.7:

a. Identify risk events that may occur in the business process. Risk events are put in the left column as E_i.
b. Assess the severity of the risk events occurs by using 1-10 scale where the largest number represents extreme severity or catastrophic impact. The severity of risk event is put in the right column of as S_i.
c. Identify risk agents and assess the likelihood of occurrence of each risk agent. The same scale is used, 1-10 scale, where the largest number represents the almost certain to happen. Risk agent (A_j) is placed on the top row of the table and respective occurrence is on the bottom row as O_j.
d. Develop a risk event relationship matrix between risk agent and risk event. Rij {0, 1, 3, 9} where 0 represents no correlation and the following numbers show low, moderate, and high correlations.
e. Develop the correlation matrix between risk agents which a will be placed in the "roof". This matrix portrays the relationship between risk agent and how is the impact to each other using positive and negative symbols such as ++ to represent strongly positive effect, + for a positive effect, 0 for no effect, – for negative and – for strongly negative effect according to Six Sigma Study Guide (2010).
f. Calculate the aggregate risk potential of agent j (ARPj) which is determined as the product of occurrence likelihood of the risk agent j and the aggregate impacts generated by the risk events caused by the risk agent j as in equation 2.1.
g. Rank risk agents according to the potential of aggregate risk in a descending order.

Table 2.7 Example of HOR 1 Model

Business Process	**Risk Event (Ei)**	**Risk Agent (Aj)**			**Severity of Risk Event I (Si)**
		A1	**A2**	**Aj**	
Plan	E1	R11	R12	R1j	S1
	E2	R21	R22	R2j	S2
Source	E3	R31	32	R3j	S3
	E4	R41	R42	R4j	S4
Make	E5	R51	R52	R5j	S5
	E6	R61	R62	R6j	S6
Deliver	E7	R71	R72	R7j	S7
	E8	R81	R82	R8j	S8
Return	E9	R91	R92	R9j	S9
Occurrence of risk agent j		O1	O2	Oj	
Aggregate risk potential j		ARP1	ARP2	ARPj	
Priority rank of agent j					

Source: Pujawan and Geraldin, 2009

where: Aj = risk agent j

Ei = risk event i

Oj = the probability of occurrence of risk agent j

Si = the severity of impact if risk event i occurred

Rij= the correlation between risk agent j and risk event i

ARP_j = the aggregate risk potential of risk agent j

2.3.2.2 House of Risk Phase 2 (HOR 2)

In this phase, action required needs to be done first, considering the difference in effectiveness and degree of difficulties in performing. It is the best way to choose a simple action but could reduce the likelihood of risk occurrence effectively. The development of HOR2 is done through the following process (Pujawan and Geraldin, 2009) and the example is shown in Table 2.8:

a. Select risk agents that have high-priority rank. This can be done using Pareto analysis of the ARPj, to be dealt with in the second HOR. The selected risk agent will be located on the left side (what) of HOR2. Put the corresponding ARPj values in the right column.
b. Identify actions that can be used to prevent risk agents.
c. Determine the relationship between each preventive action and risk agent (Ejk) using the value of 0,1,3, and 9. Each represents no, low, moderate, and high relationship respectively between action k and agent j. Moreover, this could be considered as the degree of effectiveness of action k in downsizing the likelihood of occurrence of risk agent j.
d. Calculate the total effectiveness of each action as follows:

$$TE_{\mathrm{k}} = \sum ARP_{\mathrm{j}} E_{\mathrm{jk}} \forall k \quad (2.6)$$

e. Assess the degree of difficulties in performing each action, Dk, and put those values in a row below the total effectiveness. It can be represented by a scale such as Likert or another scale as long as it shows the fund and other resources required in doing the action.
f. Calculate the total effectiveness to difficulty ratio,

$$ETD_k {}^{\checkmark}\!_4\, TE_k = D_k \quad (2.7)$$

g. Assign rank of priority to each action (Rk) where the number 1 is for the highest ETDk.

