# OPTIMISATION CONTROL PROCESS IN REMANUFACTURING SYSTEM

Submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

**MOHD KHUSAIRI BIN MD SAID**

FACULTY OF MANUFACTURING ENGINEERING

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# DECLARATION

I hereby, declared this report entitled “Optimisation Control Process In Remanufacturing System” is the result of my own research except as cited in references.

Signature : ……………………………………

Author’s Name : MOHD KHUSAIRI BIN MD SAID

Date : 2 SEPTEMBER 2021

# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfilment of the requirement for Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

……………………..................................

**(DR. NUR AIDAWATY BINTI RAFAN)**

# ABSTRAK

Pembuatan semula adalah salah satu inisiatif untuk mengekalkan sisa yang terbuang atau produk terguna menjadi lebih berguna. Kajian ini memfokuskan pada jalur pemasangan dalam sistem pembuatan semula dalam industri automotif yang bertujuan untuk menetapkan strategi untuk meningkatkan efisiensi dan mengoptimumkan proses kontrol menggunakan kaedah Taguchi. Kajian ini dilakukan untuk mengenal pasti masalah semasa, seperti proses barisan pemasangan yang tidak sistematik, masa pemprosesan yang tidak dapat diramalkan, dan kualiti produk yang tidak menentu. Dengan menggunakan simulasi Arena, tiga model susun atur yang diusulkan dirancang yang menghasilkan parameter Taguchi. kaedah Taguchi dilakukan analisis yang merujuk keadaan lebih kecil lebih baik dengan menggunakan parameter model susun atur yang diusulkan yang menyumbang keadaan output optimum di Level 3 dengan nilai nisbah S/N adalah -37,02 dB, validasi 5,63%, dan rata-rata untuk masa pemprosesan dan bilangan stesen yang diperoleh ialah 73.00 dan 84.33. Prestasi model susun atur yang dicadangkan dianalisis menggunakan simulasi di Arena selama 20 jam dengan kedatangan setiap 7 jam. Dalam hasil yang diperoleh ini, susun atur simulasi (3) adalah susun atur yang optimum yang meningkatkan jumlah produksi yang merupakan jumlah bahagian yang dihasilkan dari model susun atur ini adalah 273 bahagian, jumlah bagian dalam adalah 819 bahagian, dan kerja dalam proses (WIP) adalah 510.74 bahagian. Berdasarkan kaedah Taguchi dan hasil simulasi Arena, susun atur 3 yang dicadangkan adalah susun atur keadaan yang optimum. Sebagai penambahbaikan kajian ini adalah mencadangkan susun atur ini dapat diterapkan pada yang industri lain, untuk mengusulkan idea baru dengan menggunakan atribut yang sama, menerapkan aplikasi analisis lain, dan kualiti produk perlu dipertimbangkan kerana ketidakpastian dari segi bahan.

# ABSTRACT

Remanufacturing is one of the initiatives to sustain the waste or used products or components. This study focuses on the assembly line in remanufacturing systems in the automotive industry that aims to establish strategies to improve efficiency and optimize the control process using the Taguchi method. This study was conducted to identify the current problem, such as the unsystematic assembly line process, unpredictable processing time, and uncertainties quality of the product. By using the Arena simulation, three proposed layout model was designed that generated the Taguchi parameter. Taguchi method was performed the analysis referred the condition of smaller is better by using the parameter of proposed layout model that contributes optimal condition output in Level 3 with the value of S/N ratio is -37.02 dB, validation of 5.63%, and mean for processing time and the number of station obtained of 73.00 and 84.33. The performance of the proposed layout model was analyzed using the simulation in Arena for running 20 hours with the arrival every 7 hours. In this result obtained, the simulation layout (3) is the optimal layout that increases the number of production which is the number of parts out generated from this layout model is 273 parts, the number of the part in is 819 parts, and the work in progress (WIP) is 510.74 parts. Based on the Taguchi method and Arena simulation result, the proposed layout 3 is the optimal condition layout. As an improvement of this study is to propose this layout can be applied to another industry, to propose the new idea by using the same attributes, applying to another analysis application, and the quality of product need to be considered due to uncertainties in term of material

# DEDICATION

This study is wholeheartedly dedicated to my beloved parents, who have been my source of inspiration and gave me strength when I thought of giving up, who continually provide their moral, spiritual, emotional and financial support.

To my lovely supervisor, Dr Nur Aidawaty Binti Rafan, Senior Lecturer of Universiti Teknikal Malaysia Melaka, for giving me the opportunity to do research and providing invaluable guidance throughout this research. Her sincerity and motivation have deeply inspired me.

To the friends I made and love strongly, they know who they are. For lending me their ears and hands throughout completing this thesis and degree. For putting up with my each worst mood and go along with my unwise decisions.

And lastly to my bestfriend, Nurul Ismahani Adilah binti Abu Hassan who always be a supportive friend, my best cheerleader, my pillars of strength throughout completing my final year project.

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In the name of ALLAH, the most gracious, the most merciful with highest praise to Allah. Finally, I manage to complete this final year project victoriously with all the effort I made. I would like to thank to my respected supervisor, Dr. Nur Aidawaty Binti Rafan, for the most beautiful mentoring session that was given to me throughout the project, endless motivation for me to keep striving, humble advice and full support of guidance throughout the study. Also, to all the technician that giving me full support and always help me hand in hand from the scratch. Without them, I may not stand where I am right now.

Last but not least, I would like to thank to Faculty of Manufacturing Engineering UTeM for letting me to have this gold opportunity as a student in the faculty and permitted me to use all the equipment for this project. The memory, knowledge and skills that I obtained here will I use in my future career.

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| End of Life | - | EOL |
| Gross Domestic Product | - | GDP |
| National Automotive Policy | - | NAP |
| Ministry of International Trade and Industry MALAYSIA | - | MITI |
| Original Equipment Manufacturers | - | OEM |
| End-of-Life Vehicles | - | ELV |
| Independent Remanufacturers | - | IR |
| Analytic Hierarchy Process | - | AHP |
| Fuzzy Interpretive Structural Modeling | - | FISM |
| Taguchi method | - | TM |
| Orthogonal Array | - | OA |
| Signal Noise | - | S/N |
| Design of Experiments | - | DOE |
| Work In Progress | - | WIP |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| Percentage | - | % |
| Degree | - | ° |
| Decibels | - | dB |
| Minutes | - | mins |

# CHAPTER 1

## INTRODUCTION

### 1.1 BACKGROUND OF STUDY

The manufacturing industry is one of the largest in the world. These industries are important for the welfare system in the human population and another reason is for technological and economics of the country. From the data in the United States, the manufacturing industries create wealth with the manufacturing account for about 15% Gross Domestic Product (GDP) and also affect the country has natural resources such as s agricultural lands, mineral deposits, and oil reserves (Mikell P. Groover, 2010).

From the manufacturing industry is growing rapidly and use a lot amount of natural resources. Therefore, these continue with the issue of the waste management that required to be controlled in higher-level and more efficient move due to environmental regulations. Initiatives were applying is remanufacturing that the waste or end of life product needs to sustain in the development industries and reduce the number of use the natural resources. The largest number of waste or end of life product is continuity to the critical scenario and become one of the environmental impacts and affect the world ecosystem. The result from the waste management of remanufacturing lithium-ion battery from electric vehicles which is the reduction of energy consumption and greenhouse gas emissions is 8.55% and 6.62% respectively (Siqin Xiong, 2019).

The remanufacturing is the best initiatives but to fulfil the needs that meet the customer requirements is the challenge for the supplier to think before proposing their product to the customers. Remanufacturing product may be attributed to their properties, the good product will go through a certain process to compete their properties almost similar to the original or natural product has been made. In Malaysia, the Implementation remanufacturing industry is still growing and needs more exposure to take a lead in global environmental sustainability in these industries. From a view of point customers, the remanufactured product can be considered to be the same as the new product (N.M. Yusop, 2015)

The process that involved in the remanufacturing system is different in every company because the flow of the process is not standardized and the research about the process needed in the remanufacturing system is still continuing to make the system more systematic and efficient. The planning of the system is important to the company because it can maximize their profit and serves the product at the higher quality same as a new product. Most of the challenge in the remanufacturing system is the processing times due to the uncertain quality of the product that will remanufacture and these issues will affect the demand that required by customers will be delayed (Peter Lundmark, 2014).

In order to solve this situation, this project is set to introduce the study on investigation of the optimisation control process in the remanufacturing system. The process involved in the system is still unsystematic and this study aims to counter the problem which is to remove the uncertain process. The method used for this study is using the Taguchi Method that will optimize the process in the remanufacturing system. By using the Taguchi Method, the flow of process will be analysed one by one and make the comparison with another layout.

## 1.2 PROBLEM STATEMENT

Remanufacturing development need for the automotive industry in Malaysia because to enjoy various initiatives of green technology and supporting the campaign of safe our environment. To ensure that the product is appropriate for remanufacturing, the uncertain quality condition of the used or waste product may be considered so each producer has the technology of the product. In order to improve the remanufacturability of automobile products, concern for remanufacturing must be integrated into certain areas of vehicle design, including joint procurement, choice of components, the layout of systems, handling and transportation, etc. (Yüksel, 2010).

Otherwise, remanufacturing is the strategy for material recovery so that it will involve several processes in the operation. The highly variable of processing times in remanufacturing operation is the problem that occurs because the condition of the waste product is unpredictable. High inventory levels, high process throughput times are the major problem in the remanufacturing process which can be tackled by the traditional concept of operations management (Seitz, 2007).

In remanufacturing, the environment of the remanufacturing sector in Malaysia is still fresh and the process involves also still on research and in future will be standardized by the government to sustain the remanufacturing sector. In 2006, one of the initiatives for sustain the remanufacturing industry in Malaysia, the National Automotive Policy (NAP) is has been established by the government which are Ministry of International Trade and Industry MALAYSIA (MITI) (Ministry of International Trade and Industry MALAYSIA, 2009). The process involves in the remanufacturing is different in every company, the basic concept of remanufacturing operation remains the same which is Inspection and Grading, Disassembly, Reprocessing, and Reassembly. By using the Taguchi method, it will optimize the operation involves in remanufacturing.

## 3. OBJECTIVES

The purpose of this study is to optimize the remanufacturing operation by using the Taguchi method. Detailed objectives of this study are as follows:

1) To identify the problem of the current remanufacturing system
2) To propose the model by using the Taguchi method
3) To analyse the performance of the remanufacturing system after applying the Taguchi method.

## 1.4 SCOPE

This project focused on the study of topics relating to the remanufacturing system literature review the including journals, case studies and articles (remanufacturing companies, manufacturing, Taguchi Method, etc.). It basically affects the whole remanufacturing systems process in the automotive industry. This project would concentrate on the study of remanufacturing in automotive and Taguchi Method literature. This project aims to establish strategies to improve efficiency and optimize in the control process the remanufacturing system and to improve performance by using the Taguchi Method, as well as to improve the quality of service to customers and work procedures. After investigating by reviewing and make a comparison, it is possible to analyze issues that frequently exist in the remanufacturing system across different processes.

## 1.5 SIGNIFICANT OF STUDY

The aim of this project is to optimize and improve the effectiveness of the use of all the process in the remanufacturing system and to improve the efficiency of the services sector as an alternative method of expanding the country's economy in competition with other countries that are increasing in the remanufacturing system and services sector. When performing a reviewing, it is possible to investigate issues that also reduce processing times in the remanufacturing system in automotive industries, meaning that this investigation is not limited to an evaluation in the selection of control process to be analysed during the data acquisition phase. There are some benefits that can be obtained when this study is completed, the remanufacturing can make a comparison about their existing flow of the process that will be optimized and reduce the number of processing times and make comparison with the other methods.

## 1.6 ORGANIZATION OF REPORT

The overall organization of the study takes the form of three chapters, including this introductory chapter. Chapter 1 discusses the background of the study and the problems that are identified through the research on journals, articles and current news. It is then accompanied by targets that are set to be accomplished across a lens that narrows down the research field. The significant of the study to the machining industry is also disclosed.

Chapter 2 begins by reviewing the remanufacturing development in the world and also the confusion of the meaning remanufacturing. It was then continued reviewing the remanufacturing process in the automotive industry that included all the basic principles and the perspective about remanufacturing development. After that, the review focusing on the assembly line that the important factor of this study and review the basic process in the assembly line with the challenges and barrier. Lastly, the methods for experimenting with the procedure of the assembly line layout by using the Taguchi method application.

Chapter 3 describes the methods and procedures to achieve the objectives mentioned in this study. The flow starts from the assembly line layout that will be designed through the Matrix Laboratory (MATLAB) and generated the three layout design with the different arrangement of the assembly line sequence This is followed by using the Taguchi method, the three assembly line layout of the remanufacturing system in the automotive industry will be validated and produce the final result of optimization.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 REMANUFACTURING SYSTEM

In this chapter, the control process in the remanufacturing system is reviewed based on the previous and present control process that still applicable in the remanufacturing industry. The information gain of this study may be in form of journals, case studies, books, articles, and articles (remanufacturing companies, manufacturing production, Taguchi Method, etc.). Furthermore, this literature summarised the investigating including the previous and present control process in the remanufacturing system and the optimisation medium to improve the quality of the remanufacturing system.

