FINAL PROJECT – TI 141501

DISCRETE EVENT SIMULATION FOR PRODUCT-SERVICE SYSTEM (PSS) IMPLEMENTATION IN COMMERCIAL VEHICLE MANUFACTURER

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APPROVAL SHEET

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FINAL PROJECT

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ABSTRACT

Commercial vehicle industry shows trend shift with the entry of Indonesia's biggest start-up, Go-Jek. Go-Jek provides an online renting application for commercial vehicle Go-Box, that can disrupt the industry. Driven by increasing competitiveness and sustainability issue, commercial vehicle manufacturer should make an innovation to survive in the tight competition and reduce their impact to the environment. A new business model that combines product and service in fulfilling customer demand has emerged as a solution to the problem. This new business model is called Product-Service System (PSS). PSS consists of three business models. Product-oriented model focuses on offering physical goods to the customer. Product-oriented Service (PoS) bundles product with service that might be needed and UoS focus on the serviceability of the product by renting the product to the customer. As a new business model, PSS has several risks related to its implementation that have to be considered. To be successfully implemented, PSS implementation has to be assessed carefully to avoid unnecessary things. Therefore, discrete event simulation is used to evaluate PSS business model based on financial and environment indicators. Simulation is done to model manufacturing process and product life cycle of commercial vehicle and assess risk cost. By using market trend and combination between product-oriented model, PoS, and UoS, the manufacturer could maximize income as much as IDR 7,889,245/unit.

Keywords: Product-Service System, Discrete Event Simulation, Product-oriented model, Product-oriented Service (PoS), Use-oriented Service (UoS)

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The author recognizes that this research is not perfect and needs further development. Positive suggestions and feedbacks are highly appreciated. Aside from that, the author hopes that this report could benefit the reader, contribute to the PSS development in Indonesia.

Surabaya, 18 July 2018

Author

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CHAPTER 1
INTRODUCTION

This chapter consists of the background of the research, problem formulation, research objectives, research benefits, research scope, and report outline to summarize this research.

1.1. Research Background

Manufacturing is necessary for accelerating economic growth. The condition seen from contribution for the most of countries from manufacturing sector range from 15%-25% of Gross Domestic Product (GDP) (Singh et al., 2017). Significant growth in the manufacturing sector also has a drawback. Manufacturing generates tons of waste material that became a critical problem towards environment. Environmental decline and response due to the entire cycle of raw materials exploration and extraction, transformation into products, energy generation, and use and disposal of the product (Brundtland et al., 1987) is some critical problems from manufacturing. Manufacturing has already become the main contributors to pollution and environmental issue (Carvalho et al., 2018)

This problem created a worrying opinion from people about today's development that would pulverize future generation needs (Pieroni, 2017). In order to tackle this problem, several ideas and researches about manufacturing have been developed. The term of sustainable development in favor of reducing cost as well as helping to make the environment better emerged. (Singh et al., 2017)

Sustainable development has become widely known after Brundtland report about Our Common Future published. Brundtland report account for long-term global agenda and strategies to achieve sustainable development (Brundtland et al., 1987). There are six main topics discussed in Brundtland report that are:

1. Population and Human Resource
2. Food Security: Sustaining the Potential

3. Species and Ecosystems: Resources for Development
4. Energy: Choices for Environment and Development
5. Industry: Producing More with Less
6. The Urban Challenge

Topic of producing more with less aligns with Indonesia's development problem as manufacturing country with significant growth in the industrial sector over the past decade. According to Indonesia's industrial ministry (2017), the contribution of Gross Domestic Product (GDP) in the manufacturing sector that is stable on over 20% over previous five years shows its prominence to national economies (Kemenperin, 2017).

One of sub-sectors in the manufacturing that grows rapidly is motor vehicle, trailer, and semi-trailer. Export value data that published by Industrial Ministry shows an increasing trend over the past five years. Figure 1.1 shows the export value growth of motor vehicle, trailer, and semi-trailer export value. Motor vehicle, trailer, and semi-trailer are vehicles to carry freight for commercial purposed. Therefore, motor vehicle, trailer, and semi-trailer term can be used interchangeably with commercial vehicle and in this research commercial vehicle term will be used.

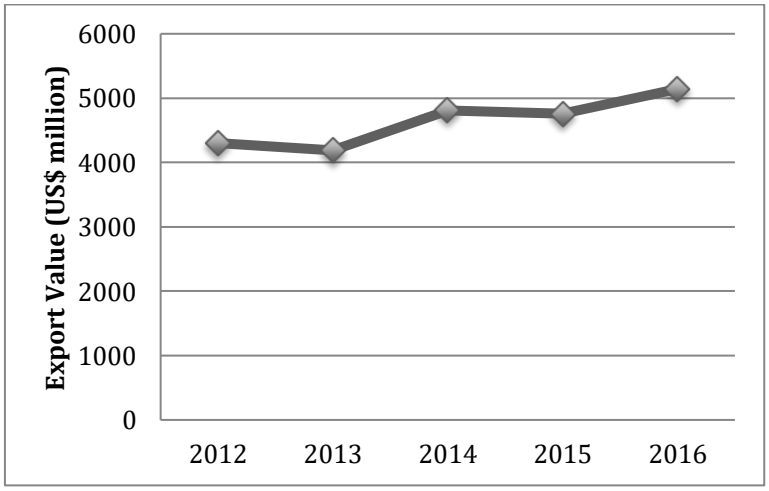

Figure 1.1 Export Value of Motor Vehicle, Trailer, and Semi-Trailer Industry in Indonesia (Kemenperin, 2017)

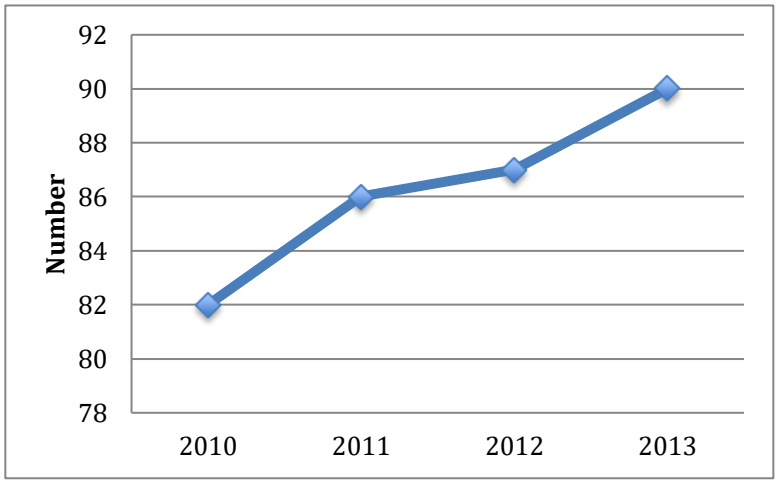

Figure 1.2 Number of Big and Medium Commercial Vehicle Manufacturer in Indonesia (Kemenperin, 2017)

There are approximately 90 of big and medium commercial vehicle manufacturers in Indonesia in 2013 with an increasing trend from 2010 as shown in Figure 1.2 that makes this sector would likely to be more competitive and challenging in the future.

As well as competitiveness, commercial vehicle manufacturer growth also resulted in increasing use in resource that would lead to sustainability problem. The increasing competitiveness and sustainability problem also affect commercial vehicle manufacturer. Customers in commercial vehicle tend to be more selective in selecting the product and seek for more than just the product that leads to specification and demand shift. Specification and demand shift showed by increasing utility of online commercial vehicle provider. The biggest ride-hailing in Indonesia, Go-Jek already release an online commercial vehicle provider called Go-Box. Go-Box already had access to more than 1.6 million users. This make the manufacturer should understand the trend and alter their business orientation to satisfy the customer.