Table 2.8 Example of HOR 2 Model

Risk Agent to be treated (Ei)	Preventive Action (PAk)			Aggregate Risk Potential (ARPj)
	PA1	PA2	PAk	
A1	E11	E12	E1k	ARP1
A2	E21	E22	E2k	ARP2
A3	E31	E32	E3k	ARP3
A4	E41	E42	E4k	ARP4
Total effectiveness of action k (TEk)	TE1	TE2	TEk	
Degree of difficulty performing action k (Dk)	D1	D22	Dk	
Effectiveness to difficulty ratio	ETD1	ETD2	ETDk	
Rank of priority	R1	R2	Rj	

Source: Pujawan and Geraldin, 2009

where: Aj = the risk agent j which required to be treated

Pak = options of preventive action

E_{jk} = relationship between each preventive action and risk agent

ARP_j = the aggregate risk potential of risk agent j

TE_k = total effectiveness of each preventive action

Dk = degree of difficulties in performing each action

ETD_k = total effectiveness to difficulty ratio of action k

2.3.3 Risk Evaluation

The next step after finding out and evaluating the risks, a mitigation plan needs to be developed, which is a plan to reduce the impact of undesired event. There are some ways to mitigate risk depends on the risk profile.

- Risk Avoidance

  Here, an organization prefers to use techniques that have been proven to be successful instead of absorbing new techniques even though it may show a promising execution or less cost.

- Risk Sharing

  In risk sharing, the organization is partnering with others to piece up the responsibility for the risk activities. When the partnering company has expertise and better understanding of the problem, which the first company does not have, this means that the partnering company is the one to share the risk associated with a portion of the project that is advantageous. Once risk event does arise, then the partnering company will get some or even all of the negative consequences of the event. Thus, the company will gain some of the benefit gained by a successful project.

- Risk Reduction

  Company will make some investment of funds to reduce the risk on a project. Hiring an expert to review or the cost estimate on a project to increase the confidence level in that plan and reduce the project risk.

- Risk Transfer

  Transferring risk is a way to reduce the effect of risk event by giving it to other parties. For example, the purchase of insurance on certain items is an action of transferring risk to insurance company.

2.4 Review of Previous Research

In determining the objectives and method of this research, studies on previous research is conducted. There are several existing researches that can be used as consideration for developing the method and approach. Table 2.9 shows the review of previous researches related to the similar field of studies.

Table 2.9 Previous Research

No	Author	Type	Title	Method	Result
1	Molina-Besch (2005)	Journal	Product-Service Systems for Office Furniture: Barriers and Opportunities of the European Market	Interview	The obstacles of PSS for office furniture and the product characteristics that are suitable to implement PSS.
2	Costa et al. (2015)	Journal	Sustainable product-service systems for an office furniture manufacturer: How insights from a pilot study can inform PSS design	Life Cycle Assessment (LCA)	Evidence of the typical challenges based on the pilot study in conceptualizing PSS model using service design principle and LCA on furniture product
3	Surjani et al. (2015)	Conference Paper	Collaborative Design of Product-Service System with Multi-Segment: Framework and Model	Literature Study	Develop conceptual model to design multi-segment PSS
4	Zaman (2016)	Master Degree Research	Product-Service System (PSS) Implementation with Multi-Layer QFD in Commercial Vehicle Company	Multi-layer QFD and F-AHP	PSS business model design based on HoQ of QFD Multi-layer (2 actors) on commercial vehicle manufacturer
5	Park et al. (2016)	Journal	Generating New Product-Service System Concepts Using General Needs and Business System Evolution Patterns: A Furniture PSS Case	Customer General Needs (GN) and Business System Evolution Pattern (BSEP)	Propose new PSS concepts by identifying general GN and applying BSEP on office furniture product

Table 2.9 Previous Research (con't)