### 2.1.1 Introduction of Remanufacturing System

Remanufacturing is an important element of the new world technology for the global economy of sustainable development to growth. The management and technology of remanufacturing assemblies are more relevant. The role of engineering in ensuring the effectiveness of the production line and the quality of remanufactured goods (Liu et al., 2019). Remanufacturing has been described as one of the most effective strategies for providing a successful End of Life (EoL) recovery in today's resource-efficient and global ecosystem. A circular economy has been defined as an industrial system that is restorative or regenerative by intentions and design by The Ellen MacArthur Foundation (The Ellen MacArthur, 2013).

Remanufacturing is a method where used products are torn down to become same as a new condition product and the product recovery from End-of-Life (EOL) that restores used goods to their original state with minimal loss of material and energy for sustainable production (Priyono et al., 2015). Figure 2.1 shows the product is from used components and End-of-Life (EOL) that recover to become more useful and meet the requirements same as new condition products without any lack of performance and contribution to sustain the environmental friendly in manufacturing industries to maintain the ecosystem without the harmful impact that becomes dangerous for the future generation (The Ellen MacArthur, 2013).

Remanufacturing is one of the initiatives to sustain the waste or End-of-Life (EOL) products or components. Furthermore, every product in the world particularly components made from metal which has a lack of performance after a long period and the scenario will contribute to the waste or End-of-Life (EOL) products. Remanufacturing is the process to rebuild the performance of waste product same as new condition products after following several processes that improving the performance. Table 2.1 shows the related term of the remanufacturing

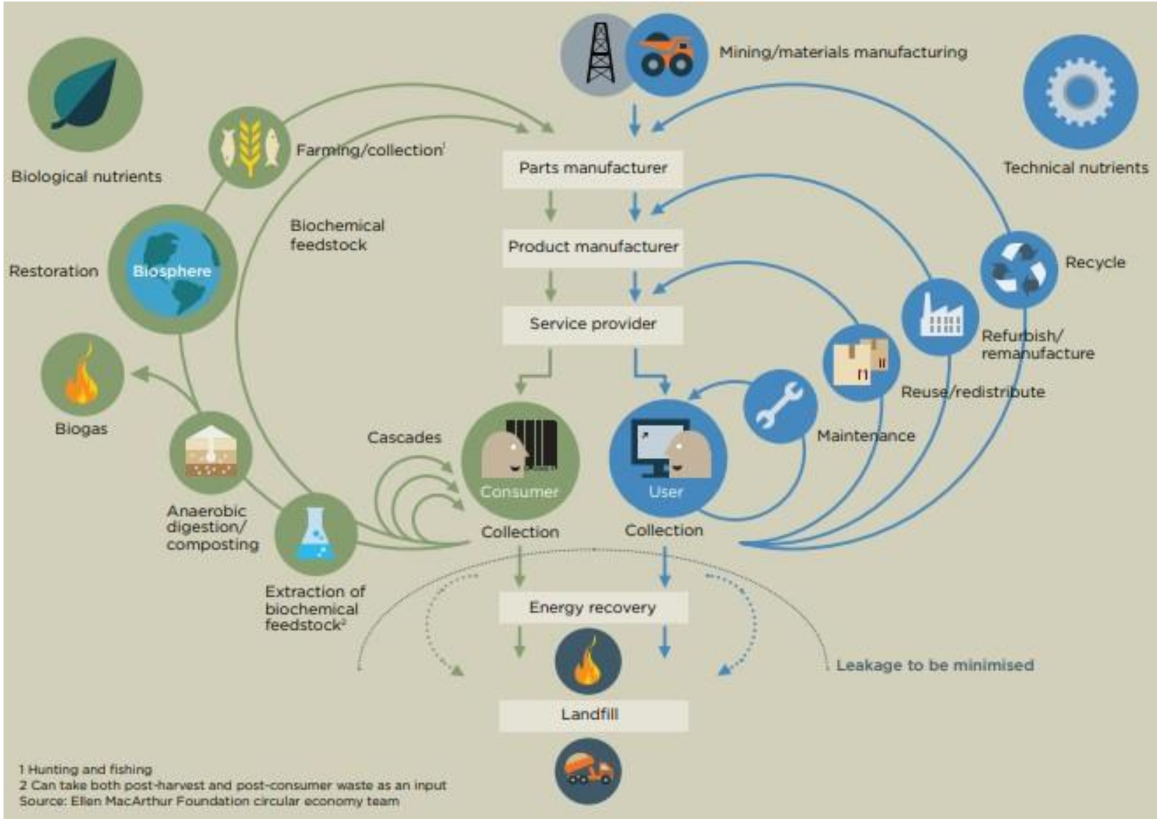



Figure 2.1 Circular Economy by Ellen MacArthur Foundation. Source: (The Ellen MacArthur, 2013)

Table 2.1 Terms related to Remanufacturing

| Term | Definition | References |
|---|---|---|
| Recondition | • The possible improvement of components that bring a product maintained in good working condition again, though not generally to a "new" state.<br><br>• Return a used product to a satisfactory working condition by rebuilding or repairing major components that are close to failure, even where there are no reported or apparent faults in those components. | Triple Win: The Economic, Social and Environmental Case for Remanufacturing (Anne-Marie Benoy, 2014)<br><br>Remanufacturing and Product Design:<br>Designing for the 7th Generation<br>(Charter & Gray, 2008) |
| Refurbish | • The most aesthetic enhancement of an item that may require creating it looks modern, with minimal feature improvements. | Triple Win: The Economic, Social and Environmental Case for Remanufacturing (Anne-Marie Benoy, 2014) |
| Repair | • Repair once again making a faulty product usable. In the development phase, an evaluation of the core of the problem is usually not carried out, which ensures that the product may not work as a new product. | Remanufacturing and product design<br>(Charter & Gray, 2008) |
| Re-use | • Generally, this concept applies to a material that has already been used. The product will retain the problems it acquired during its previous life as it will not have been repaired. | Remanufacturing and product design<br>(Charter & Gray, 2008) |
| Recycle | • Extracting a product's raw materials to use in new products. This is a good option for products which are easily constructed and have minimal numbers of components. | Triple Win: The Economic, Social and Environmental Case for Remanufacturing (Anne-Marie Benoy, 2014) |

### 2.1.2 History of Remanufacturing system

The Massachusetts Institute of Technology initiated research into the disposal of waste materials in the late 1970s. The United States publicly promoted the restoration or regeneration of waste products in the 1980s, the process named it “Remanufacturing”, while the Japanese proposed the “renewable plant technology” idea. In 1992, Russian scholars suggested to the International Heat Treatment Committee the concept of setting up "the Heat Treatment Technology Repair Committee" (Xu, 2013). Moreover, It is absolutely crucial for the term “remanufacturing” to be clearly established in a language which is accessible among the Member States. Also with a representation in place, acknowledging that terms and procedure vary across various industries is equally relevant based on the report by European Remanufacturing Network in Figure 2.2 (European Remanufacturing Network, 2015).

Based on the World Bank Report of “Remanufacturing: the experience of the United States and the revelation to developing countries”, identified the remanufacturing industries experience of the United States and explored the opportunities of certain third world countries for remanufacturing implementations. It supported the remanufacturing industries growth of the sector. The remanufacturing of used mechanical and electrical components has several decades of developmental experience in the United States, Canada, the European Union and other developing countries (Xu, 2013). Over the past decade, literature and research have sought to define “Remanufacture” because a lack of understanding of remanufacturing as a process and a method indicates the constant appearance of these meanings. Uncertainty over the concept of remanufacturing causes confusion during the implementation phase, which limits the progression towards remanufacturing development (Charter & Gray, 2008).

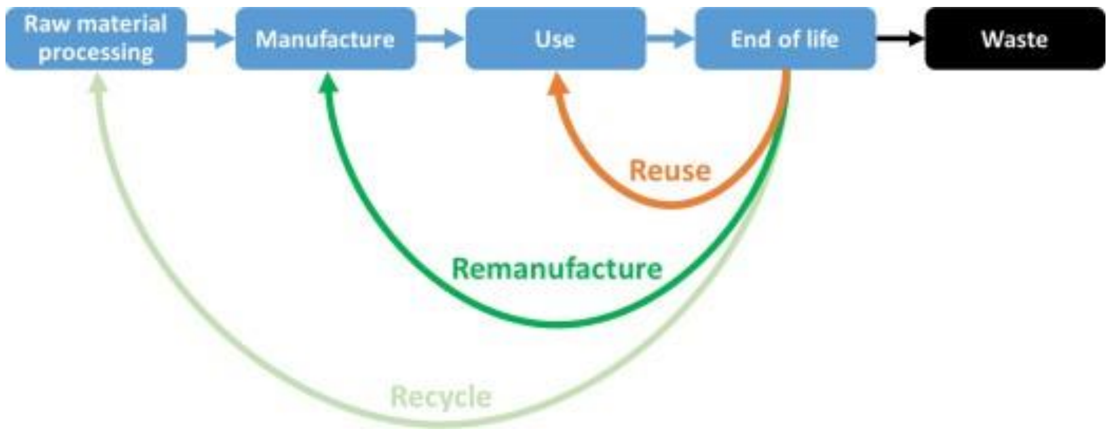



Figure 2.2 Remanufacturing in context with the circular economy. Source: (European Remanufacturing Network, 2015)

In 2005, the global remanufacturing sector gained output or profit of more than one hundred billion dollars. In the United States, the remanufacturing sector was the biggest, and its revenue hit 75 billion dollars. The remanufacturing of automotive and construction machinery contributed to more than 2/3, with production touching around 50 billion dollars. Till 2004, more than 7.48 million car engines and 2.4 million transmissions were remanufactured by Volkswagen. The ratio of remanufactured engines and parts produced by the business to the new computer was 9:1 (Xu, 2013). In the 1960s at japan, many small shops started the repairing business as their economy income. Majority of them had no large-scale manufacturing equipment to handle the product with the limited facility but only repair service for defective products was provided. Remanufactured components were really not well-known. If the broken components still can not be repaired, their alternatives were to buy any brand new genuine components (Ikeda, 2017).

More than two decades remanufacturing sector had been in the global industries, the objective of the remanufacturing giving a lot of benefits whether control and sustainable the environment impact (source of energy), reducing the number of waste products, and gained more profit to the company that implementing the remanufacturing process. Unfortunately, lack of exposure and hard approach of a policy of the remanufacturing process contribute to the slow progression of implementation in the global manufacturing sector.

### 2.1.3 Basic Principle of Remanufacturing system

In order to rebuild the surface coatings and modification developments, Corrosion, wear and harm to products or components. After a long way of experience with a lot of research begin, the specifications and production level of the remanufacturing products could not be lower than the latest product because of the quality level not meet the specifications. In the development of sustainability to follow the rules and regulation in the remanufacturing sector, energy conservation, saving materials and reducing emissions play an extremely important role (Xu, 2013).

Remanufacturing is one of the product recovery techniques, from the perspective of the consumers, the performance expectations after restoring the used product at least equal or similar to the Original Equipment Manufacturers (OEM) and at the same time provides a guarantee equivalent to the corresponding new product (Gunasekara et al., 2020). Manufacturers should analyse the end-of-life initiatives before choosing to remanufacture because if the products are commercially viable and possible for the next steps. The manufacture also should explore and research the alternatives to remanufacturing. Several variables are impacting the remanufacturability of materials. Manufacturers had to incorporate remanufacturing challenges into their goods to increase the remanufacturability of their products (Yuksel, 2010).

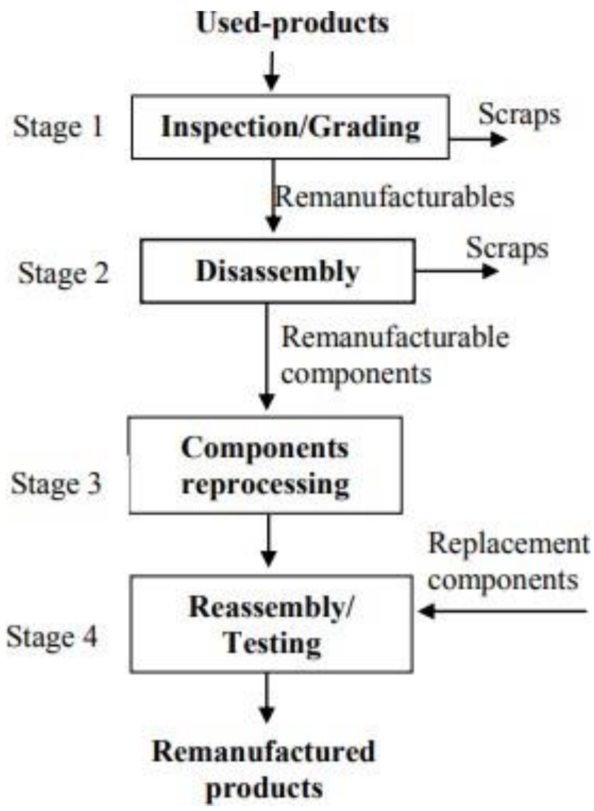



Figure 2.3  Remanufacturing process and material flow. Source (Andrew-Munot & Ibrahim, 2013)

Remanufacturing relates directly to an industrial process where its used or waste products are turned towards remanufactured products in ideas for improvement that is usually the quality of the used or waste product as good as new products. The method of remanufacturing typically consists of basic principles, namely inspection/grading, disassembly, reprocessing of components and reassembly/testing (Andrew-Munot & Ibrahim, 2013). Remanufacturing is an acknowledged sustainable strategy for environmental remediation that brings used products back to its original form with minimal energy and resource waste (Gunasekara et al., 2020). Figure 2.3 show the remanufacturing process and material flow.