The manufacturer should alter their business orientation from focusing on product to include service that will satisfy increasing heterogeneous customer preferences, decreasing environmental impact, and achieving economic sustainability

(Chen, 2015). By implementing business orientation that includes service rather than just providing product, the commercial vehicle manufacturer can obtain the benefit as mention by Chen (2015). A business model that includes service rather than just focus on product is denoted as Product-Service System (PSS).

PSS is a business model that integrates product and service to accommodate people to manufacture products with less resource by increasing product utility (Tran and Park, 2016) and continuously seek competitiveness in delivering the product (Mont, 2002). PSS grows to offer the product and service that could reduce exertion of the resource by increasing product utility. As a new business model that offers something different from the conventional business model, PSS as a set of marketable products and service joint could infiltrate to a new market niche that has not been served in the past because it is capable of fulfilling needs for clients (Goedkoop et al., 1999). Beyond fulfilling needs, PSS also increases customer loyalty by providing satisfaction-based service customer relationship (Vezzoli et al., 2014) that will help manufacturer maintain their close relation with the customer that will bring advantages over other competitors.

In addition, PSS also gives a positive effect by reducing the environmental impact of economic activity (Baines et al., 2007). The benefit also comes from the connection between environment and creation of a new business that will increase economic growth while still preserve environmental condition (Goedkoop et al., 1999).

Several global companies have succeeded the implementation of PSS as their business model. One of it was Interface, the largest commercial carpet manufacturer who offers the selection of floor-covering products and services to its customer. Interface has moved from traditional business model to PSS provider that offers series of services based on the products. Interface provides an office floor-covering service to the customer on a leasing contract where during the period of the contract, the company will take care of all maintenance aspects of the product (McAloone and Andreasen, 2002).

Although PSS offers many advantages, it also has a downside. PSS as new business model possesses risk in its implementation. There are several cases where implementation of PSS failed to make the expected profit because of lack of preparation study and careful consideration about risk where it could turn into costly account to the manufacturer if it is not anticipated (Yoon et al., 2012). Moreover, there are only limited studies about PSS in Indonesia.

Previous research has already studied about design, operational, and evaluation phase (Surjani, 2016), but most of the studies only elaborate exploratory study using interview, survey, and observation or design science (Xing et al., 2017). Whereas there is a gap between previous studies and required of scientific data to convince manufacturer to implement PSS. Therefore, simulation model using risk cost for PSS implementation has to be made. Simulation can be useful to demonstrate manufacturer the forecasted result including uncertainties and risk related to PSS implementation in the future.

Simulation will be applied to evaluate Product-oriented Service (PoS) and Use-oriented Service (UoS) alternatives based on financial and environment indicators. Simulation use result from previous studies about PSS business model design that identify customer requirement using Quality Function Deployment (QFD) (Partiwi, 2017; Zaman, 2016) to design the business process. Furthermore, service cost in commercial vehicle manufacturer generated from lean accounting used to calculate cost and profitability of the manufacturer from PSS business model (Setiati, 2016). Meanwhile, study about risk analysis to determine risk priority will be used to calculate risk cost that will be considered in this research (Christ, 2017) will be used as a variable in this research.

Simulation is applied to this problem because this problem is quite complex to be assessed by other methods and a new business process can be explored without disrupting present business process (Banks, 1998). PSS business model expected to increase profitability, decrease environmental impact, and lessen number of complaint through higher utilization rate that will affect number of product produce

and material procurement. This research will be carried in the commercial vehicle manufacturer in Surabaya that offers their product to Business to Business (B2B) and Business to Customer (B2C). The product that the company offers is a 4-wheel standard box made of aluminum panels, steel bars, and supporting components.

1.2. Problem Formulation

Problem formulation in this research is how to evaluate future business condition of PSS implementation and to convince and provide evidence that PSS implementation could conform trend shift and increase the profitability and environment aspect.

1.3. Research Objectives

Objectives to be achieved in this research are:

1. Constructing simulation model to depict the future performance condition of manufacturer based on Product-oriented model, Product-oriented Service (PoS), Use-oriented Service (UoS).
2. Compiling recommendation related to PSS implementation based on scientific proof.

1.4. Research Benefits

Benefits of this research are listed as follow:

a) The company could evaluate the implementation of PSS based on indicators.
b) The company could get the overview and decide the right business model that gives the manufacturer better profitability and environmental aspect.

1.5. Research Scope

This sub-chapter consists of research's scope and assumption applied in this research.

1.5.1 Limitations

Limitation of the research is listed below:

a) This research is limited to 4-wheels standard box made of aluminum panels, steel bars, and supporting components.

b) Performance indicator assessed in the research limited to profitability and environmental aspect.

1.5.2 Assumptions

This Research is established by assuming that the result of the previous studies can be used for this research with adjustment.

1.6. Report Outline

This research is consists of several chapters. Outline and structure of this research will be posted below as a guideline for the reader:

- CHAPTER 1 - INTRODUCTION

  This chapter consists of the background of the research, problem formulation, objective of this research, limitation, and assumption that is applied in this research, the benefit of this research, and report outline as a guideline to the whole study

- CHAPTER 2 - LITERATURE REVIEW

  This chapter outlines the concept and previous knowledge that is used in conducting this research. The literature review will outline Product-Service System (PSS), sustainability, lean accounting, risk analysis, and simulation.

- CHAPTER 3 - RESEARCH METHODOLOGY

  This chapter contains methodologies that the author used with a flowchart to explain every step in conducting this research sequentially. This research starts with problem identification and setting objectives, literature review, developing conceptual model, data collection, data processing, simulation, analysis and interpretation, and conclusion and suggestion.

- CHAPTER 4 - CONCEPTUAL MODEL, DATA COLLECTION,

AND DATA PROCESSING

This chapter consists of three parts. Conceptual Model to represent the model based on alternatives. Data collection collected from the manufacturer and previous research. Data Processing consists of data collection's process.

- CHAPTER 5 – SIMULATION AND FINDINGS

  This chapter consists of ARENA simulation model and findings during manufacturing process and product lifetime.

- CHAPTER 6 – EXPERIMENT AND ANALYSIS

  This chapter consists of experiment and analysis of simulation model. This chapter will analyze the result of each alternative based on indicators.

- CHAPTER 7 - CONCLUSION AND RECOMMENDATION

  This chapter consists of conclusion of the best alternatives and scenario for commercial vehicle construction and recommendation about the strategy that recommended in the future.

CHAPTER 2
LITERATURE REVIEW

This chapter consists of concept, theory, and method that will be used in this research. This literature review is taken from previous study, paper, and book to help the reader to understand the context of Product-Service System (PSS) that is used in this research. This literature review also covers PSS, sustainability, lean accounting, risk analysis, and simulation.

2.1 Product-Service System

Product-Service System (PSS) is a marketable set of products and services that capable of jointly fulfilling a user's need(Goedkoop et al., 1999). PSS unites product and service in one business model where each aspect supports each other. The notion of PSS originates from customer's demand shifting that is focused on the product before to a more complex combination of product and service (Morelli, 2006). PSS represents an evolution from traditional generic or conservative business with standardized services towards targeted and personalized one. This perspective came from mass production trend that dominates several sectors. PSS business model could become a competitive and sustainable business model (Arnold Tukker, 2004). PSS model enables the company to increase their competitiveness where the manufacturer could fulfill customer demand for the more integrated product and improve customer's involvement in the main business process so that customer-company relation is well preserved.