No	Author	Type	Title	Method	Result
6	Afiatna (2016)	Master Degree Research	Design and Evaluation of Product Service System in Furniture Company	Multi-layer QFD and F-AHP	PSS business model design based on HoQ of QFD Multi-layer (2 actors) on furniture company
7	Partiwi (2017)	Bachelor Degree Research	Use-Oriented Service Design in Commercial Vehicle Company Using Multi-Layer QFD	Multi-layer QFD and F-AHP	PSS business model design based on HoQ of QFD Multi-layer (3 actors) on commercial vehicle manufacturer
8	Christ (2017)	Bachelor Degree Research	Risk Analysis of Product Service System Business Model Implementation in Commercial Vehicle Manufacturer	Risk Analysis, Multi-stakeholder House of Risk	Risk assessment in PSS concept using HOR Multi-actor (2 actors) on commercial vehicle manufacturer

- In 2005, Moline-Besch conducted interviews for a research aiming at creating a list of product characteristics that are suitable to implement this business model and also figuring out the obstacles of PSS implementation in office furniture manufacturer. The result states that PSS business model is suitable for expensive products, high technology products that need maintenance and repair, products that are easy to transport, infrequently used products, and products that do not follow trends which completely do not support PSS implementation on office furniture at that time. The reason of this is because, at that time, office furniture is usually used for a long duration around 12 years, which does not seem to support the idea of renting. Unfortunately, the trend is changing and this pattern is no longer suitable for current condition. Nowadays, the behavior of customer is changing. People are more mobile and comfortable with sharing economy. The usage

pattern has been shifting from owning to renting. Consumers are willing to rent certain items including furniture products (Singh, 2017; Wallenstein and Shelat, 2017). Therefore, a research update is needed to be done.

- In 2015, Costa et al. conducted a pilot study for a new product being developed by same industry, which is an office furniture manufacturer. In the journal entitled Sustainable product-service systems for an office furniture manufacturer: How insights from a pilot study can inform PSS design, they merge the principle of service design and LCA in order to find typical challenges faced if the company remanufacture or refurbish the product when implementing product-oriented PSS and use-oriented PSS. The phase proposed is divided into research phase, ideation phase, and design and development phase with scenario of implementation in 5-year, 10-year, and 15-year. Each phase has different purpose from developing different PSS combination.
- In the same year, 2015, Surjani et al. proposes more complex problem by presenting a new model of Multi-Layer QFD in order to design collaborative PSS that involves more actors with some segmentation. The title of this journal is Collaborative Design of Product-Service System with Multi-Segment: Framework and Model.
- In 2016, Zaman implements Multi-Layer QFD in to implement PSS in vehicle manufacturer company. This research involves two actors and the methods used are F-AHP and PSS design. The title of this journal is Product-Service System (PSS) Implementation with Multi-Layer QFD in Commercial Vehicle Company.
- In the same year, 2016, Park et al. propose new PSS concepts by identifying customer general needs and using BSEP on office furniture product. This research also identifies unconsidered general needs that can actually differentiate a company's PSS design and increase its competitiveness. The approach offered is classified into three stages which are generalizing customer needs using GN-PSS linking matrix, discover new PSS ideas through direct thinking based on BSEP, and build unique competitiveness

strategy and relation with customer. This approach is believed to be an innovative approach to create new PSS concepts under a PSS environment constrained that has been exist and be able to frame unique and special customer connection in the competitive PSS field.

- In the same industry of furniture product, more research in PSS field was done to know the benefit of developing PSS in furniture sector either for the company or the customer. By using different method, which are F-AHP and designing PSS based on HoQ of QFD Multi-layer (2 actors) for the industry, Afiatna conducted Master Degree Research entitled Design and Evaluation of Product Service System in Furniture Company in 2016.
- In 2017, more research in PSS design was done to find out the benefit of developing the design in different sector and by involving more actor, which was service provider. QFD Multi-layer and F-AHP were used as the method to develop the design in the research with title Use-Oriented Service Design in Commercial Vehicle Company Using Multi-Layer QFD by Partiwi.
- In the same year, 2017, Christ wrote a research entitled Risk Analysis of Product Service System Business Model Implementation in Commercial Vehicle Manufacturer. Still at the same industry in Partiwi's (2017) research, the writer focused on the risk assessment and evaluation of PSS implementation. Multi-actor HOR (2 actors) is applied to determine what risk mitigation action should be taken by manufacturer.