In remanufacturing development preparation relates to deciding the total amount of products to be disassembled, remanufactured, manufactured that being ordered at certain times to accomplish with the specific particular targets under the constraints. While manufacturing development uses raw materials as inputs that are typically under strict quality control, remanufacturing depends on products with unpredictable qualities that are being used (Ilgin & Gupta, 2010). Remanufacturing development in organization given a lot of the advantages that contribute to environmental development knowledge, companies should recognise their degree of engagement in practical remanufacturing to make the implementation phase smooth and efficient (Rizova et al., 2020).

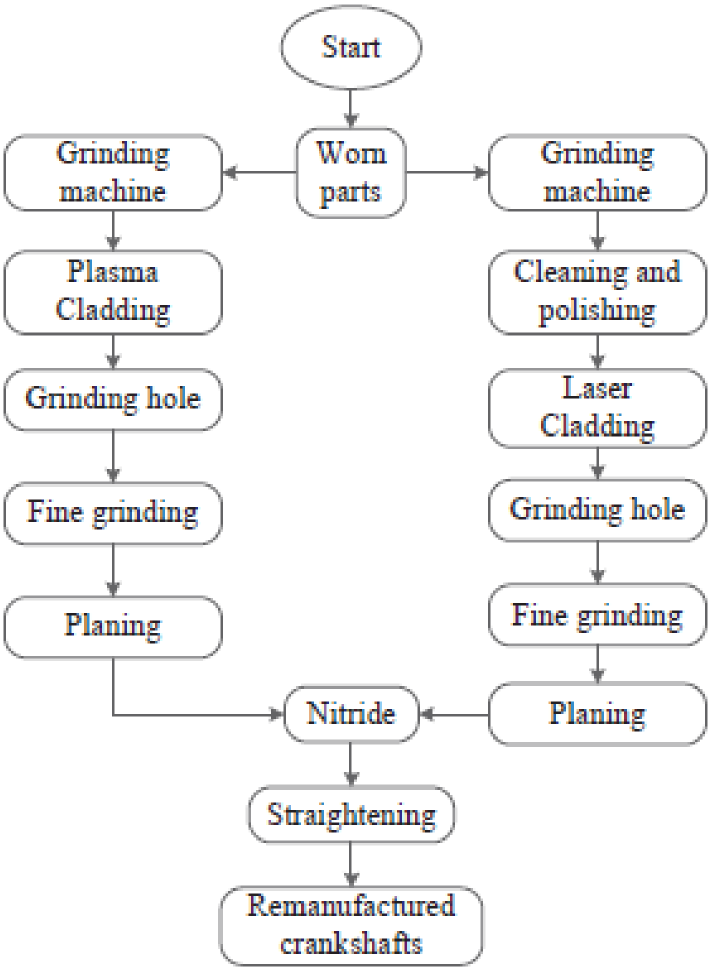



Figure 2.4 The roadmap of remanufacturing machining. Source (Liu et al., 2018)

Accurately predict the batch size of the product for disassembly, remanufacturing, and remanufacturing assembly. A multi-objective remanufacturing development preparation system based on genetic algorithm to increase the efficiency of remanufactured products and decrease the cost of remanufacturing output (Jiang et al., 2016). The sustainability of machining technologies for remanufacturing requires benefits according to economic, social and environmental. Regarding the limits of remanufacturing machining processes, the advantages are reflected in terms of cost, profit, efficiency, time, consumption of resources, use of materials and waste (Liu et al., 2018). Figure 2.4 shows the roadmap of remanufacturing machining.

Remanufacturing development has been implemented in the industry from the last two decades. The lack of exposure about the benefits remanufacturing to the company is the main causes the implementing remanufacturing still far and the objective is not verified. The principle of remanufacturing development is a guideline being referred and followed. Moreover, the basic steps of remanufacturing are involved in a certain process of production which is the material or product disassembly, inspection, remanufacture, and assembly.

## 2.2 REMANUFACTURING IN AUTOMOTIVE

The basic principles of the remanufacturing process mostly will include several steps or process which is inspection, dismantling, painting, repairing, assembling, and testing. In automotive industries, the remanufacturing development of automotive part almost the same with the basic principles. The different in remanufacturing steps, that manufacturing normally does not have in the process would be among these disassembling and cleaning steps (Ikeda, 2017).

Remanufacturing operations are directly related as contributions to End-of-Life Vehicles (ELV). As one of the major factors is for protecting the environment, countries such as in Europe have implemented the End-of-Life Vehicles (ELV) guideline. In the past, a few studies have been undertaken to resolve the need for laws and regulations on ELV reuse in Malaysia. Based on interviews conducted by Amelia et al., ELVs were proposed as a recovery plan to launch an environmentally friendly automotive industry in Malaysia (Amelia et al., 2009).

### 2.2.1 General Process in Remanufacturing

In the new world of the industrial revolution that contributions to the rapid changes in technology, product life cycles are now becoming shorter and lead to a critical situation for the environment. Therefore, due to the strict law and regulation of environmental by the government. Manufacturers require to pull back end of their life cycle product to be useful for the automotive industry or another sector. Before selecting the product is capable to be remanufactured, manufacturers also must analyse end-of-life strategies, if the product can be a value which is economically viable and practicable, the point of view manufacturers should explore alternatives to remanufacturing (Yuksel, 2010).

Remanufacturing refers specifically to an operational activity where the used or waste components are converted to remanufactured products in concepts for enhancement that are typically as strong as new products for the consistency of the used or waste product to becoming a more useful product and also environmental friendly. Usually, the remanufacturing approach consists of key elements, involving inspection/grading, disassembly, product reprocessing and reassembly/testing (Andrew-Munot & Ibrahim, 2013).

Usually, remanufacturing starts with the handover at the remanufacturer of a used component (called a core) where it goes through a sequence of industrial processes, which is the process including disassembly, cleaning, remanufacturing of components and removal of un-remanufactured parts, reassembly and testing to create the remanufactured product. The main causes of remanufacturing are environmental issues about the need to minimise pollution during the manufacturing phase of content extraction and also the rest of the product life cycle (Winifred L. Ijomah et al., 2007). Figure 2.5 shows the general process that including in remanufacturing development.

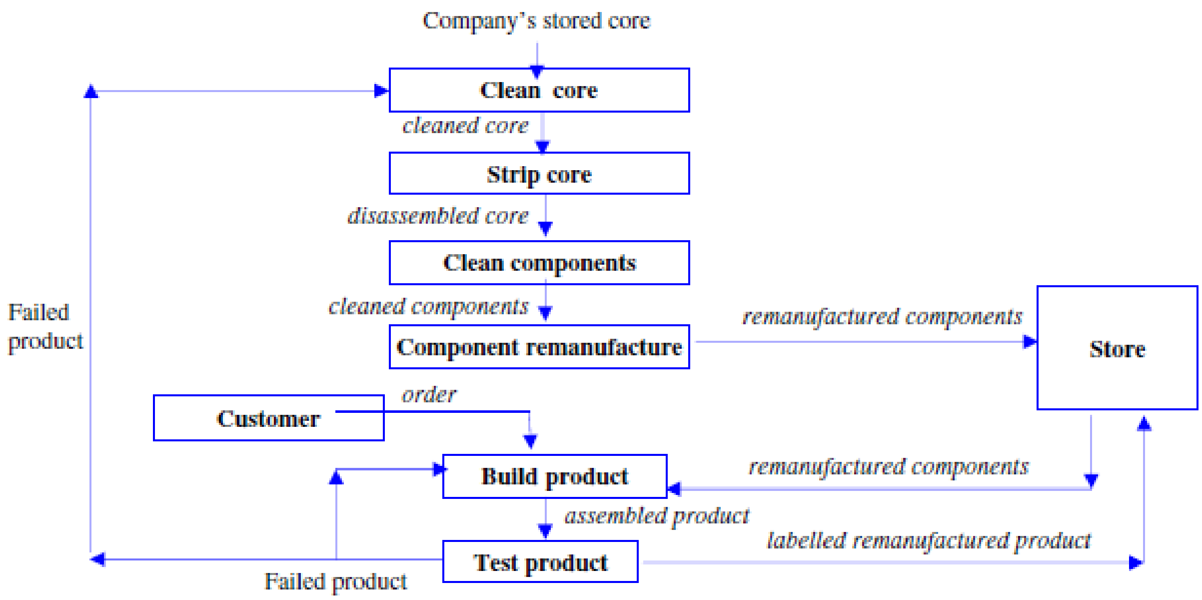



Figure 2.5 Shows the general process in remanufacturing. Source (Winifred L. Ijomah et al., 2007)

Based on the interview session with Mr Mohamad Ismail (Person in Automotive Industry), the remanufacturing in Malaysia is still undergoing and rarely implemented by the original equipment manufacturer (OEM). Moreover, mostly the rejected or defect part and product will be delivered back to the third party company (sub-company) to rebuild well known as remanufacturing the defect. Based on the point of view Mr Mohamad Ismail, mostly the rejected part it is has a minor defect on the surface and the part will through the certain treatment accomplish by the third party company (sub-company). Mr Mohamad Ismail also shared knowledge about the remanufacturing process which including several stages such as inspection, disassembly, cleaning, remanufacture, assembly, and testing (Ismail, 2020). Figure 2.6 The illustration of the remanufacturing process of the car part.

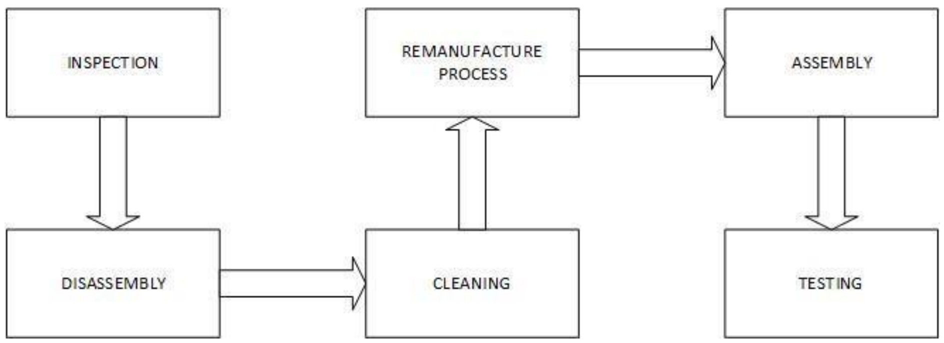



Figure 2.6 Remanufacturing process of the car part. Source (Ismail, 2020)

In 2010, research was undertaken by the Spanish Association for the Environmental Treatment of end of life vehicle to evaluate the amount of end of life vehicle recovered in Spain by analysing 1100 recovered vehicles. The study concluded that 86.5% of the total waste being recovered while roughly 15% of the total ELV waste moved to landfill sites (Charter & Gray, 2008). When vehicles are collected and dismantled, metal parts and other recyclable parts are separated. Some of the parts are being through the remanufacturing development to becoming useful product like to be second-hand components (Yano, 2006). Figure 2.7 The level of percentage for waste product recovery in Spain for 2010.