There are many benefits come from PSS as service that is flexible and according to customer needs with high quality for customer side (Aurich et al., 2010). For the manufacturer side, PSS could increase customer's loyalty. Furthermore, it could expand opportunity to increase efficiency, increasing relation with customer and expanding the market.

2.1.1 History of PSS

Previous understanding of business model century ago was overshadowed by the success of giant companies such as Ford, Coca-Cola etc. Many companies seek and rushed towards low costs and neglected the segmentation of customers where each customer has their own uniqueness. The concept of segmentation raised in the 1950s, followed by niche marketing in the 1980s. This concept gained momentum and replace the old concept of mass production to lower the production cost with producing many same products. The concept started to alter to mass customization in the 1990s with the notion that every customer has its own market segment with the specific requirement that must be fulfilled.

The change of customer perspective on mass customization also affected the change of customer understanding on the production system. The society went from focusing on production systems to products. The following stage was the discovery of product's surrounding factors, such as marketing, performance over time, product's life cycle, reparability etc. and the last finding was actually customers only demand for the services instead of the products where customer satisfactory relies on service of the product.

2.1.2 PSS Classification

PSS consists of three main categories, which each category can be divided into eight sub-categories. The complete explanation of PSS with its sub-categories can be seen in Figure 2.1 while categories of PSS will be explained afterward

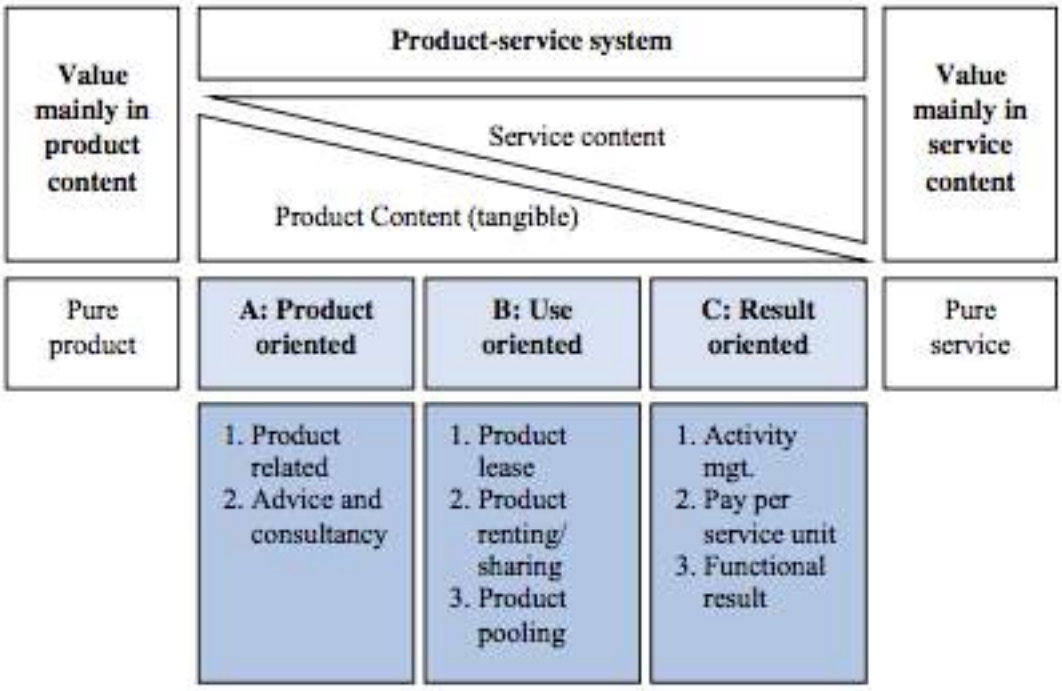

Figure 2.1 Main and Sub-Categories PSS (Tukker,2004)

- Product-Oriented Service

  In this category, the company focuses on offering product with a small part of service that might be needed in product lifetime. The first sub-category is product-related service where the company offers service that is most likely needed. The second sub-category is consultancy where the company is giving an advice on the usage of the product

- Use-oriented Service

  Use-oriented Service (UoS) is already shifting their focus to offer service rather than product. This shift can be outlined from the business model that keeps the ownership of the company. The company only offers the functionality of the product. First sub-categories of UoS is product lease where customer pay to the company for the product's functionality where the product can be used exclusively. Second sub-category is product renting and sharing which is similar to the first category except the customer doesn't have

exclusive right to use the product. The third is product pooling where it is similar to product renting except the product functionality will be used together with other people at the same time.

- Result-oriented Service

  Result-oriented Service (RoS) business model offers an intangible product with an agreement between producer and customer. First, sub-category is activity management or outsourcing where the company uses third-party as outsource to use their intangible product. The second category is pay per service unit where the customer pays the company based on service unit completed basis. The third subcategory is functional result where it gives independence for the company to deliver the output.

Christensen and Tan (2000) define that innovative products have to contain difference to the existing product generates appropriate, valuable and desirable impact on the manufacturer, customer, and society.

The challenge is to make an improvement that can impact positively to these three stakeholders. Innovation in PSS should give positive impact to these three stakeholders based on Triple Bottom Line. Figure 2.2 shows how innovation in PSS will give positive impacts to three stakeholders

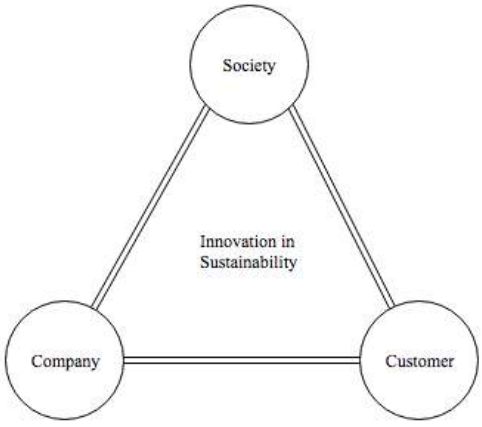

Figure 2.2 Three-forces model (Christensen and Tan, 2000)

2.1.3 PSS characteristic

PSS characteristic could be divided into two terms; PSS for eco-efficiency and PSS for sustainability.

- PSS for Eco-efficiency

  PSS is introduced to customers in terms of reducing the whole and thorough product resource that is used. To clarify this concept, take washing machine as an example. There are many stakeholders that are included in serving a function of a washing machine that is needed from the customer point of view. There are parties to provide detergent, electricity, water, maintenance etc. PSS for eco-efficiency is derived from the new convergence of interest between all stakeholder to assess the new form of interaction between stakeholders to come up with a better and efficient system (Porter and Kramer, 2006). Characteristics of PSS for eco-efficient are:

  a) Satisfaction-based economic model: Stakeholders make better and more efficient interaction and bring their partnership to a new level that will bring better profit for all of them
  b) Based on the interaction between stakeholder: Stakeholders make better and more efficient interaction and bring their partnership to a new level that brings better profit for all of them
  c) Environmental impact potential: Besides bringing fortune for all stakeholders, PSS also could bring a big impact on reducing waste and have a big impact on the environmental problem

- PSS for Sustainability

  Building sustainable PSS is hard and thrilling because it starts with PSS design for sustainability. It is a strategy to make the interest of customer align and coherent with the product by using the satisfaction-based approach. The designer should design the product thoroughly not just one single product that they are used to. They have to characterize the interaction and system connection between stakeholders, which consists of different types of

connections and have to come up with innovation to respond particular demand for satisfaction. In the clean clothes example, the designer should design the product considering all aspect inside of serving a washing clothes function. System configuration could be paid per wash, including home delivery of washing machine, electricity, water, and detergent supply, maintenance, upgrading and end-of-life collection. These approaches require high ability and skill known as strategic design (Vezzoli et al., 2001).