Based on the literature review, there is still limited research on furniture industry related to PSS design and risk assessment that consider the role of service provider along with the manufacturer and customer. Whereas to implement PSS as a new strategy in a business process must be able to accommodate the interests of all stakeholders. This study closes the gap of previous research and to complete The development of PSS will be based on the PSS type to result the appropriate design for a furniture company. In addition, the risk of implementing PSS will be assessed to determine the mitigation act should be taken.

This research is also to complete a group research that discussed PSS as the main idea. The research is conducted on two main objects, which are commercial

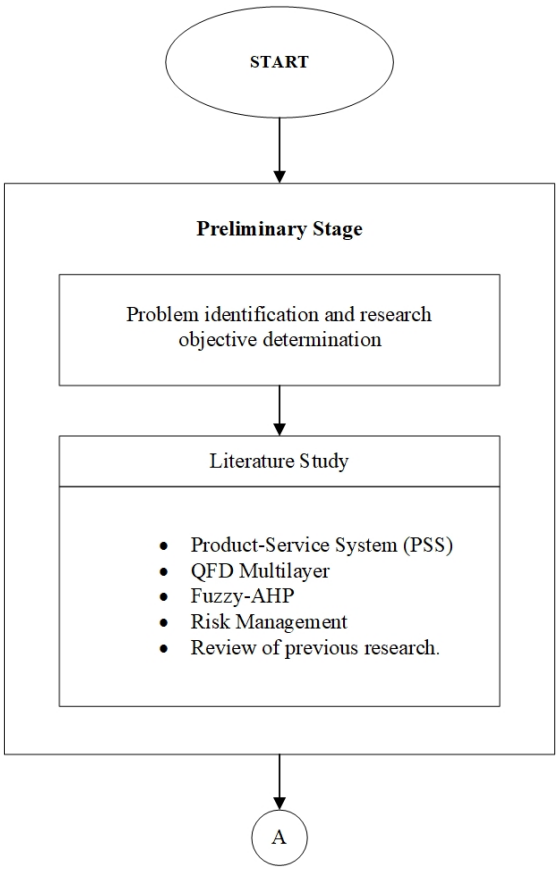
vehicle manufacturer and furniture industry. On commercial vehicle manufacturer, Partiwi (2017) has talked about the concept of multi-actor PSS Design when implementing UoS. On the same object, Christ (2017) analysis the risk of PSS implementation. While on furniture industry, Afiatna (2016) has studied the implementation of PoS and make an evaluation. Therefore, this research will complete the big research by studying the UoS Design in furniture industry followed by the risk that might occur in both PoS and UoS implementation.

CHAPTER 3
RESEARCH METHODOLOGY

This chapter defines the methodology and its explanation to guide the research process in becoming a systematic and clearly directed research. The phases are classified into three phases which are preliminary stage, PSS design, and risk management.

3.1 Research Methodology Flowchart

The methodology to conduct this research is shown below in Figure 3.1.