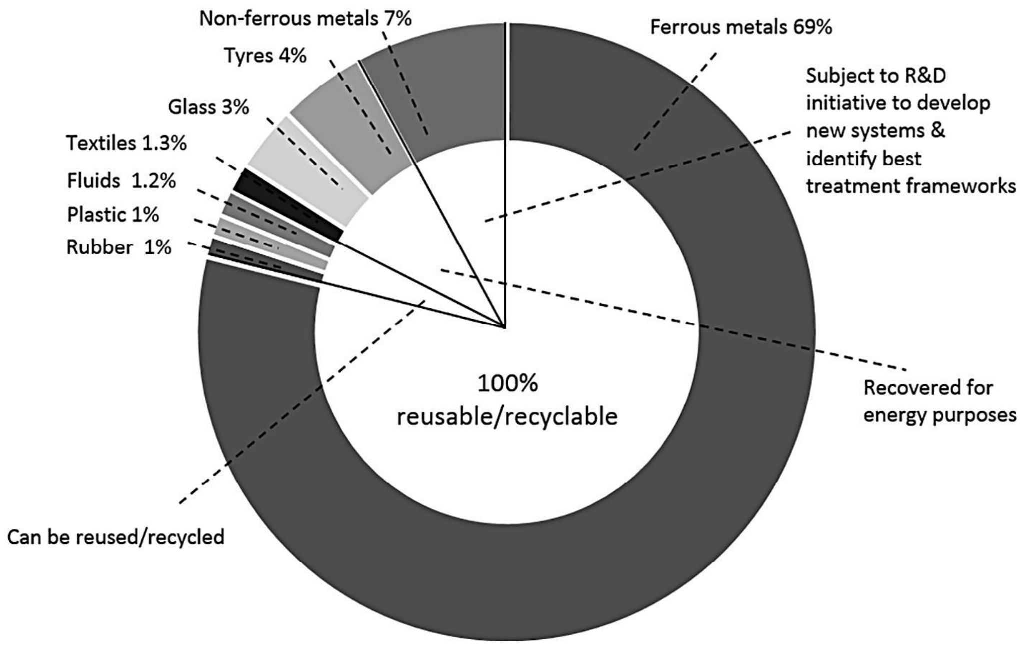



Figure 2.7 Waste recovery (end of life vehicle) level in percentage breakdown in Spain for in 2010. Source (Wong et al., 2018)

### 2.2.2 Challenges and Barriers in Remanufacturing Process

The philosophy of remanufacturing is reasonably appropriate and suggested to be introduced within the Malaysian automotive industry. There are also some challenges to be addressed before it is possible to make the remanufacturing development more important and broadly recognized (Yusop et al., 2016). remanufactured product is treated to becoming the characteristics good as a new product. Despite these benefits in developed countries such as India, remanufacturing is still not so common and structured. In terms of strategic, tactical and organisational management stages, developed countries face many problems when adopting the remanufacturing as an alternative for their economy business (Chakraborty et al., 2019).

Remanufacturing processes are popular in the United States and are valuable. However, the management of production planning and control activities in remanufacturing development differs greatly compare to management activities in manufacturing process development (Guide, 2000). The strategies will include the implementation of technical know-how and skills, the development of a quality management system within the framework of the standard remanufacturing conceptualization and quality seal for remanufactured items, the clarification of trading conditions for remanufactured goods and the promotion of supply and demand for remanufactured products via environmental policies (Sahari, 2004).

It should be discussed that within the remanufacturing development, some unique characteristics are primarily present. If not adequately considered, the production planning process for implementation of the remanufacturing development will be more complicated. In this context, it is really important for any research on remanufacturing processes to consider these particular characteristics. The findings of unique characteristics such as variable inspection yields of used products, variable disassembly yields of constituent components, variable reprocessing efforts of constituent components, multiple-key remanufacturing stages with inter-dependency between stages, multiple-types of constituent components, and matching and reassembly the same set of constituent components into final products in the customer-driven environment (Andrew-Munot & Ibrahim, 2013).

The remanufacturing development should be planned according to the 'DfRem' guidelines, it will contributions to the remanufacturing of a used product may be successful. Otherwise, this may pose uncertainty in the remanufacturing operation, especially in disassembly operations. The acquisition of uncertainty may impact the effectiveness of the management of the remanufacturing process. Uncertainties related to the acquisition time, quality and quantities are considered as the challenges in remanufacturing (Chakraborty et al., 2019). The challenge of balancing supply and demand will generate through the uncertainties within the supply of used products and the demand for remanufactured products, it is contributions to be a problem. If a remanufacturer tries to balance supply and demand they pose challenges and issues of inventory management and monitoring. There are also a large number of sources in standard remanufacturing processing which increases the difficulty (Lundmark et al., 2009). Figure 2.8 shows the uncertainties due to supply and demand.

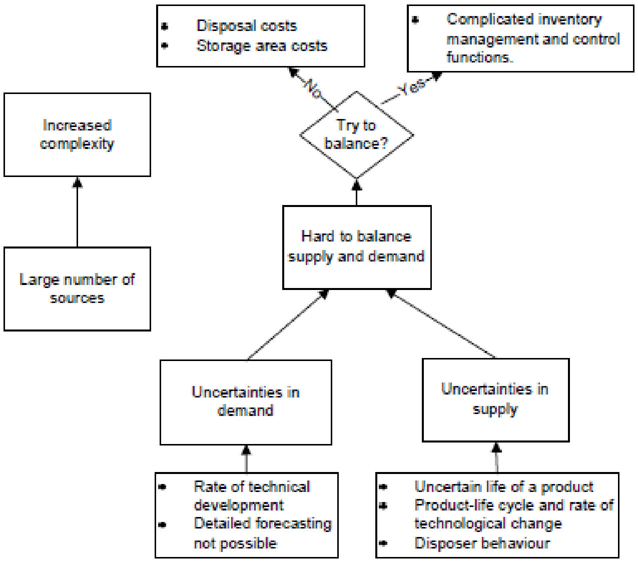



Figure 2.8 challenges due to the uncertainties of supply and demand. Source (Lundmark et al., 2009)

These study findings were used to analyze the decision on machining, optimise the production process and boost the effectiveness of remanufacturing. The initiatives of remanufacturing development technologies have been strongly encouraged but remanufacturer should be through a certain barrier during the implementation phase which is like a measurement of remanufacturing machining systems is generally performed from a quality, cost, time, resource and environment perspective, but the measurements of these indices are not standardised, addition to the challenges in using the current methods of evaluation (Liu et al., 2018). Table 2.2 show the findings of challenges in remanufacturing process

Table 2.2 The findings of challenges and barrier in the remanufacturing process

| **Authors** | **Research** | **Findings** |
|---|---|---|
| (Ngu et al., 2020) | Review on current challenges and future opportunities in Malaysia sustainable manufacturing: Remanufacturing industries | Challenges remanufacturing system in Malaysia<br>• Local remanufacturers are facing challenges to improve the efficiency and effectiveness<br>• facing the difficulty to access the specific technical data, testing standards, tools, diagnostic and types of machinery |

| | | |
|---|---|---|
| (Liu et al., 2019) | A review on remanufacturing assembly management and technology | The identified barriers in the remanufacturing system<br>• Uncertainty of quality of returned used products<br>• Poor standards of product recovery activities like repairing and reconditioning<br>• Difficulty in production schedules due to varying process |
| (Guide, 2000) | Production planning and control for remanufacturing: industry practice and research needs | Challenges in the remanufacturing system<br>• Uncertainty timing and quality<br>• Uncertainty in material<br>• Unbalance with demands<br>• Highly variable processing time |
| (Seitz, 2007) | A critical assessment of motives for product recovery: the case of engine remanufacturing | The major problem in the remanufacturing process<br>• High inventory levels<br>• High process throughput times<br>But It is also finding that the long term supply of spare parts is the major motivation for product recovery. |
| (Saavedra et al., 2013) | Remanufacturing in Brazil: case studies on the automotive sector | The original equipment manufacture (OEM) has much more advantage than independent remanufacturer in case used product supplier, the market of a remanufactured product. |
| (Jiang et al., 2016) | Reliability and cost optimization for remanufacturing process planning | One of the main problems posed by remanufacturing is to ensure that remanufactured products are reliable when they come from cores of different conditions. |

Remanufacturing development contribute the strong advantages to the company that implemented especially in the automotive industry. Moreover, remanufacturing development continuously adapts the knowledge of environmental sustainability and control a large amount of waste product. However, remanufacturing development also has several challenges and barrier during the implementation phase. The major problem in remanufacturing development such as unpredictable the processing time, uncertainty quality of the product, and uncertainty the quantity of the product. Remanufacturing development is hard to implement because the flow of process include in remanufacturing is not clear enough and the process in every company is different.

## 2.3 PERSPECTIVE OF REMANUFACTURING DEVELOPMENT

Remanufacturing development has been recognised as an efficient technique that helps to increase the use of resources and materials, reducing environmental pollution and manufacturing costs as a result (Liu et al., 2018). Remanufacturing is a validated strategy of environmentally sustainable recovery that restores used products with reduced loss of material and resources to their original state(Gunasekara et al., 2020).

In Malaysia, remanufacturing efforts have been motivated by raising knowledge of environmental sustainability, along with an internal motivational factor that is vehicle product value imbalance due to increasing material expense(Yusop et al., 2016). Remanufacturing is a way of putting used products into a " like-new " operational condition with a corresponding warranty. Its importance is that, in contrast to conventional production, it can be both productive and less harmful to the ecosystem (Winifred L. Ijomah et al., 2007).

Remanufacturing is an exceedingly valuable practice because it restores the end of life products to situations that are as equivalent or better than new ones. The increasingly strict environmental regulations and economic demands have contributed to the dramatic growth of the world's remanufacturing industry (Jiang et al., 2016). For most small independent remanufacturers, the capability of design to recognize and resolve remanufacturing inefficiencies is poorly known or meaningless, since they have limited to control over the development process. The development process is dominated by Original Equipment Manufacturers (OEMs) and could theoretically control remanufacturing (Charter & Gray, 2008).

### 2.3.1 Scenario Remanufacturing system in Malaysia

In the Malaysian Roadmap for Remanufacturing, some suggestions of positive implications generated by remanufacturing development technologies as well as some imminent challenges encountered to implement this green development operation will be analyzed. Remanufacturing efforts are motivated by raising understanding of environmental sustainability together with a motivation that becomes the gap in vehicle prices due to the increasing material costs. This approach is strongly supported by the Malaysian National Automotive Policy (NAP2014) with the latest progress is the establishment of nation remanufacturing roadmap (Yusop et al., 2016).

The remanufacturing industries in Malaysia are also using different terms to represent its remanufacturing activities. Of all the remanufacturing sectors in Malaysia, the aerospace industry had the highest market size (RM3.4 billion) in 2015, led by the automotive industry (RM345 million). Moreover, the scenario of the remanufacturing industry can be categorized into two types of remanufacturers in Malaysia, which are original equipment manufacturers (OEM) remanufacturers and independent remanufacturers. Although most independent remanufacturers (IR) operate in small to medium-sized quantities, while the original equipment manufacture (OEM) produced the product of remanufacturing in the large scales size (W. L. Ijomah & Childe, 2007).

Remanufacturing development of automotive parts and components for the commercial vehicles is active in the automotive remanufacturing industries in Malaysia. While in this automotive sector, the market value is not the highest among the Malaysian remanufacturing industries. Almost all of the remanufacturing of automobile parts in Malaysia is implemented in order to satisfy local industry demands by medium and small independent remanufacturers. Gearbox, starter, transmission, alternator,clutches, turbocharger , axles and air compressor are the most common remanufactured automobile parts and components carried out by Malaysian independent remanufactures. Moreover, the automotive parts and components also exported to South East Asia, Europe and North America based on the demand (Ngu et al., 2020). Figure 2.9 shows the typical process in remanufacturing development in the Malaysia automotive industry.

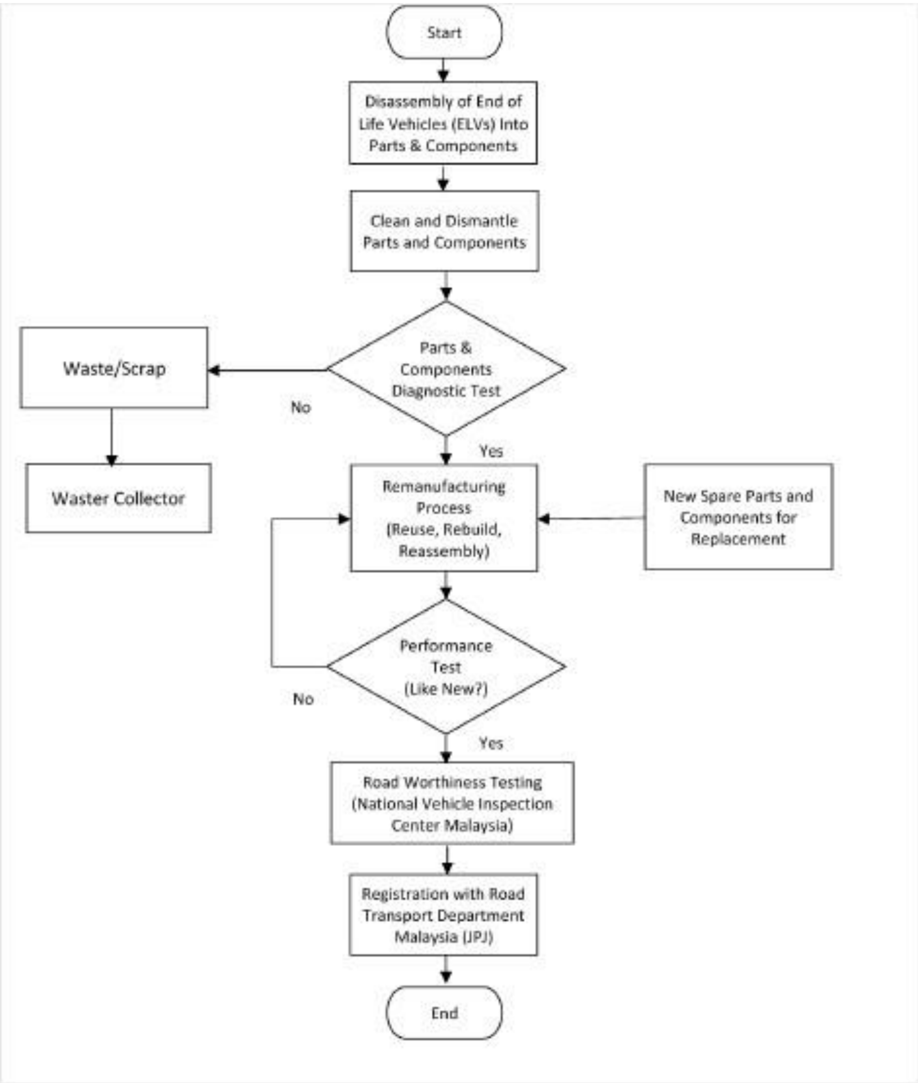



Figure 2.9 the typical remanufacturing process of a vehicle in Malaysia. Source (Ngu et al., 2020)

The remanufacturing development in Malaysia is undergoing to be one of the beneficial sector to support the economy of a country. Due to the unpredictable quantity of the end of life vehicle, government through the Malaysian National Automotive Policy (NAP) that conducted by the Ministry of International Trade and Industry Malaysia. The government fully supported the remanufacturing industry to control the environment sustainability but the remanufacture still having challenges during the development, especially for the independent remanufacture because mostly the product produce must equivalent or better than the original equipment manufacture product (OEM). The remanufacturing development is not synchronized and standardize, the remanufacturing process is different between all the remanufacturer company.