2.2 Sustainability

PSS as a business model has an objective to develop sustainable business and environment. Sustainability is a concept where a company is covering not only profit but also the earth and humans. The company's objectives are on the one hand economically justified, on the other hand, ecologically acceptable and socially expected (Zak, 2015).

Sustainability as a concept can be achieved by increasing standard of living that is existed nowadays and reduce the level of resource consumption, pollution output, and consumption pattern. There are several approaches that can be implemented to achieve the objective of sustainability (Alhaddi, 2014):

1. Dematerialization
2. Extending the product life
3. Eco-efficiency
4. Recycling and claiming product material back
5. Reducing efficiency of the product usage phase

Accurate strategies have to be implemented to achieve sustainability objectives. Based on several approaches that are listed above, strategies that can be suitable for sustainability is leasing and renting. Leasing arrangement will give environmentally advantageous to embraces the concept of reuse and recycle. The concept of reuse and recycle can be achieved if both of producer and customer agreed to return the leased product. Leasing strategy will support dematerialization of the

product by reducing the products produce, extending product life by serving routine maintenance of the product and embracing recycle of the product.

Renting means the certain products are agreed to be given out in a certain period. Short period in renting will embraces the customer to use the product more intensively opposed to single owner usage (Alhaddi, 2014).

2.3 Lean Accounting

Lean accounting varies from traditional accounting in many ways. Lean accounting accounts based on Value Stream Mapping of the company while traditional accounting accounts for the cash flow that has been occurred and recorded. Lean accounting is more suitable to calculate service cost in PSS because it accounts based on Value Stream Mapping that has not required cash flow to be occurred. Furthermore, lean accounting support company to seek continuous improvement and help manufacturer move towards lean enterprise (Setiati, 2016).

Lean accounting is defined as an accounting process to provides accurate, timely, and understandable information to support lean transformation in organization (Solomon and Fullerton, 2007). This transformation is carried out throughout the enterprise (Maskell and Kennedy, 2007). Lean accounting also evolved to overcome several obstacles of lean accounting implementation as s traditional accounting already became an essential part of management system and it is often lag behind the management's expectation (Blochl et al., 2017).

Although implementation of lean accounting still limited and there are several barriers that hinder implementation of lean accounting in the company, there are several advantages of the lean. Based on five principles of lean accounting by (Kovacheva, 2010), lean accounting is simple and fast accounting that eliminate any waste in transactions and it is clear, timely and easily understood. This advantages also enhanced by (Cesaroni & Sentuti, 2014) who contradict traditional accounting and lean accounting where they promote several lean advantages like lean, fast, maximize flow and promote continuous improvement.

The example of lean accounting implementation in the company will be taken form final project from (Setiati, 2016). In this final project, Setiati (2016) used lean accounting to calculate service cost and cost incurred in PSS implementation in commercial vehicle manufacturer. This study will help this research to provide service cost that is occurred in PSS implementation in commercial vehicle manufacturer.

Lean accounting implementation starts with Value Stream Mapping (VSM). VSM is performed to break down each activity and assess cycle time (C/T), Value Added (VA), and Non-Value Added (NVA). The VSM and its breakdown activities are shown in Figure 2.3.

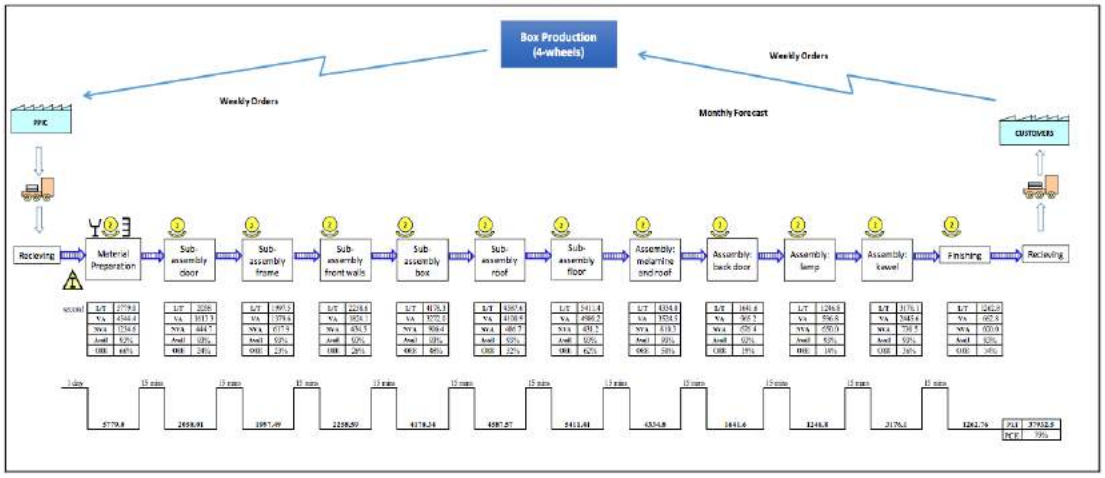

Figure 2.3 Value Stream Mapping in Commercial Vehicle Manufacturer (Setiati, 2016)

Value Stream Costing performs subsequent VSM to calculate each box in the VSM and assess each activity with cost allocation. Table 2.2 shows Value Stream Costing as an example of lean accounting application in previous research that accounts for labor cost. This service cost will be used as cost occurred in the manufacturer to calculate profitability.

Table 2.1 Value Stream Labor Cost (Setiati, 2016)

MATERIAL PREPARATION					
Activity	**Value-added**	**Non value-added**	**Allocation**	**Paycheck per Day**	**Cost of Activity**
Cutting: box supporting					
Preparation		**250.00**	0	Rp 400,000.00	Rp -
Cutting	**1800.00**		0.063	Rp 400,000.00	Rp 25,000.00
Transportation		**300.00**	0	Rp 400,000.00	Rp -
Bending					
Preparation		**250.00**	0	Rp 400,000.00	Rp -
Bending	**1000.00**		0.035	Rp 400,000.00	Rp 13,888.89
Transportation		**300.00**	0	Rp 400,000.00	Rp -

2.4 Risk Analysis

One thing that will be assessed in the PSS simulation model is the risk. Risk defined as a source of failure that resulted in bad impact (Johansen, 2010). Risk and uncertainties cannot be divided and act as one united even though it has differences (Mun, 2006). Risk assessment consists of identification, analysis, and evaluation that is systemic to help decision making and prediction of future risk (Parenreng, 2016). There are many types of risk that can happen. Explanation of risk types in business can be seen in Table 2.3.

Table 2.2 Risk Type in Business (smallbusiness.com)

No.	Risk Type	Explanation
1	Strategic risk	Every company would have a strategy in their business sector to increase their revenue and performance. There will be an investment that company should have done to implement the strategy. Strategic risk elaborates when the strategy has become less effective and company struggles to reach its goals as a result.
2	Compliance risk	Law changes all the time while the company should keep complying with the law. When the law is outdated, there will be new law produced to change the old one. As the time goes, company may need to comply with the new rules that didn't apply before.
3	Operational risk	Operational risk refers to unexpected failure in the day-to-day operations of the company. The failure could cost the company for the lost sales happen or company should put more money to correct the failure.
4	Financial risk	Financial risk refers to financial impact that happens because of cash flow in and out of the company.

Table 2.3 (cont') Risk Type in Business (smallbusiness.com)

No.	Risk Type	Explanation
5	Reputational risk	Reputation plays a significant role in generating revenue. Bad reputation from the company could damage company's revenue greatly.