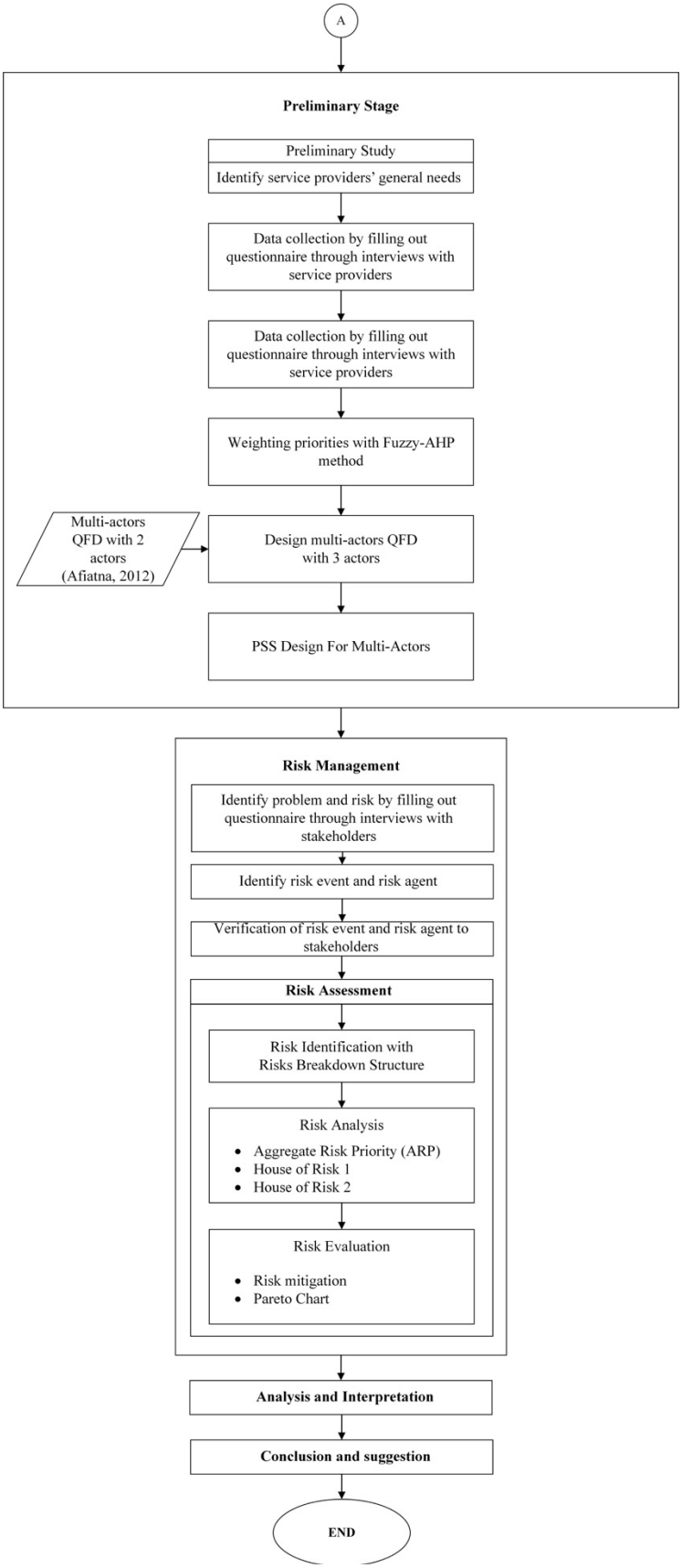


Figure 3.1 Research Methodology Flowchart

3.2 Preliminary Stage

As the opening stage, the first step is to identify the problem that needs to be analyzed and solved through this research. Identification process and reviewing literature are done to get the idea on how to make a better business model for the company based on the existing condition in PT Exigo.

3.2.1. Problem Identification

Identifying problem is a method to find and understand a problem that has been happening so that research objectives can be formed. After figuring out the problem, which PT Exigo has not included service provider as a part of the PSS study in the company, then the objectives are created which is to engage service provider in the design of Multi-Actor Product Service System for furniture industry using F-AHP method based on HoQ from multi-actor QFD. As a result, the application of the new business model might be risky, so risk assessment must follow. By using the concept of House of Risk (HOR), multi-actor assessment will be done in two steps followed by the mitigation options for the company.

3.2.2. Literature Review

In this phase, the literature study is collected from several resources such as thesis, book, journal, article, and websites. With reference to the related topic, the literatures are about product-service system, multi-layer QFD, fuzzy-AHP, risk management, and review on previous research as a base of the problem-solving in the company's case.

3.3 Multi-Actor PSS Design

In this stage, the first step is to do preliminary study on the service providers' general needs by filling out questionnaire through interview. Object of observation in this research is service providers that provide furniture rental. There will be two type of service providers involved, which are regular and eventual. Both voices will be identified, but only the voice of regular service provider is used for the design.

Then, from each of service providers will do preliminary interview process to gather the information. Before the questionnaire was disseminated a preliminary

study was conducted to test the instruments to be used in the main study. This needs to be done to support the success of research in accordance with the objectives of the study. General Needs

In the next step, F-AHP is done as the further processing for the data obtained. From the data that has been processed next will be developed PSS design using Multi-layer QFD. The data needed are primary data gathered from service provider and secondary data from previous research about QFD multi-actor involving only customer and the company.