## 2.4 THE ASSEMBLY LINE PROCESS

Since the first industrial revolution, manufacturing sectors have moved drastically. Though automation in the industry has grown tremendously over the past decades. for the efficient and smooth during the production, the industry introduced the assembly line as a beneficial solution. The assembly line is typically made up of a set of stations interconnected by a conveyor belt. With the belt's support, products will pass through stations by following the arrangement sequence. At each station, certain tasks are performed on products to be fully assembled (Mahdi Mokhtarzadeh, Masoud Rabbani, 2020).

The semi-automated assembly line is commonly used in many industries at the current situation such as the manufacturing industry, consumer electronics, white products, and shipbuilding. A series of sequential stations represents a standard assembly line. Tasks are carried out cyclically down the line using various techniques, such as robots, human operators or human operators with assistive equipment. In order to reduce task time and improve output performance, operators can obtain assistance from the assisting equipment (assembly line). moreover, the automated unit is more suitable for complicated or specialised operations (Zhang et al., 2020).

### 2.4.1 Assembly Line in Remanufacturing System

Remanufacturing is now seen as an important strategy for the global economy's sustainable development. However, it is difficult to fulfil the demands of consumers with the standard of remanufactured products, which has been a challenge that restricts the development progress of the remanufacturing industry. In order to increase the production efficiency and quality of remanufactured products, remanufacturing assembly management and technology has much more robust in term of the engineering knowledge during the product development process (Liu et al., 2019). To optimise the results of remanufacturing by enhancing the consistency of the product, increasing the remanufacturing rate and reducing cost. According to the unpredictable condition of returned products, the option of remanufacturing processes is complicated and operating performance also depends on operators that render operations time-consuming and error-prone (Jiang et al., 2016).

In the remanufacturing development, the remanufactured products are a combination structure assembly which according to a certain assembly series, consists of reused parts, remanufactured components and original manufacturing components and then satisfies a variety of technical standards. The final performance of the remanufacturing assembly is influenced by the remanufacturing design, material properties (basic materials and coating layers of parts), disassembly, cleaning, remanufacturing process, inspection on the quality of the product and other factors as an integrated element of the remanufacturing development method (Liu et al., 2019). Figure 2.10 shows the assembly line layout of the remanufacturing system with the quality of the remanufactured product

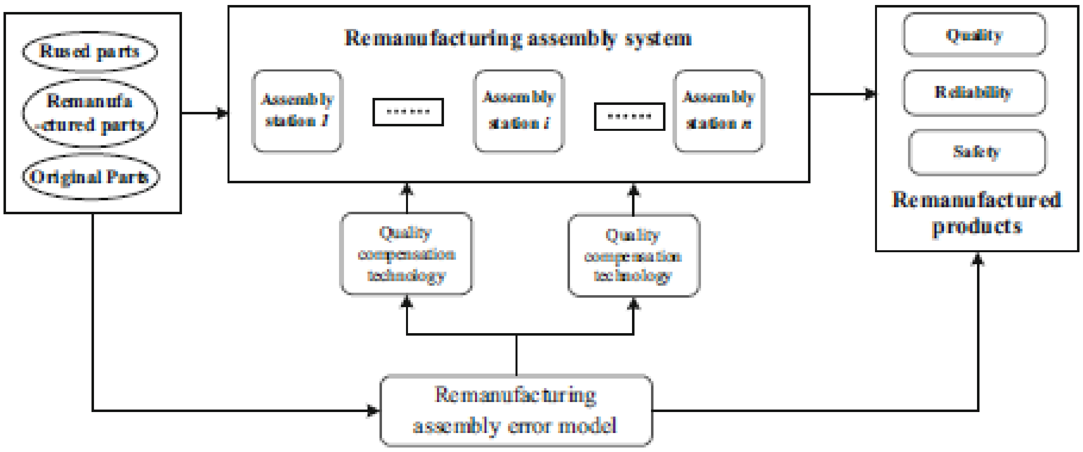



Figure 2.10 The Assembly Line Layout of Remanufacturing System. Source (Liu et al., 2019)

In a complex and unpredictable condition of the product, efficient control of the remanufacturing assembly process has been described as a major challenge for remanufacturers. The improvement of the remanufacturing assembly system is carried out primarily by integrating various remanufacturing components, but less guidance is issued for the efficient management of the remanufacturing development. The reassembly process is unpredictable and complex due to multi-input and multi-output the product, therefore the procedure guidance should be on-line in order to enhance the consistency of remanufactured products and the production performance of the remanufactured assembly in the various conditions of the actual development phase (Liu et al., 2020). Figure 2.11 shows the illustration of the uncertainty handling in the remanufacturing process.

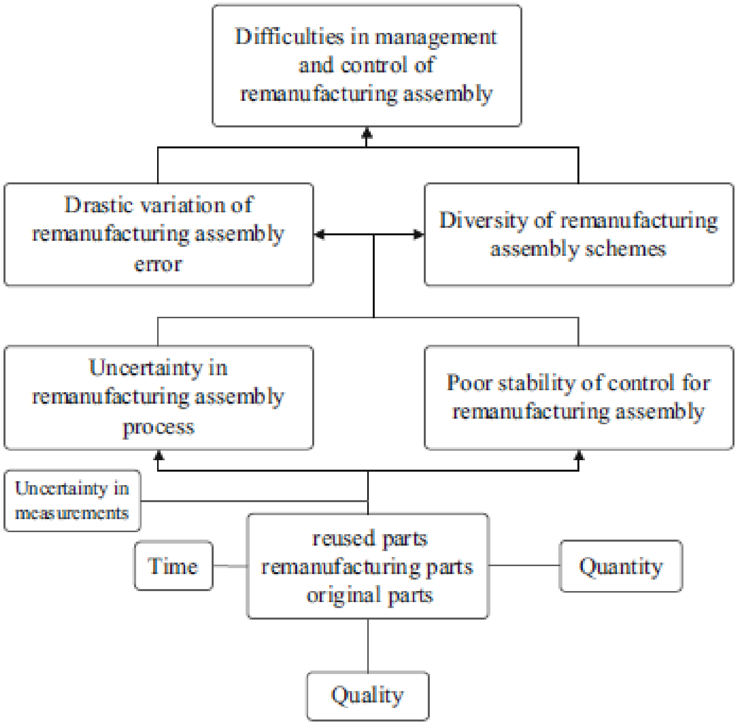



Figure 2.11 The illustration of uncertainty in the remanufacturing process. Source (Liu et al., 2019)

Based on the interview session with Mr Mohamad Ismail, the assembly line is a very important component in remanufacturing development. Assembly line generated to increase the production processing times and make the production line very effectiveness. Moreover, the assembly line is the sequence arrangement of several stations which is starting from the welding stations, painting station, assembly frame station (wiring, engine, & roof lining), inspection station, the repair process station, and vehicle quality station. Based on the explanation, every station will have specific processing times requirements. If one of the stations having a problem during the production, this effect on the whole assembly line will facing the bottleneck situation (Ismail, 2020). Figure 2.12 shows the illustration of the process flow in the automotive industry.

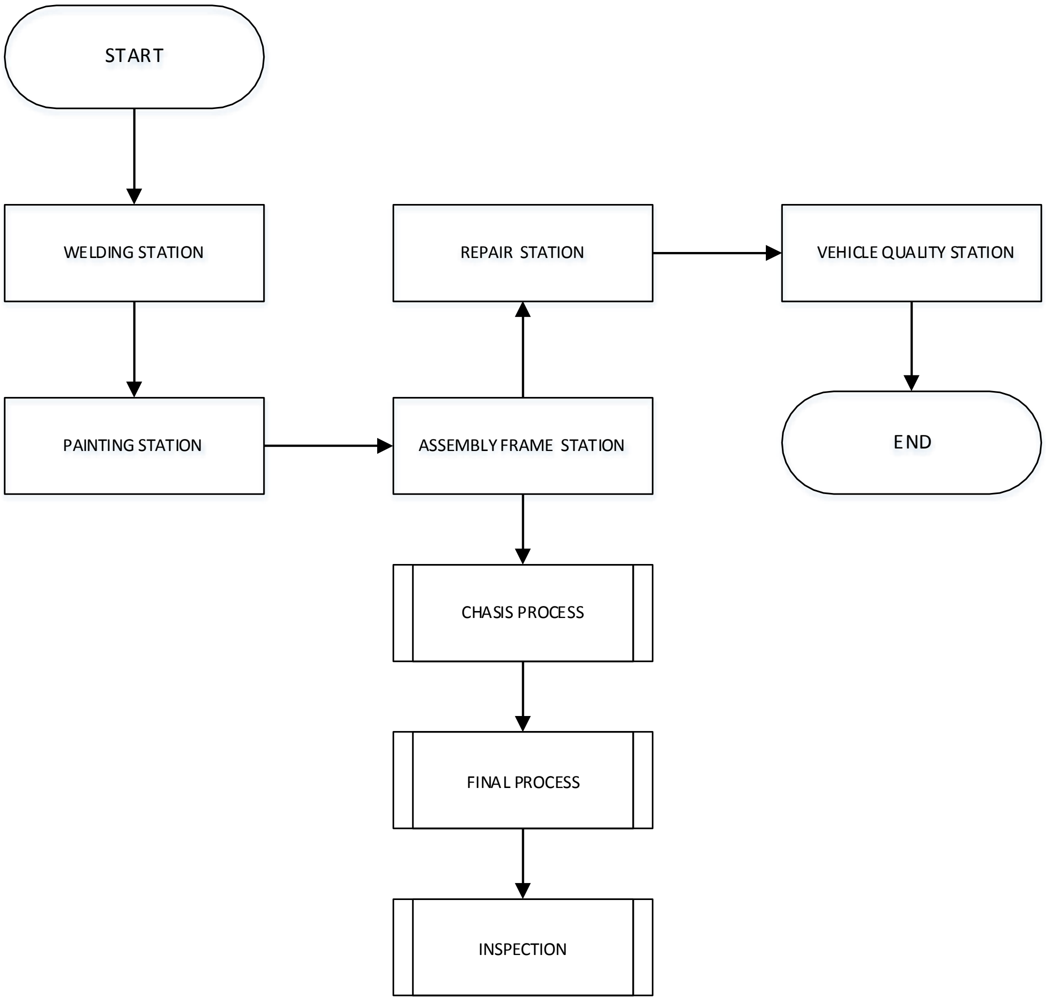



Figure 2.12 The Illustration of Assembly Line in Automotive Industry. Source (Ismail, 2020)

The assembly line is the backbone of the remanufacturing system to fulfil the consumer's requirements and demand. On the other hand, the assembly line is the best solution to all company in the manufacturing sector implementing due to reducing the number of processing times and contributed to require high demand from the consumers. However, based on all advantages of the assembly line, but this development still having several challenges and barrier because the major risk on the assembly line is the bottleneck or well known as delay during the production. Due to the many uncertainties and unpredictable of the remanufacturing development product, the assembly line should be continuously optimizing their system to make it very effective.