Risk occurs because of the hazard that is not managed well. Even though hazard has the potency to be disadvantageous but it isn't absolutely become the source of risk (Johansen, 2010). When hazard meets risk source, it could turn into risk. Risk source can be defined as activity, condition, energy or potential agent that resulted in consequences.

This research will elaborate previous research conducted in commercial vehicle manufacturer to assess risk occurs in the manufacturer. Risk analysis that has been conducted by previous research will be used to calculate risk cost that happens in PSS implementation. Table 2.4 shows an example of risk analysis from previous research that will be used as a foundation to calculate risk cost.

Table 2.3 Risk Analysis on Previous Research

Risk Agent		CARP	%ARP	Cumm. %
RA7	Salesman can't define customer preference	505	13.06%	13.06%
RA4	High lead time of material procurement	351	9.07%	22.13%
RA5	Customer asks for low price with high quality product	340	8.79%	30.92%
RA1	Difficulties in designing product	288	7.45%	38.37%
RA8	Human error in working process	280	7.24%	45.60%
RA9	High lead time of working process	280	7.24%	52.84%
RA6	raw material defect	266	6.88%	59.72%
RA10	Inconsistent customer order	266	6.88%	66.60%
RA15	High insurance premium for every rented vehicle	255	6.59%	73.19%
RA11	Repair cost is costly and need more effort	210	5.43%	78.62%
RA18	Renting cost is almost the same as buying new product	156	4.03%	82.65%
RA13	Restriction from government regulation	152	3.93%	86.58%
RA12	Low service level of manufacturer	110	2.84%	89.43%
RA16	Demand uncertainty of rented car	108	2.79%	92.22%
RA3	Increase price of raw material	106	2.74%	94.96%
RA14	Limited insurance coverage	100	2.59%	97.54%
RA2	Change in marketing strategy	63	1.63%	99.17%
RA17	Insufficient vehicle of rented vehicle	32	0.83%	100.00%

2.5 Simulation

A system is defined as a group of objects that joined together in some regular interaction. The behavior of the system evolves over time is studied by developing a simulation model. Simulation is the representation of the complex condition of the real world (Banks, 2010). It is also used to conduct a numerical experiment to give a better understanding of the system condition using computerized model (Kelton, 2002). According to (Carson et al., 2006). Simulation can be used for the following purposes:

1. Simulation enables to study internal interactions of a complex system
2. Alteration of the model's behavior can be studied

3. Design a simulation model could give you knowledge
4. Changing input and observed the output can produce the insight about most important variable
5. Simulation can be used as a pedagogical device to reinforce analytic solution methodologies
6. Simulation can be used to experimenting with new policies
7. Simulation can be used to verify the analytic solution
8. Simulating different capabilities can help determine the requirement
9. Simulation can be used as training to learn new thing
10. Helpful to visualize system

In this research, simulation is used to forecast and experiment with a new business model. Without simulation, experimenting with a new business model will disturb the existing business model, time-consumed, and costly. Model the system using simulation also gives several advantages rather than another method such as the mathematical model. The advantages of a simulation are listed below (Pearson, 2007):

1. Simulation could be done without distracting the model
2. Simulation does not use much time to be done
3. Simulation able to deal with complex interaction system
4. Simulation could perform various type of model and problem

There are many simulations classification existed. The classification can be divided into:

- Static vs. Dynamic: Static is used when the system is not changed over time while dynamic is used when the system changed over time
- Deterministic vs. Stochastic: Deterministic and stochastic both belong to the dynamic simulation. Deterministic is used when the system contains no random variables while stochastic used when there is a random variable

- Continuous vs. Discrete: Continuous is used when the model changes continuously as a function of time while discrete used when the model is changing instantaneously.

Simulation has several steps that have to be followed to result on the accurate model of the system. These several steps have to be followed sequentially. Step of the simulation in form of flowchart is shown in Figure 2.4.

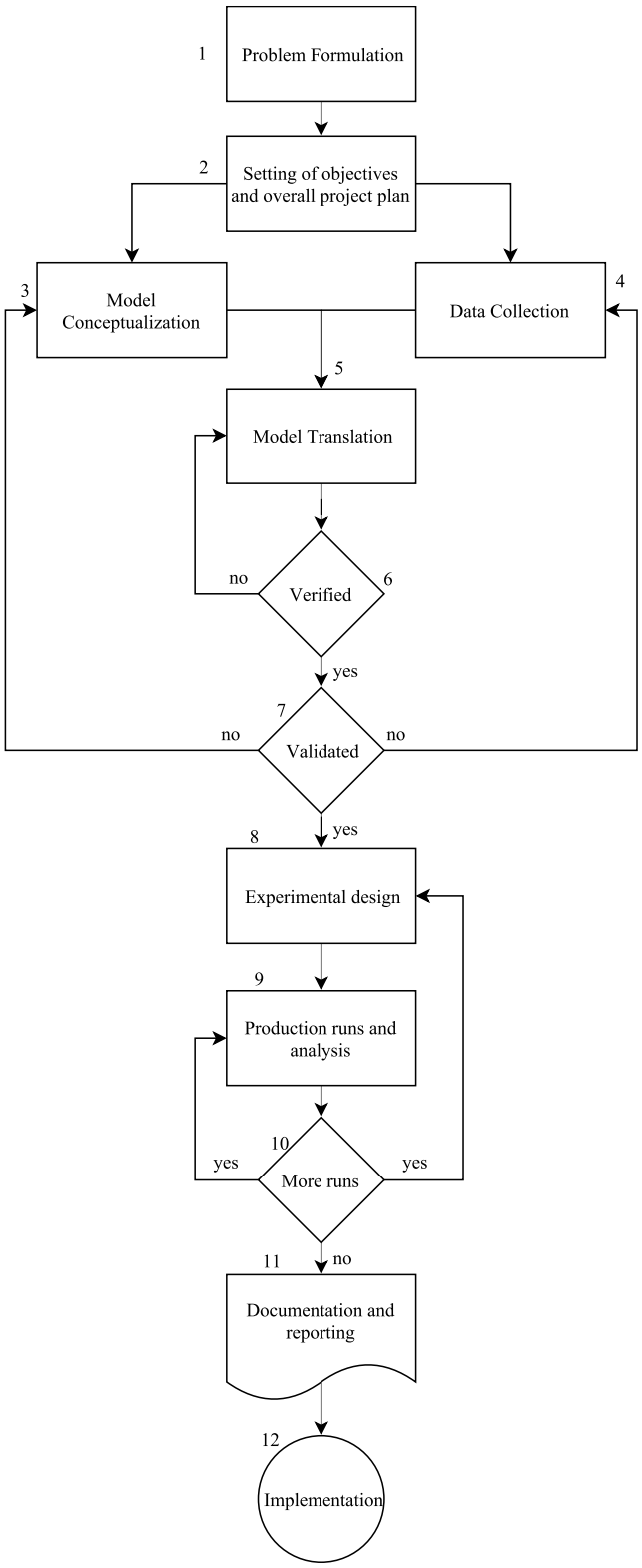

Figure 2.4 Flowchart of Simulation Step (Banks, 1998)

1) Problem Formulation: The main objective of simulation is to solve the problem. Therefore, researcher should begin with problem formulation. In this phase, researcher has to state the problem that wants to be solved by simulation model. The problem should be described clearly. Researcher also has to make sure that the problem is understood and agreed by the policy maker
2) Setting objectives and overall project plan: Subsequent to problem formulation, researcher should set the objectives of the simulation model. Objectives of simulation model are the questions to be answered by simulation. The question can consist of evaluation based on indicators. This research objective is to evaluate business model based on indicators
3) Model Conceptualization: Model conceptualization builds an ingenious model to depict the real system. This model should contain essential features of the problem that will be modified and characterized based on the system. Model complexity should not exceed what it is intended. Too complex model will only make the result inaccurate.
4) Data Collection: Data collection phase should be started early where it takes large portion of time to accomplish simulation model. Data that is collected could be classified into primary and secondary data. Primary data or first-hand data is the data that is collected by researcher. Primary data could be collected using several methods like; measurement, interview, questionnaires, and observation. Secondary data or second-hand data is the data that is provided to researcher like historical data. In this research, researcher will use both types of data to enrich the simulation model
5) Model Translation: Conceptual model that has been made previously will be translated into simulation program. There are two types of simulation program. First type is simulation language where the modeler should accomplish the model with coding like GPSS/H or the second type is used special-purpose simulation software like ProModel and Arena.