The criteria to be used in this study are considered general need of multi-actors involved in the scope of research. The criteria of interest to multi-actor, hereinafter referred to as variables, are obtained from previous studies. In Table 3.1 describes general need criteria for each actor.

Table 3.1 General Needs

Variable	Aspects	Description	Reference
Provider needs	Cost	The cheap price of materials and equipment	(Duru et al., 2013)
		Low operating costs	
	Finance	Ease of managing finances (bank, etc)	
	Operational	Easy for maintenance	
		Easy machine operation	
		The good quality of the equipment	
	Design	Have good durability	
		Available designs	
Customer needs	Purchase	Low cost	(Kim et al., 2012)
		Easy to purchase	
		Product / service lifecycle information	
	Use	Multi-function	
		Environmental-friendly raw materials	
		Eco-friendly resources	
		Reduction of raw materials	
		Customization	
		Optimization of use	
		Performance	
		Low maintenance	

Table 3.1 General Needs (con't)

Variable	Aspects	Description	Reference
Customer needs	Use	Flexible	(Kim et al., 2012
		Durable	
		Stable	
		Easy to use	
		Availability of space and time	
		The added value of usage	
	Dispose	Environmental-friendly waste	
		Ease of waste disposal	
		The added value of waste disposal	
Service provider needs	Cost	Operational cost	(Duru et al., 2013)
	Managerial	Good management	
	Performance	High speed service	(Chou et al., 2015)
	Empathy	Approach, ease of access, and effort to understand the needs of service providers	
	Maintenance	Low maintenance frequency	
		Service maintenance	
	Customization	Customization for rental	
	Ease of renting	Cooperation for renting furniture	
	Provider trust	Trust in cooperation	
	Delivery	Ease in delivery to be leased	(Ekiz et al., 2009)
	Security	Insurance	
	Policy	Payment method policy	

Using the data collected, then multi-actor QFD can be transformed into PSS business model design that is appropriate for PT Exigo.

Based on the previous research by Afiatna (2016), the general needs of manufacturer were already identified and called as Voice of Manufacturer (VoM). Then, a validation will be done to make sure that the data still fit the current condition. Table 3.2 shows the VoM and weight of each needs.

Table 3.2 General Need of Manufacturer

No	Dimensions	Weight
1	Low material cost	0.08356
2	Low equipment cost	0.01501
3	Low operating cost	0.19973
4	Ease of managing finances (bank, etc.)	0.12855
5	Easy machine operation	0.08651
6	Labor productivity	0.20419
7	The good quality of equipment	0.11213
8	Modular design	0.17032

Source: Afiatna, 2016

Verification of VoC is also conducted to some customers based on the same previous research. Customers that involved as respondents are potential customers for the renting system proposed. Table 3.3 presents the general need of customers with some adjustment in terms of the use-oriented service.

Table 3.3 General Need of Customer

Stage	Description	Source
Purchase	Affordable rental rate	Schenkl et al., 2014, Kim et al., 2012., Afiatna., 2016
	Easy to purchase	Kim et al., 2012., Afiatna., 2016
	Product information	Kim et al., 2012., Afiatna., 2016
	Good service	Schenkl et al., 2014
	Ease of delivery and return rented furniture	Partiwi, 2017
Use	Multifunctional	Kim et al., 2012
	Customization	Kim et al., 2012., Afiatna., 2016
	Low maintenance	Kim et al., 2012., Afiatna., 2016
	Easy to use	Kim et al., 2012., Afiatna., 2016
	Durability	Shcenkl et al., 2014, Kim et al., 2012., Afiatna., 2016
	Policy (payment method, lease term, tolerance)	Partiwi, 2017
	Anticipation of unexpected event (insurance)	Partiwi, 2017
Use & Disposal	Environmentally-friendly	Kim et al., 2012., Afiatna., 2016

3.4 Managing Risk

The risk management in this process is divided into two sub-phases, which are preparatory phase and risk assessment.