### 2.4.2 The Approach Optimisation in the Assembly line

During the development, the framework of the assembly line in the remanufacturing system has been generated for production is to meet the requirements of the demands from consumers. By applying the Analytic Hierarchy Process (AHP) as an approach in designing the framework of the assembly line in the remanufacturing system. On the other hand, the analytic hierarchy process also contributed to optimizing the assembly line by analysing the influences that lead to the bottleneck situation happen. The measurements were created using a set of decisions that reflect how much more concerning a specific feature and one variable dominates another (Subramoniam et al., 2013). Figure 2.13 shows the process to identify the validation of the remanufacturing framework design by using the Analytic Hierarchy Process (AHP) method.

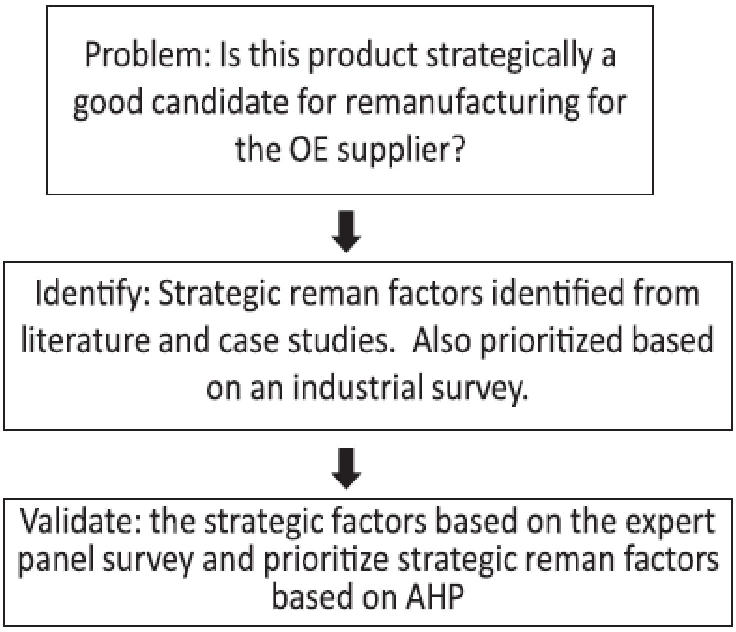



Figure 2.13 The Validation Process of Remanufacturing Framework using AHP. Source (Subramoniam et al., 2013)

The Analytic Hierarchy Process (AHP) become a strategy to self-value that analyses intangible variables through the pairwise comparisons of decisions reflecting the superiority of one factor over another in relation toward a resource they connect. AHP is also one of the most commonly implemented in decision-making methods with different requirements. The Analytic Hierarchy Process (AHP) consist of several stages during the implementation phase such as on the first stage the problem must be clearly defined, the second stage is starting to creating the hierarchy, third stages is based on the problem and starting constructing the set of pairwise comparison, and the last stage is weighting the criteria under comparison based on the priorities that already derived (Zabihi et al., 2020).

The implementation of Fuzzy Interpretive Structural Modeling (FISM) allowing to consider the effects of main opportunists and constraints by remanufacturing to enhance the lifespan of automobile products. On the remanufacturing development, Fuzzy Interpretive Structural Modeling (FISM) capable to identify and analyse the systemic correlations between the factors identified. Based on the result of Fuzzy Interpretive Structural Modeling (FISM), the major problem or constraints in remanufacturing automotive product which is the low cost, less on the price market, cheap labour cost, and fast turn around (Chakraborty et al., 2019). Figure 2.14 show the Fuzzy Interpretive Structural Modeling (FISM) diagram that applied in the remanufacturing of the automotive industry

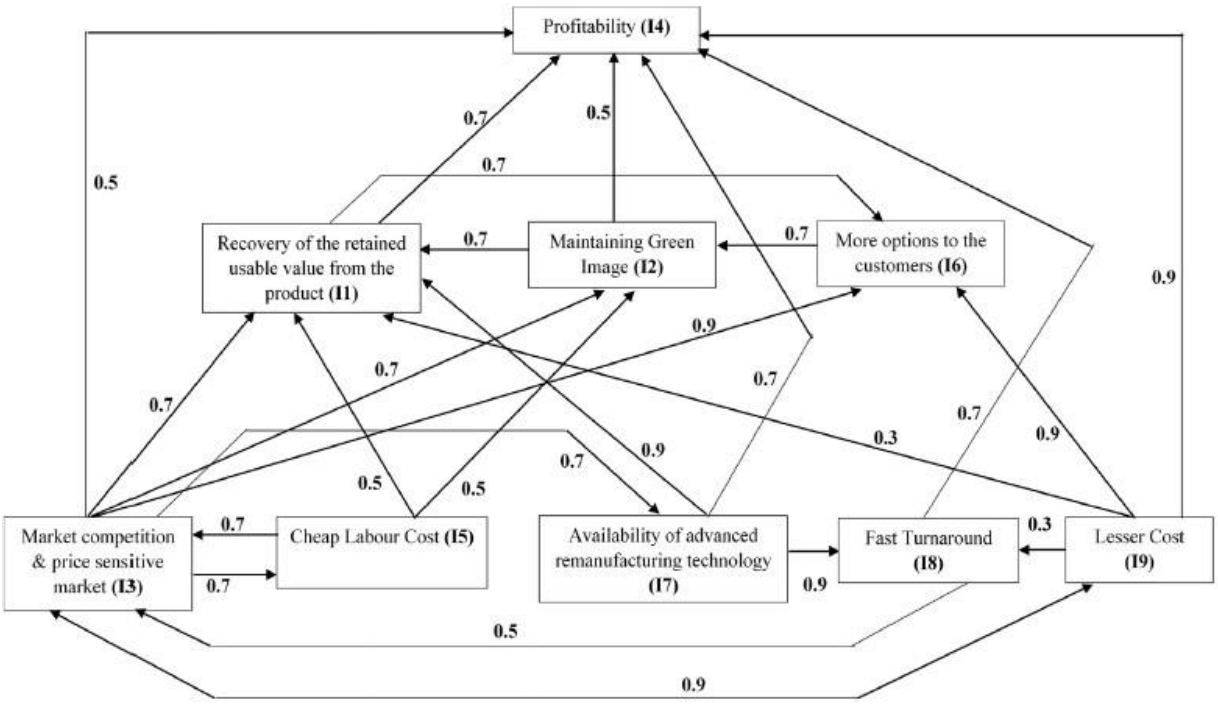



Figure 2.14 The Fuzzy Interpretive Structural Modeling (FISM) diagram of remanufacturing in the automotive industry. Source (Chakraborty et al., 2019)

The assembly line in the remanufacturing is the complex and unpredictable situation because of the large number uncertainty on the remanufacturing product. The uncertainty of the input product will support the contributions of the bottleneck in the assembly line and affect production efficiency. By using the several approaches like a Fuzzy Interpretive Structural Modeling (FISM) and Analytic Hierarchy Process (AHP) capable to analyse the destructive or the root causes that contribute the bottleneck in the assembly line. Therefore, the assembly line in the remanufacturing system will optimise and can produce at a higher pace.

## 5. TAGUCHI METHOD

Genichi Taguchi has invented a Taguchi method (TM) to improve output robustness and allows for easy quality assurance by quantitative reduction of variance during the period. Application measurement for the optimization is performed in order to provide excellent control over through the quality, productivity and cost dimensions of the system. Taguchi's method strategy to experimental design is straight forward to implement and apply to consumers with little statistical expertise (Semioshkina & Voigt, 2006).

The method of optimisation is important to make the system continuously improvement rather than to make the system more efficient and smooth during the running process. The Taguchi method proposed technique is based on fractional factorial test models labelled as Orthogonal Array (OA) that minimize the number of experimental studies. Mostly the selection of OA is depending on the factors and the level has been using in the Taguchi method. by using OA, several control parameters can be calculated, which consequently influence the output function, thus decreasing the size of the testing process (Shahavi et al., 2016).

### 1. Basic Concept of Taguchi Method

Taguchi method can be classified into three main conditions which are first larger the better, mostly this conditions being applied for the agriculture sector that using optimisation on the yield of harvest. Second is smaller the better, which is this condition has been used in the collection and optimisation for the carbon dioxide emission. The third is on-target or minimum variation, which is this condition has been applied to the assembly process during the production. Besides that, the standard deviation also can be measure by using the Taguchi method because Taguchi method applied the signal noise (S/N) ratio to prove the result by generating the graph that displaying the mean shows in Figure 2.15 (Semioshkina & Voigt, 2006).

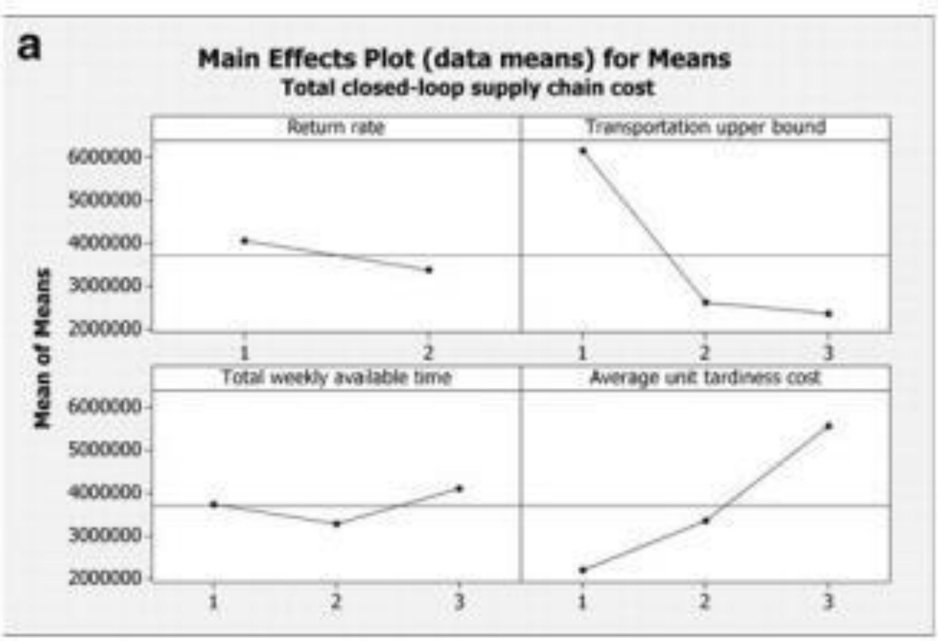



Figure 2.15 The graph S/N ratio of the remanufacturing by using the Minitab application.

Based on this research, the result of finding the Taguchi method has been applied for this study is to investigate the parameter being used between the relationships among the process in the anechoic chamber. The parameter did with the factor and level that is used. The parameter included such as the transfer area (1/2, 3/4, 1/1), stiffening pattern (unidirectional, 90 degrees, 45 degrees), transfer temperature (80, 100, 120) shows in Table 2.3 (Lai & Tu, 2016).

Table 2.3 The Parameter in The Process of Anechoic Chamber. Source (Lai & Tu, 2016)

| **Factors** | **Level** | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| transfer area | 1/2 | 3/4 | 1/1 |
| stiffening pattern | undirectional | 90 degrees | 45 degrees |
| transfer temperature | 80 | 100 | 120 |

### 2.5.2 Application of Taguchi Method

Clove oil is an essential oil that has been used in agriculture and cosmetic products. the biodegradable antibacterial agent produces the product. To preserve and improve the antibacterial effectiveness of oils in aqueous alternatives emulsions were included. By using the Taguchi method, a study is to optimise the parameter of clove oil nanoemulsion that to achieve the target which the stable emulsions This approach included the parameter which using the orthogonal array with the level 9 (L9) (Shahavi et al., 2016). Table 2.4 shows the parameter has been applied in the clove oil nanoemulsions that will be optimised.

Table 2.4 The Parameter of L9 for Clove Oil Nanoemulsions. Source (Shahavi et al., 2016)

| | Parameters | | | |
|---|---|---|---|---|
| Experimental run number | Clove oil concentration (wt%) | Emulsifier concentration (wt%) | Mixed HLB number | Ultrasonication time (s) |
| 1 | 2.5 | 2.5 | 9.0 | 150 |
| 2 | 2.5 | 5.0 | 12.0 | 300 |
| 3 | 2.5 | 7.5 | 15.0 | 450 |
| 4 | 7.5 | 2.5 | 12.0 | 450 |
| 5 | 7.5 | 5.0 | 15.0 | 150 |
| 6 | 7.5 | 7.5 | 9.0 | 300 |
| 7 | 15.0 | 2.5 | 15.0 | 300 |
| 8 | 15.0 | 5.0 | 9.0 | 450 |
| 9 | 15.0 | 7.5 | 12.0 | 150 |

The major reason of the quality brake linings is important and complex because of the materials has been used is intricate for an automotive brake device, as they contain various additives which are complex in physical and chemical properties. Moreover, based on the robust industry in the manufacturing sector, the Taguchi method takes responsible to optimise the parameter of brake lining production (Kim et al., 2003). Table 2.5 shows the parameter of the brake lining process to be optimised by using Taguchi method

The Taguchi method is the classical method rather than another Design of Experiments (DOE) which more functionality but the Taguchi method is still relevant to be implemented because the steps required is simple and more convenient. Taguchi method can be generated by using the computerised system which is by using Minitab Application rather than the conventional method is using the calculation. Based on this research, mostly the Taguchi method has been applied to optimise the parameter of the material that has been used.