6) Verification: Verification used to test whether the simulation model already represents the conceptual model. The similarity can be assessed from input parameters and logical structure whether it already represented correctly in the model
7) Validation: Validation used to test whether the conceptual model already represents the actual system. The process will be repeated until the model accuracy is judged acceptable
8) Experimental design: In this phase, the researcher should determine alternatives that are to be simulated. Besides that, researcher also have to determine length of initialization period, length of simulation runs, and the number of replication has to be made
9) Production run & analysis: Subsequent to experimental design, production run and analysis are used to measure the outcome of the system from the simulation.
10) More Runs: Analyze whether the runs already completed or not
11) Documentation & report: program documentation is necessary to be used for other simulation
12) Implementation: Implement the recommendation from simulation in the real-world system to observe the result

2.6 Previous Research

This chapter consists of several previous researches about PSS that help the writer to further his knowledge and also to establish this research. Previous research has already studied about design, operational, and evaluation phase of PSS, but most of the studies only elaborate exploratory study using interview, survey, and observation or design science (Xing et al., 2017). Whereas there is a gap between previous study and required of scientific data to convince manufacturer to implement PSS. Therefore, simulation model of PSS implementation has to be made to convince

manufacturer that PSS implementation will give positive effect on company's financial and environment indicators.

This sub-chapter classified into previous research in PSS and lean accounting. Lean accounting also discussed here because this research will be used previous study about lean accounting to determine the service cost.

2.6.1 Previous Research in PSS Implementation

In general, previous research in PSS already covers the literature study, design and operation phase of PSS using Quality Function Deployment (QFD) and House of Quality (HoQ). Apart from implementing PSS as their business model, the manufacturer should assess the profitability by considering risk cost related using financial and simulation model

Thesis by Zaman (2016) explained about design phase in PSS implementation using QFD Multi-layer and HoQ for multi-segment manufacturer to compare performance for both manufacturers. This research followed by Partiwi (2017) that adding new stakeholder that was customer to assess multi-stakeholder in commercial vehicle manufacturer. This research also used QFD and HoQ to evaluate specification for both parties.

At the same time, Christ (2017) researched about risk analysis of the commercial vehicle manufacturer using House of Risk (HOR) for multi-actor to assess all the risk related to PSS implementation. Risk analysis on this research will be used as the basis to calculate risk cost in this research.

All previous study summarized by journal by Xing et al. (2017) that explain us most of the studies of PSS implementation classified into literature review, exploratory studies, design science, action research, and combined study. This journal shows us that the study on this topic is still scant although it has huge potential

Table 2.4 List of Previous Research in PSS in Commercial Vehicle Manufacturer

Parameter	Previous Research			
Year	2016	2017	2017	2017
Type	Master Thesis	Final Project	Final Project	Journal
Writer	Akhmad Nidhomuz Zaman	Ajeng Nurvidaningsih Partiwi	Nevadia Cintya Christ	Ke Xing, Mario Rapaccini, Fillipo Visintin
Title	Kajian Implementasi Metodologi Desain Product Service System (PSS) dengan QFD Multi Layer di Perusahaan Karoseri	Perancangan *Use-Oriented Service* Pada Perusahaan KaroseriDengan QFD *Multi-Layer*	Risk Analysis of Product Service System Business Model Implementation in Commercial Vehicle Manufacturer	PSS in Healthcare: an under-explored field
Object	Commercial vehicle manufacturer	Commercial vehicle manufacturer	Commercial vehicle manufacturer	Healthcare facilities
Method	Study PSS Multi-Segment design with modification in QFD Multi-Layer by integrating with Product Service Blueprint using Fuzzy-Analytical Hierarchy Process to assess customer priorities and QFD and HoQ for both customer and company	Identify requirement of all the entities in the business model using QFD Multi-Layer by assessing 12 criteria: quality of commercial vehicle, cost, management, performance, empathy, maintenance, customized service, delivery, policy, reputation, market segmentation, and company readiness	Risk analysis in implementing PSS on commercial vehicle manufacturer industry using House of Risk (HOR) multi-actor for both risk occurrence and preventive action	Using literature review to explored study that have been made in terms of PSS implementation in health care facilities.

Table 2.5 (cont') List of Previous Research in PSS in Commercial Vehicle Manufacturer (cont')

Parameter	Previous Research			
Year	2016	2017	2017	2017
Type	Master Thesis	Final Project	Final Project	Journal
Writer	Akhmad Nidhomuz Zaman	Ajeng Nurvidaningsih Partiwi	Nevadia Cintya Christ	Ke Xing, Mario Rapaccini, Fillipo Visintin
Output	Study of QFD multi-layer method for commercial vehicle manufacture and comparison of PSS design between two company	Recommendation for the company to provide insurance on the service, inspection process and conducting a survey to the customer on the regular basis, and using ISO	Give a recommendation to the company for the most severe risk in implementing PSS and its preventive action	Study of PSS implementation mostly motivated by instigating system thinking and guide the design of healthcare solution

2.6.2 Previous Research in Lean Accounting

Previous research in lean accounting will help to determine the method to calculate the cost of product & service offers by the company to estimate the profitability of the company. Thesis by Sholihah (2015) studied about cost assessment in Industrial Product-Service System using several cost management method which one of them is lean accounting (Sholihah, 2015).

While Setiati (2016) researched about implementation of lean accounting in commercial vehicle manufacturer to support implementation of PSS by assessed service cost in the manufacturer

Table 2.5 List of Previous Research in Lean Accounting

Parameter	Previous Research	
Year	2015	2016
Type	Master Thesis	Final Project
Writer	Mar'atus Sholihah	Nur Intan Setiati
Title	Cost Management Methodology for Industrial Product-Service System	Lean Accounting as A proposed Cost Structure To Support Product-Service System (PSS) Transformation in PT. X
Object	Industrial Product-Service System	Commercial Vehicle Manufacturer
Method	Cost assessment for Industrial Product-Service System using Activity-Based Costing, Time-Driven Activity-Based Costing, Process-Based Costing and Lean Accounting	Using lean accounting to generated value stream mapping and costing and Production Lead Time (PLT) to calculate Cost of Goods Sales (CoGS)
Output	Cost assessment that is most suitable for Industrial Product-Service System	Cost of Goods Sales (CoGS) of the product using lean accounting approach

2.6.3 Previous Research in Simulation

The first journal elaborates increasing trend of simulation and high performance computing in solving the problem. Current development of simulation use cloud computing and big data access to increase its accuracy

The second journal is the example of simulation implementation to solve the transportation problem. In this study, simulation used to depict the transportation and supply chain process and proposed improvement.