3.4.1 Preparatory Phase

In this phase, the PSS design created will be analyzed to identify the possible risk happen. Doing direct observation to the company, doing interview, making documentation, collecting historical data, giving questionnaire to the manufacturer, chosen respondents or customers, and interviewing service providers are the activities to identify the risk. The chosen respondents are the loyal customers who give feedback and communicate with the company.

3.4.2 Risk Assessment

After the data gathered, the assessment can be started following the risk management process stated by ISO (31000:2009b), which are risk identification, risk analysis, and risk evaluation. First, all risks in the list are identified using Risk Breakdown Structure (RBS).

The result will become the input to the next process which is creating Aggregate Risk Potential (ARP). Each risk event is assessed based on severity and likelihood of occurrence to build relationship matrix between risk event and risk agent. Then the result will be used to rank the risk agents. Since there are a lot of risks identified, not all of them needs to be considered. Therefore, the rank of risk agent will be the key to select which risks need to be reviewed. As a result, House of Risk 1 is developed.

The next step is to determine which preventive action has to be done first, considering how effective and difficult it is to perform. The best one is the simple one with the most effective impact to reduce the impact of risk event (Pujawan and Geraldin, 2009). Each option is evaluated, ranked, and chosen by the highest priority of risk agents. After that, the relationship between each preventive action and risk agent needs to be determined. The total effect can be seen from the degree of difficulty and effectiveness ratio so it is possible to rank the mitigation options. House of Risk 2 is the output of this process.

Risk mitigation, which is an action to reduce negative impact that follows risk, will be selected by making Pareto chart. The result then can be used by provider to make future strategy when implementing PSS design.

3.5 Conclusion and Suggestion

This step is the final stage of the research, where conclusion that answers the objectives and suggestion is written. Conclusion will give the result of analysis on how to develop business model based on PSS and what risk could be avoided as the effect of PSS implementation to support the business in furniture industry. Recommendation for the company is written based on the result from analysis while suggestion is made as input for the next research.

CHAPTER 4
MULTI-ACTOR PSS DESIGN

This chapter consists of the description of observation object and use-oriented service design (UoS). In the description of the observation object, it shows the profile of the each observation objects in the research and classify them based on the characteristic. There are three observation objects in general but only two are explained which are PT Exigo as manufacturer and service provider.

The use-oriented service design consists of the data collection, data processing, and multi-layer QFD for furniture industry. Data for multi-actor PSS design was collected through filling out questionnaire and conducting interview to score the dimensions of service provider's general needs while interviews were conducted to enrich the factors that have not been covered in the preliminary study. In data processing, data that has been collected then being processed using some methods that has been proposed. A software named PSS Multi Actor is used to facilitates the process of designing PSS for multi-actor. After that, multi-layer QFD is applied to solve conflict resolution of interests between each actor. The relative importance for each actor have been computed by F-AHP in the previous section.

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CHAPTER 5
RISK ASSESSMENT

This chapter consists of the preliminary study, result of questionnaire, and the data processing. The process of data collection related to risk assessment starts from preliminary study, risk identification, risk analysis, House of Risk 1, preventive action identification, and House of Risk 2.

In the preliminary study, interviews were done to each actor involved, which were manufacturer, service provider, and customer. In the further process, the result used as an input for questionnaire.

In risk identification, the result of risk event and risk agent are identified. Each risk agent is designated to related risk event. In order to show the relationship between risk event and risk agent, some risk breakdown structures are created based on the actors affected, process in the company, and business-process.

After the risk event and agent were identified, the process of risk analysis was done in order to assess the severity to risk event and occurrence to risk agent. The method used is based on the HOR developed by Pujawan & Geraldine (2009). The assessment become the input for the data processing using HOR1.

From HOR1, some risk agents were prioritized to get mitigation action. Therefore, an identification of preventive action was done and became the input of HOR2. This made the it possible to select the most effective action for the case study.

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CHAPTER 6
ANALYSIS AND INTERPRETATION

This chapter discusses the analysis and interpretation of multi-actor PSS design and the risk assessment of its implementation in furniture industry.