Table 2.5 The Parameter of Brake Lining Manufacturing Process. Source (Kim et al., 2003)

| | Factors | Level | | | |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 |
| Molding | Time (min) (A) | 6 | 8 | 10 | 12 |
| | Temperature (°C) (B) | 150 | 175 | 200 | 225 |
| | Pressure (MPa) (C) | 27.0 | 29.5 | 32.0 | 34.5 |
| Heat treatment | Time (h) (D) | 4 | 6 | 8 | 10 |
| | Temperature (°C) (E) | 175 | 200 | 225 | 250 |

# CHAPTER 3

# METHODOLOGY

## 3.0 INTRODUCTION

This project is set to introduce the study on investigation of the optimisation control process in the remanufacturing system. The process involved in the system is still unsystematic and this study aims to counter the problem which is to the uncertain process. As mentioned in the title, this study more focusing on the remanufacturing system. The remanufacturing system is the initiatives that develop the used components to be back as a new condition component. In addition, this study is to optimise the control process which is an assembly line in the remanufacturing development that having several problems to be investigated.

## 3.1 PROJECT FLOW

Basically, this chapter will emphasize the procedures and validation of the remanufacturing system that involved several steps and preparation before the implementation in the optimisation method. The first step will begin with the investigation on the assembly line process which is the challenges and barrier of the remanufacturing system in the assembly line process. Based on the challenges and barrier, the major problem or root causes will be analysed and this is conducted to the several attributes that will be included in the optimisation procedure.

Moreover, the assembly line layout of the remanufacturing system will be designed with including all the parameter. On this study, three assembly line layout will be designed and make a comparison which layout that fully optimises in the high pace. During this study, all the three assembly line layout will be analysed by using design of experiment (DOE) which is using the Taguchi method. In addition, the validation result also will be generated from the Taguchi method. Figure 3.1 shows the flow chart related to the project procedure.

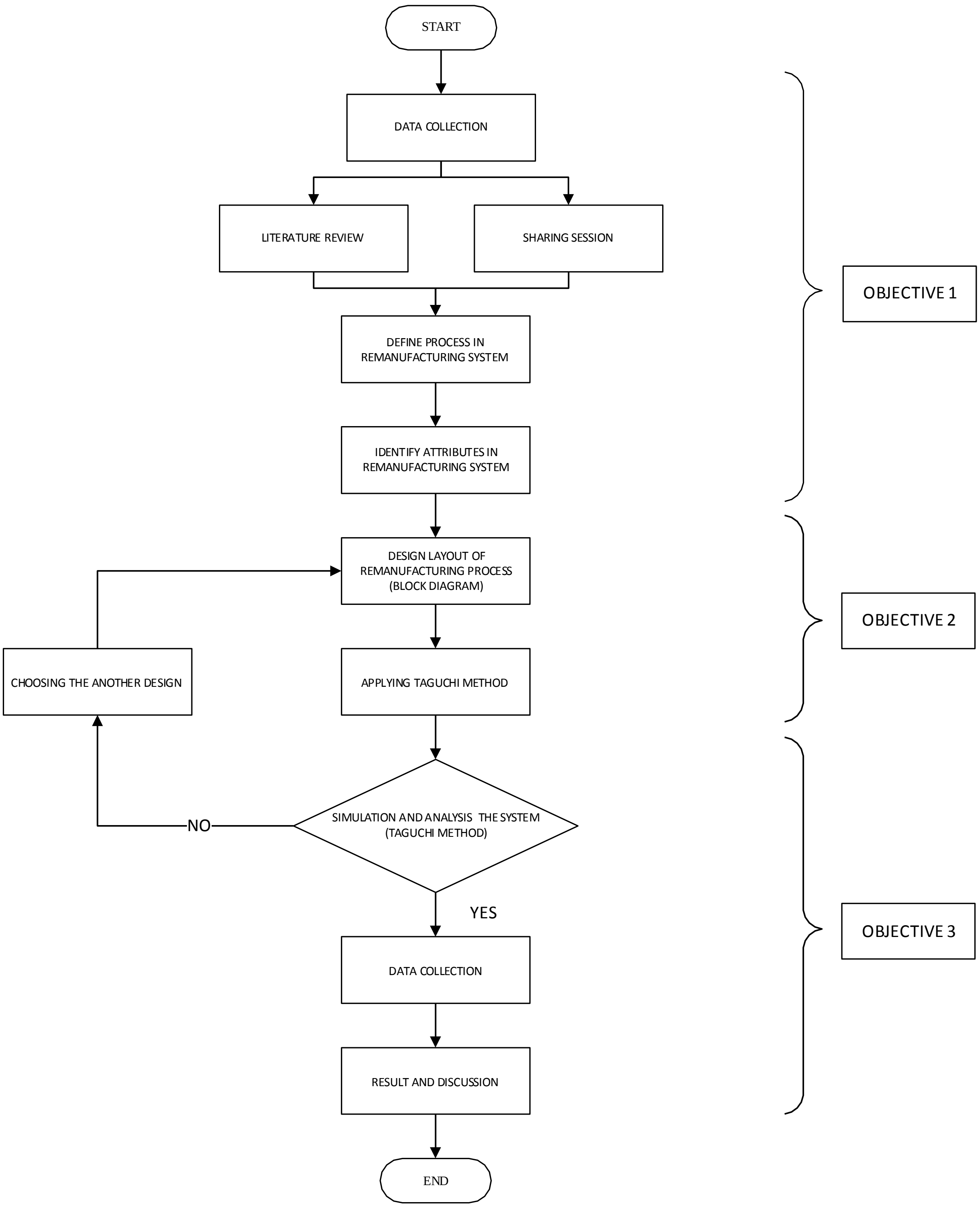



Figure 3.1 Illustration Flow Chart of Project Procedure

### 3.1.1 Project Gantt Chart

The Gantt Chart of this project will introduce the flow process during this study that including the PSM 1 and PSM 2. In addition, this Gantt Chart is a guideline to complete the project by following the schedule. Table 3.1 and Table 3.2 shows the process flow of PSM 1 and PSM 2.

Table 3.1 Gantt Chart of PSM 1

| | | WEEKS | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NO | TITLE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1. | **TITLE DISCUSSION AND BRIEFING WITH SUPERVISOR** | | | | | | | | | | | | | | | |
| 2. | **FIND THE RELATED ARTICLE AND JOURNAL** | | | | | | | | | | | | | | | |
| 3 | **SELECTION METHOD OF COLLECTION DATA** | | | | | | | | | | | | | | | |
| 4. | **CHAP 1: PROBLEM STATEMENT & OBJECTIVE** | | | | | | | | | | | | | | | |
| 5. | **CHAP 1: BACKGROUND & SCOPE** | | | | | | | | | | | | | | | |
| 6. | **CHAP 2: LITERATURE REVIEW** | | | | | | | | | | | | | | | |
| 7. | **ANALYSIS RESULT FROM COLLECTION DATA** | | | | | | | | | | | | | | | |
| 8. | **DRAFT PROGRESS** | | | | | | | | | | | | | | | |
| 9. | **CHAP 3: DESIGN FLOW OF PROCESS** | | | | | | | | | | | | | | | |
| 10. | **CHAP 3: SIMULATION & ANALYSIS SYSTEM** | | | | | | | | | | | | | | | |
| 11. | **PREPARATION PRESENTATION** | | | | | | | | | | | | | | | |
| 12. | **PRESENTATION** | | | | | | | | | | | | | | | |
| 13. | **REPORT SUBMISSION** | | | | | | | | | | | | | | | |

Table 3.2 Gantt Chart of PSM 2

| | | WEEKS | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NO | TITLE | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| 1. | **DISCUSSION WITH SUPERVISOR** | | | | | | | | | | | | | | | |
| 2. | **PSM 2 PROGRESS PLANNING** | | | | | | | | | | | | | | | |
| 3 | **PSM 1 REPORT REVIEW & RECTIFY** | | | | | | | | | | | | | | | |
| 4. | **PROPOSE THE ACTUAL DESIGN PROCESS (BLOCK DIAGRAM)** | | | | | | | | | | | | | | | |
| 5. | **SIMULATION OF THE SYSTEM (TAGUCHI METHOD)** | | | | | | | | | | | | | | | |
| 6. | **ANALYSIS & EVALUATION OF THE SYSTEM** | | | | | | | | | | | | | | | |
| 7. | **CHAP 4: RESULT AND DISCUSSION** | | | | | | | | | | | | | | | |
| 8. | **CHAP 5: CONCLUSION AND RECOMMENDENDA TION** | | | | | | | | | | | | | | | |
| 9. | **REPORT IMPLEMENTATION** | | | | | | | | | | | | | | | |
| 10. | **PREPARATION PRESENTATION** | | | | | | | | | | | | | | | |
| 11. | **PRESENTATION** | | | | | | | | | | | | | | | |
| 12. | **REPORT SUBMISSION** | | | | | | | | | | | | | | | |

### 3.2 DESIGNING LAYOUT

The assembly line in the remanufacturing system is included several sequences of the process station that connected each other. The assembly line is the sequence arrangement of several stations which is starting from the welding stations, painting station, assembly frame station (wiring, engine, & roof lining), inspection station, the repair process station, and vehicle quality station (Ismail, 2020). Moreover, the assembly line layout will be designed by following all the processes included. Figure 3.2 shows the assembly line process in the automotive industry.

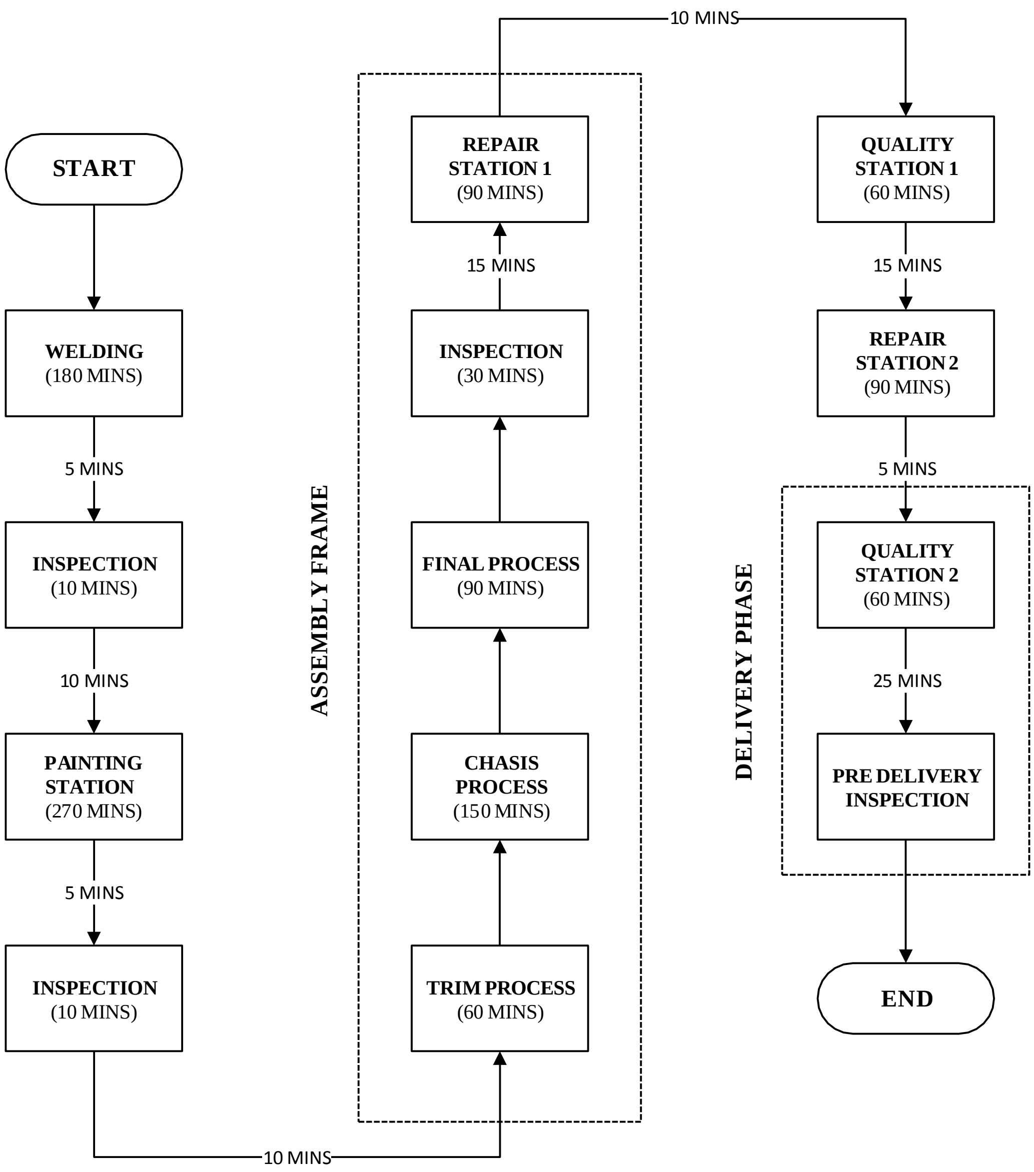



Figure 3.2 The Illustration of Assembly Line in Automotive Industry. Source (Ismail, 2020)

Based on the study, this project will begin with designing the assembly line layout in the remanufacturing system for the automotive industry. The layout designed in the Arena simulation application that capable of simulating the assembly line in the remanufacturing system. Arena is a discrete event simulation and automation software developed by Systems Modeling and acquired by Rockwell Automation. This application is not just specified for control engineering, the another function of Arena simulation including data collection, data processing, mathematical modelling, algorithm creation, and parallel computing (Kamrani et al., 2014). Figure 3.3 shows the example of the simulation model using Arena.