Table 2.6 List of Previous Research in Simulation

Parameter	Previous Research	
Year	2018	2017
Type	Journal	Final Project
Writer	Sandro Fiore, Mohamed Bakhouya, Waleed Smari	Uly Kurniawati
Title	On the road to exascale: Advances in High Performance Computing and Simulations—An overview and editorial	Permodelan Simulasi Distribusi Jalur Laut PT Petrokimia dengan Mempertimbangkan Supply and Transportation Disruption
Object	Industrial Product-Service System	Commercial Vehicle Manufacturer
Method	Literature review and observation about increasing trend of simulation and high performance computing	Using ARENA to simulates distribution channel of fertilizer of PT Petrokimia
Output	Increasing trend of simulation using big data and cloud computing	Improvement proposal to increases number of ship and capacity that will result on increasing service level

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CHAPTER 3
RESEARCH METHODOLOGY

This chapter consists of research methodology flowchart and the explanation about the flowchart. The flowchart consists of nine steps. Research's flowchart is shown in Figure 3.1.

Step of flowchart starts with problem formulation to formulates the problem that want to be solved in this research, literature review to seek for other research and study that already assess about PSS implementation, develop conceptual model to present complex system into the model, data collection to collect data that is required to established this research, scenario development to generate scenarios that will be used in the research, data processing to process the data that already collected to input data, simulation to generate expected outcome and convinces manufacturer based on scientific proof, analysis and interpretation to analyze outcome that resulted from simulation, and conclusion and suggestion to give recommendations to the manufacturer based on our research

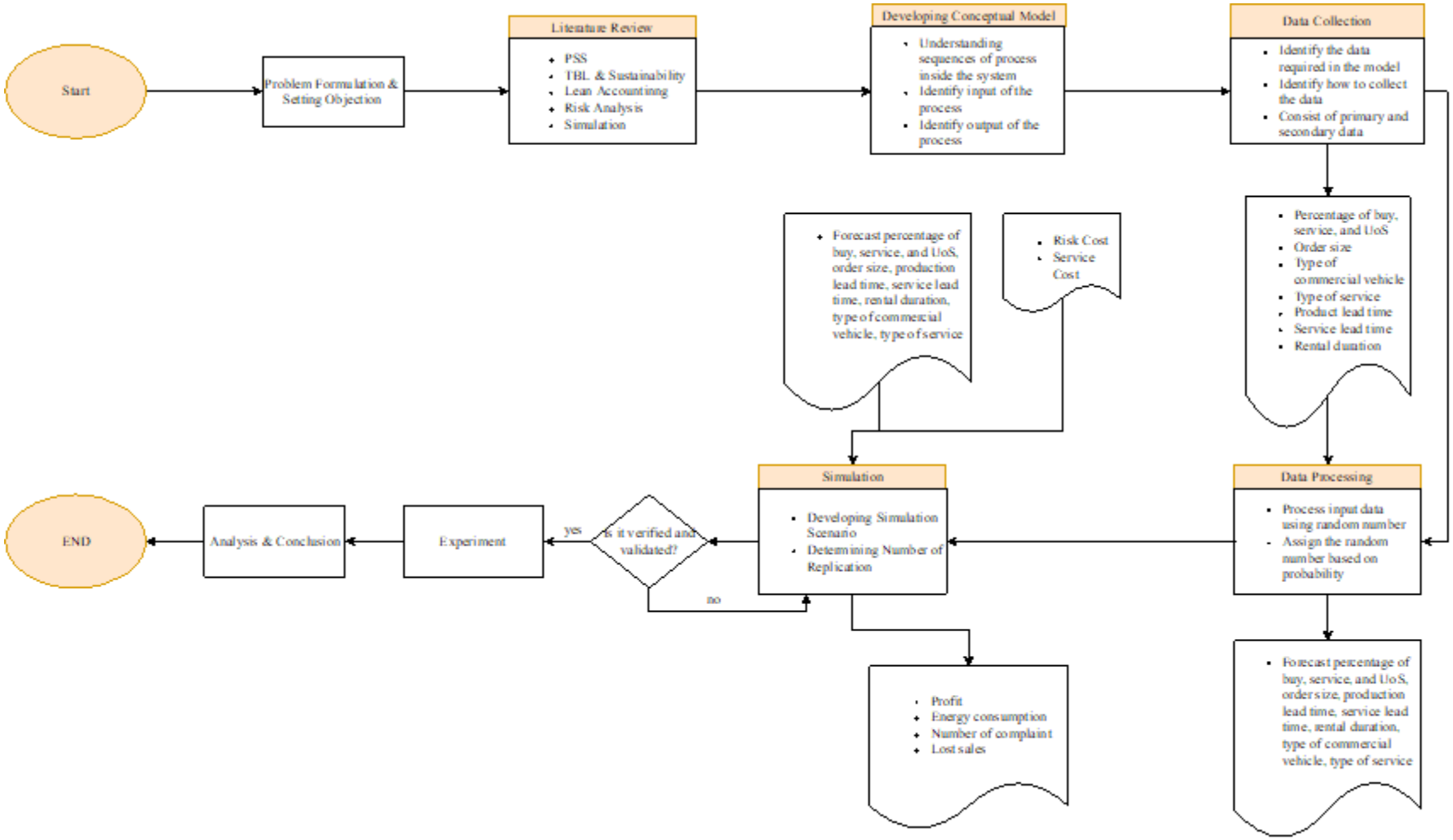

Figure 3.1 Research Flowchart

3.1 Problem Formulation and Setting Objective

Initial phase starts with problem formulation and setting the objective. Problem formulation is done to understand the problem regarding the topic and formulates the objective of the research based on the problems that have been formulated. Problem formulation can be identified from the chosen object that can be improved.

Problem formulation in this research is to evaluate PSS business model implementation in commercial vehicle manufacturer using financial modeling and simulation with risk cost and convinced that PSS implementation could increase the financial and environment indicator. The objective of this research is to find the best scenario of business model to be implemented in commercial vehicle manufacturer.

3.2 Literature Review

Literature review is an activity to review all previous study that is useful to accomplish this research. There are several studies about PSS model, sustainability, risk analysis, lean accounting, and simulation. Study about PSS model is done to further knowledge of the writer about PSS concept. PSS has three categories of model, which are: product, PoS, and UoS,

PSS model will be connected with sustainability as their objective besides profit from the financial perspective. Manufacturer has to consider sustainability of the business and environmentally besides generating maximum profit. Literature review also contains lean accounting used by previous study to calculate service cost that will be applied in this research.

3.3 Develop Conceptual Model

Conceptual model is depiction and imitation of the system that is built to illustrate the sequential process of the system. Conceptual model is useful to know the process flow inside the system.

The construction of a model of the system can be defined as much art as much science (Carson et al., 2006). Building appropriate model is not instantaneous, there are set of instruction that should be followed to build a

successful and appropriate model (Morris, 1967). The art of modeling starts with the ability to find out essential feature of the problem, modify the assumptions that characterize the system and then enrich and elaborate the model until finding the result.

Conceptual model is built to clarify the sequence of research step. Conceptual model starts from business process of the object, which is commercial vehicle manufacturer. Business process of the object will be translated into flowchart that could represent the input and output of each step.

There are four requirements that are needed according to Banks (2010). This requirement is needed to make the conceptual model valid:

a) Validity
b) Credibility
c) Utility
d) Feasibility

This research consists of two alternatives that will be constructed to conceptual model. The first alternative is Product-oriented Service (PoS). PoS is a conservative business model where the manufacturer sells the product directly to customer. Customer owns the physical product that is sold by the manufacturer with several main services.