In the analysis of multi-actor PSS design, the needs of each actor are analysed. The result after conflict resolution will be compared to the previous weight calculated by using F-AHP. The purpose of this process is to see whether the priority of each actor will change if one actor's needs are combined with the other actor. Moreover, the result is used to create a PSS design. From the data have been obtained, two comparisons were conducted between product-oriented and use-oriented service, and the voices of regular and eventual service providers.

In the analysis of risk assessment, this section is divided into several subchapters. Those are preliminary study analysis, risk identification analysis, risk assessment analysis, House of Risk 1 analysis, House of Risk 2 analysis, and product-system risk analysis. In the last subchapter, a comparison is done to see whether there is any different risk occur in the implementation of PoS and UoS in furniture industry.

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CHAPTER 7
CONCLUSION AND SUGGESTION

This chapter will show the conclusion of the research and recommendation that is attained by completing the research.

7.1 Conclusion

This subchapter presents the conclusion which was obtained after completing the research.

1. In the design of this use-oriented PSS, there are three main actors identified, which are manufacturer, service provider, and customer. After conflict resolution, the priority of manufacturer changes and become labor productivity, modular design, ease of managing finances, the good quality of equipment, and low material cost. These changes are affected by existence of service provider and customer.
2. While for service provider, there are 10 criterions to fulfill their needs. Those are cost, management, performance, empathy, customization, deliver, company readiness, policy, and company reputation. The priority of service provider changes when other actors are involved resulting performance, cost, maintenance, management, and customization at the top rank. This is affected by the need of manufacturer and also customer.
3. The need of customer in the implementation of use-oriented PSS is different compared to product-oriented PSS. There are 13 criterions that need to be fulfilled, which are affordable rental rate, easy to purchase, product information, good service, ease of delivery and return on rented furniture, multifunctional, customization, low maintenance, easy to use, durability, policy, anticipation of unexpected events, and environmentally-friendly. After synchronization, the priority is affordable rental rate, good service, durability, multifunctional, and ease of delivery and return of rented product. The changes in priority are affected by the needs of manufacturer and service provider.

4. Synthesis was conducted to discover the needs that can meet all actor's need. The result shows that providing consultation service for optimal usage is at the first rank. Providing insurance services and using online apps for better services have the same priority as technical responses. While minimizing operational cost, providing special division for renting, and the usage of strong, durable, and recycle materials are at the third rank of technical responses. The result of synthesis matrix is used as the basis of designing PSS blueprint.
5. Regular service provider and eventual service provider have different priority for furniture renting. Based on the F-AHP calculation, regular service providers prioritizes performance, cost, empathy, maintenance and customization. On the other hand, eventual service provider needs mostly are management, performance, maintenance, cost, and delivery. The differences in priority is obtained because of the different characteristic of the product they offer, their customer, and also the period of renting.
6. Risk events and risk agents that occur in the implementation of PSS mostly affect manufacturer and customer at the same time. There are 25 risk events which occurrences are triggered by 37 risk agents. 40% of risk agents dominantly occur in manufacturer and customer because they are strongly correlated so they have the receive the same risk. In the meantime, there were 15 preventive actions identified.
7. In HOR1, the objective is to make priority to the most affecting risk agent. After doing the calculation, 8 of 15 risk agents were chosen because of its cumulative of occurrence reach 80%. From this result, preventive actions are determined and resulting 15 actions that are expected to decrease the occurrence of risk agents for all actors. Those are online communication, survey and marking, modular design, limited customization, prepare time schedule, let customer fix the product, limit the modification, decline customer request, reconditioning, create branding and promotion strategy, explain the benefit to customer, study on market, create product that fit most of the target market, prepre back-up furniture for long term contract, and education.

7.2 Suggestion

The suggestion for the next research are:

1. The scope of this research is to design the PSS business model and to analyze the risk of PSS in furniture industry. Further research can be done to create the action plan and to calculate the risk cost of the implementation.
2. The customers being observed in this research are general and do not follow the segmentation of the company. For the next research, this segmentation could be considered as a part of the analysis.

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BIOGRAPHY

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