The second alternative is Use-oriented Service (UoS). UoS is business model where manufacturer only sells functionality of the product while the physical product still owned by the manufacturer. Customer only rents the product for a certain period of time. Both of the alternatives here will add by risk cost to calculate the risk of implementation of both alternatives

3.4 Data Collection

There is a constant interplay between the construction of the model and the collection of required data (Shannon, 1975). As the complexity of the model change, amount of data needed to be collected as an input also change. Data collection phase is a phase that takes a large portion of the total time required to perform the simulation. There are several ways to obtain the data, which are

giving the questionnaire, observe directly to the manufacturer or using the manufacturer's historical data

Data that collected in this research will be used as input of simulation model. The data that is collected can be classified into two types. First is data comes from the manufacturer and the second data is data from previous research. Example of data from previous research is service cost of commercial vehicle manufacturer that was assessed using lean accounting (Setiati, 2016) and risk cost developed from risk analysis (Christ, 2017).

3.5 Data Processing

After defining an input, the process continues to data processing wherein this phase the data that is collected will be processed. For example, order inter-arrival data which consists of the date of every order received by manufacturer have to be transformed into the set of data that could be read by simulation as inter-arrival model

In order to transform inter-arrival data into the set of data that is readable by simulation model, the data is processed using input analyzer to fit it into distribution. The distribution of inter-arrival is used as an input data for the simulation model.

3.6 Simulation

Simulation has to be done in assessing new business model to know whether the future business model will surpass manufacturer's expectation. Simulation will be carried out using input data that have been collected in data collection phased. There are two kinds of data that is used as an input in this simulation. The first is the data that is collected from the manufacturer while the second data is data that is collected from previous research. Example of this kind of data is service cost and risk cost. Service cost is the data that is drafted from previous research carried by Setiati (2016) and will be used in this research to calculate profitability while risk cost is cost that is derived from risk severity and occurrence that is collected from previous research by Christ (2017).

Simulation starts with scenario development that will be evaluated in this simulation model. Scenario will be made based on two alternatives of business model, which are: Product-oriented Service (PoS) and Use-oriented Service (UoS). PoS business model offers customers to buy the product and service related to the product while UoS offers leasing model which the customer only buy functionality of the product. Scenario in this simulation can be classified based on variables in the simulation like order size, specification, and leasing duration.

The next step is determining number of replication. Number of replication help simulation to represent the real system and avoid Random Input Random Output (RIRO). Number of replication help to reduce random input generate by simulation.

Simulation has to be done in this research to assess the future condition of PSS implementation. Simulation will include risk cost as the part of simulation. Simulation also will help the company to clarify uncertainties of PSS implementation in terms of financial and environment

3.7 Verification & Validation

Verification and validation phase consists of logic testing between simulation model and conceptual model and real-world system. Verification is done to test whether the logic inside the simulation model is the same with conceptual model and real-world system. Verification will be accomplished by debugging in discrete simulation software. As for simulation's logic test done by observing model animation and simulation output.

Validation is process to assure that simulation model represents the real system. This process can be accomplished by comparing simulation model and real-world system. If there isn't any significant difference, the simulation model is assumed to be valid.

3.8 Experiment

Experiment starts after the model was verified and valid. Experiment will be done to test each scenario that has been made before. Scenarios that can be

tested consist of basic scenario and combination between scenarios. Each scenario will be tested to know which scenario that give the best outcome based on profitability, energy consumption, lost sales and number of complaint.

3.9 Analysis & Conclusion

This phase is carried out to analyze and conclude the result of simulation for each scenario, Product-oriented Service (PoS) or Use-oriented Service (UoS). The result of simulation will be the foundation for researcher to analyze and giving recommendation to the manufacturer about an alternative that gives the best opportunities from profitability and triple bottom line. Triple bottom line indicators in this research limited to energy consumption and number of complaint only.

Based on the analysis, company could get an insight of each scenario and its performance based on indicators. Based on the information and insight of each scenario, company could get evidence whether PSS business model is better than conventional business in terms of triple bottom line. This research also can be useful as a suggestion and feedback for further research regarding to this topic.

CHAPTER 4
CONCEPTUAL MODEL, DATA COLLECTION & PROCESSING

This chapter consists of conceptual model that is built to depict the business process of the commercial vehicle manufacturer. The business process classified into product-model, Product-oriented Service (PoS), and Use-oriented Service (UoS) alternatives. Each business process has its own model to fulfill customer's demand and serves the functionality of the product. Therefore, a conceptual model is constructed for business process and product lifecycle from manufacturing process until product usage and disposal. There are several differences on each alternative on price, service offered, and how to manage damaged product and product disposal.

Subsequent to developing conceptual model, data required for simulation is gathered from several sources. The data collected can be divided into two part. First is existing condition data to depict subsist manufacturer's performance in commercial vehicle manufacturer. Several previous studies like risk analysis of Product Service-System (PSS) implementation, cost calculation in commercial vehicle manufacturer, and production time analysis.

The second part is forecast data about customer preference to PoS and UoS business model. The data consists of customer preference towards PoS and UoS from previous research and interview with the owner and head of department. After all data has been collected, several types of data have to be processed to be used in this research.

CHAPTER 5
SIMULATION AND FINDINGS

5.1 Arena Model

This chapter consists of simulation model of product lifecycle in commercial vehicle. Figure 5.1 shows a helicopter view of the simulation model while the sub-model will be explained below.

CHAPTER 6
ANALYSIS & DISCUSSION

This sub-chapter consists of analysis based on simulation experiment that has been done in the previous chapter. Analysis in this chapter covers performance analysis between basic alternative, PoS analysis, and scenario analysis.

CHAPTER 7
CONCLUSION AND RECOMMENDATION

This chapter consists of research conclusion and recommendation for future research.

7.1 Conclusion

Based on the research that has been accomplished, it summarized that:

1. PoS became the best initial alternative for financial indicator with profitability of IDR 7,889,245/ unit while UoS alternative is the best alternative for social and environmental with total lost sales of IDR 170,155,814 and carbon usage of 4.37 tons/unit.
2. Scenario 6 which generate order arrival from market trend and get the lost sales from product became the best combination scenario.

3. The best number of commercial vehicle for UoS alternative in selected scenario is 15 vehicles where it gets the smallest lost sales of IDR 51,494,146.
4. Product and PoS have almost the same electricity usage while UoS has much better efficiency because one unit of vehicle could be used for several customers.

7.2 Recommendation

Recommendations for the manufacturer and for future research are

1. Manufacturer should record reliability data of their product to know the quality of their product and benchmarking to other competitors
2. Future research might consider a global condition rather than assessing only one manufacturer
3. Future research might use third party or service provider as entity in the business

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BIOGRAPHY

The author, Satria Wira Buana is the youngest son in his family. He was born in Jakarta on March 4, 1996. He went to SDK 1 BPK Penabur (2002-2008) for elementary school, SMP Kolese Kanisius (2008-2011) for junior high school, SMA Kolese Kanisius (2011-2014) for senior high school. After finishing senior high school, the author went to Industrial Engineering Department. Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia.

During the college time, the author actively engaged with international program and student exchange. The author selected as an exchange student to UTeM Melaka, Malaysia. Besides that, the author also got an opportunity to experience Istanbul Aydin University Summer Camp in Istanbul. The author also had interest in industrial competition and basketball. The author has won Industrial Paper and Action (INPACT) 2018 in Universitas Sumatera Utara. The author also won V-COM Airlangga University in 2016 and Liga Mahasiswa East-Java region in 2017 for basketball. For further discussion, the author can be contacted through: satriawira1996@gmail.com