Figure 3.3 The simulation model using Arena. Source (Kamrani et al., 2014)

The assembly line layout will be designed with the three different layout model and different arrangement that every layout consist of the same attributes with different value following the Taguchi parameter, which is the several statio will be combined each other. The arrangement of sequence in the assembly line has done by using the Arena simulation. Figure 3.4 shows the process flow of designing the assembly line layout of the remanufacturing system in the automotive industry.

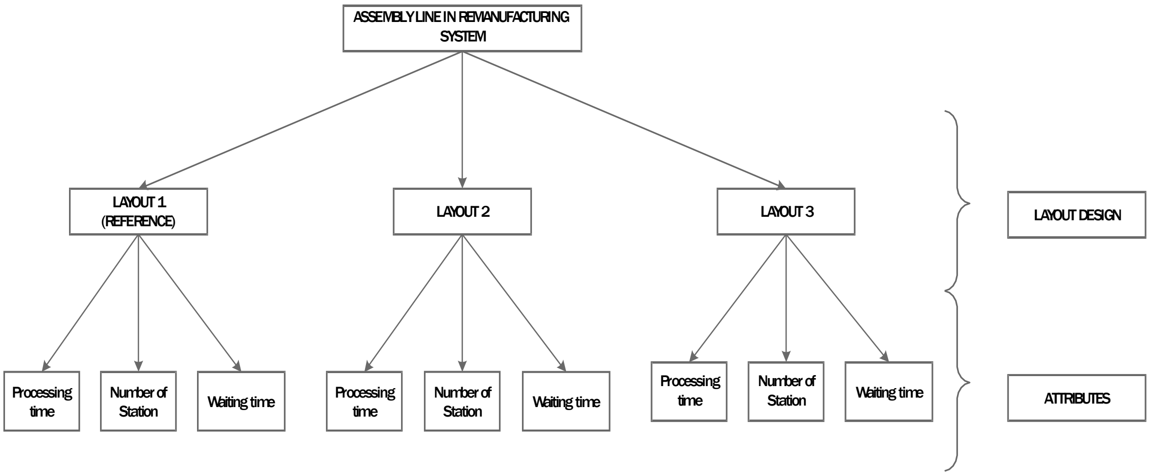



Figure 3.4 The Illustration of process flow in designing the assembly line in the remanufacturing system

### 3.2.1 Simulation using Arena

Based on the proposed layout model, the simulation design is generated using the Arena simulation that indicated every layout model performance with the specific number input. The simulation phase will contribute based on the proposed layout model which is three layout model. The input for this simulation follows the proposed layout model and data collection based on the actual situation of the assembly line. Arena software was used to simulate the given system to assess its significant output, such as a number of output, number of input, and work in progress (Kamrani et al., 2014). Figure 3.5 The Illustration of how to use the Arena Simulation.

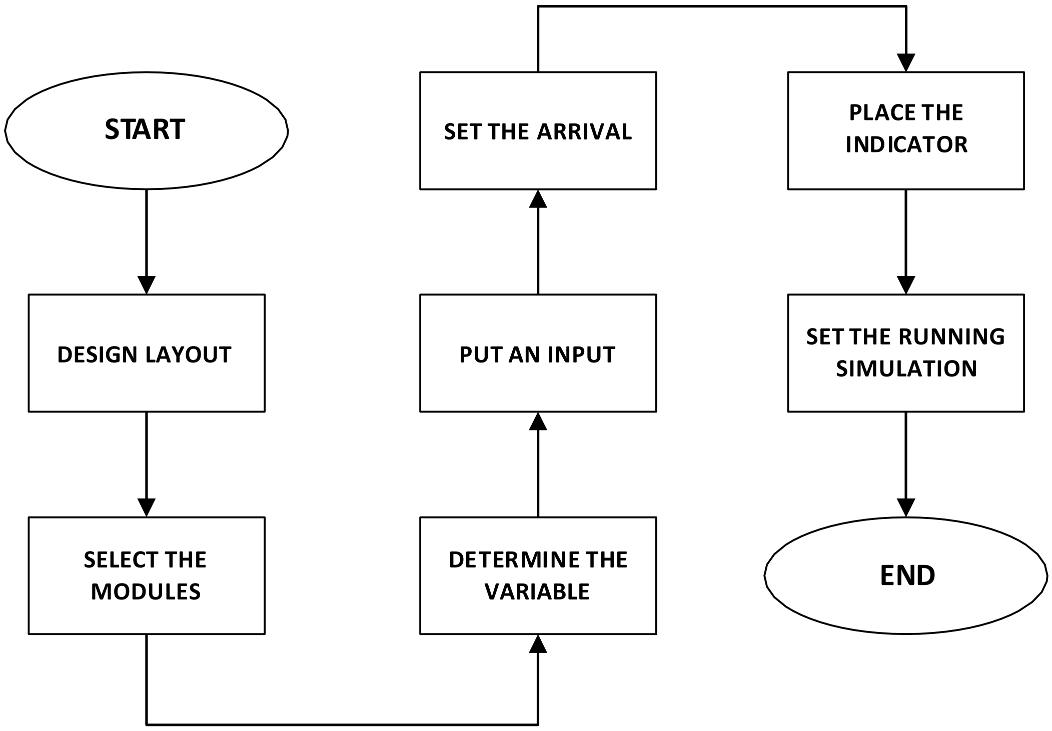



Figure 3.5 The Illustration of how to use the Arena Simulation

### 3.3 DATA COLLECTION

Based on the study, there are several attributes or factors that capable to be used in this project because all the attributes or factors is already discussed in the problem statement. In addition, all the attributes or factors contain the parameter or input that may affect the assembly line based on this project. The input is unpredictable and uncertainties during the assembly line process of a remanufacturing system.

The attributes or factors has been analysed from the reseach on this study and all the attributes will be optimise by using the Taguchi method to displayed the final result. The attributes including in this project which is first is unpredictable of the processing time in the assembly line process (Yuksel, 2010), second is uncertainties quality of the input product (Seitz, 2007), and third is unpredictable of the quantity product in the assembly line (Yuksel, 2010). The parameter that including in the attributes as input for the assembly line process is still on the research progress for this project. Table 3.1 shows the attributes for this project that will including the parameter.

Table 3.1 The Attributes For Assembly line layout

| **Attributes** | **Parameter** | | |
|---|---|---|---|
| Processing time | 1200 mins | 1180 mins | 1150 mins |
| Number of Station | 13 | 12 | 11 |
| Waiting time | 100 mins | 90 mins | 75 mins |

## 3.4 TAGUCHI METHOD TESTING

Based on this study, the project will conducted by using the Taguchi method to investigate the assembly line. Taguchi method will be using the three attributes that already specified with the input also known as a parameter. Moreover, the Taguchi method that conducted the analyse process which to validate and make a comparison between the three assembly line layout is better in term of optimisation.

The method of optimisation is important to make the system continuously improvement rather than to make the system more efficient and smooth during the running process. The Taguchi method proposed technique is based on fractional factorial test models labelled as Orthogonal Array (OA) that minimize the number of experimental studies. Mostly the selection of OA is depending on the factors and the level has been using in the Taguchi method. by using OA, several control parameters can be calculated, which consequently influence the output function, thus decreasing the size of the testing process (Shahavi et al., 2016)

By using the Minitab application, the Taguchi method will be generated with all the input support to validate the data collection. All the data collection will be used as an input in the Minitab application. The first step is to define all the input and decide the Taguchi method design which is the level and factors in Figure 3.5. The second step is to select the number of testing run shows in Figure 3.6. Third Step is to fill all the data collection into the Minitab application shows in Figure 3.7. The result of validation will show in signal noise (S/N) ratio that shows in Figure 3.8.

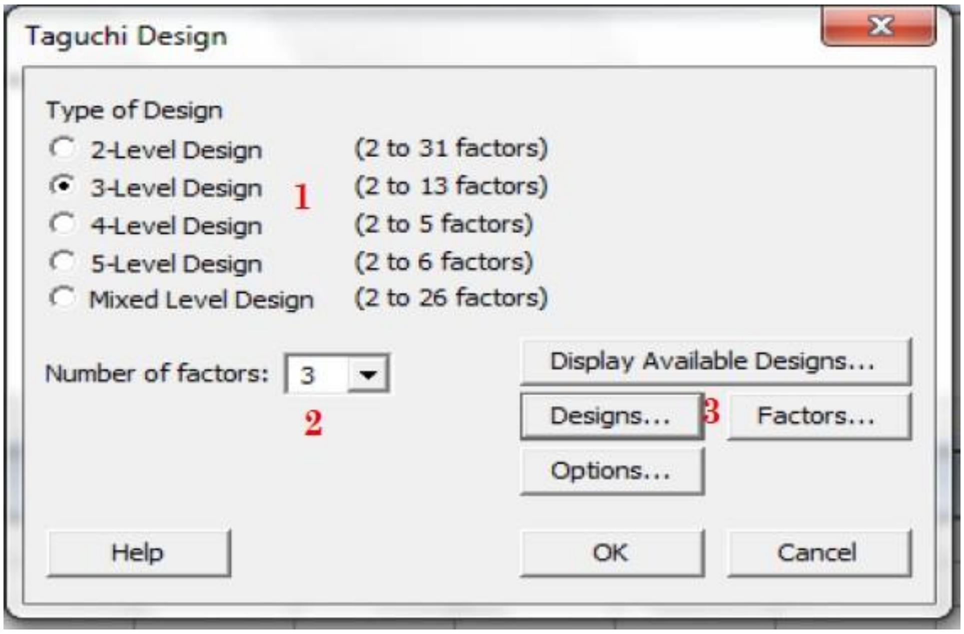



Figure 3.6 Select the Taguchi Method Design

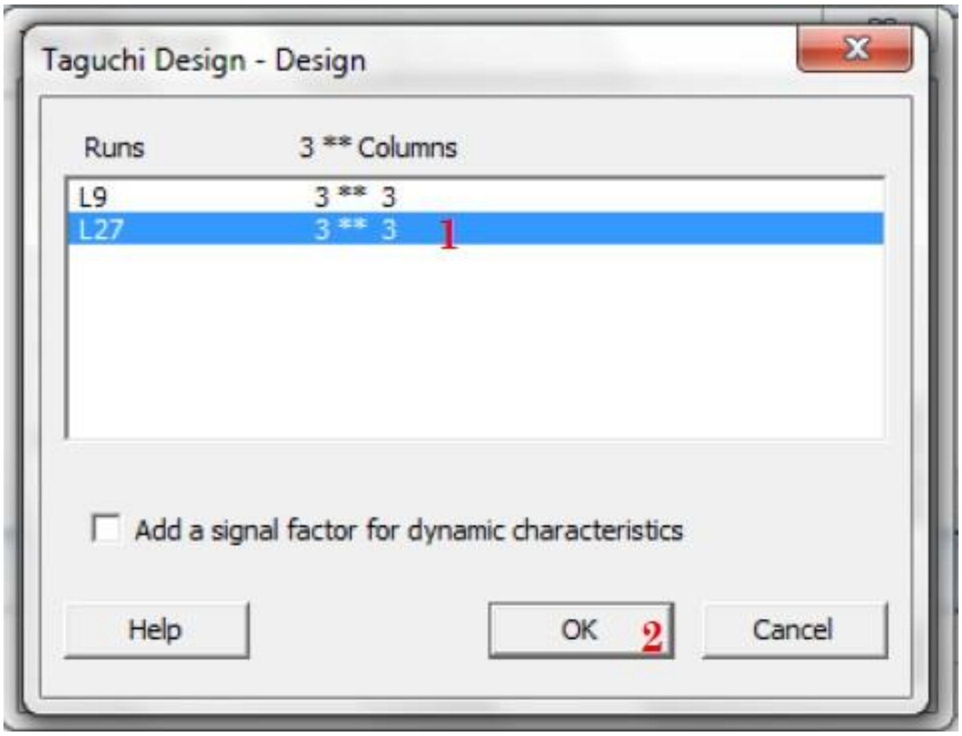



Figure 3.7 Select Number of Run for Testing

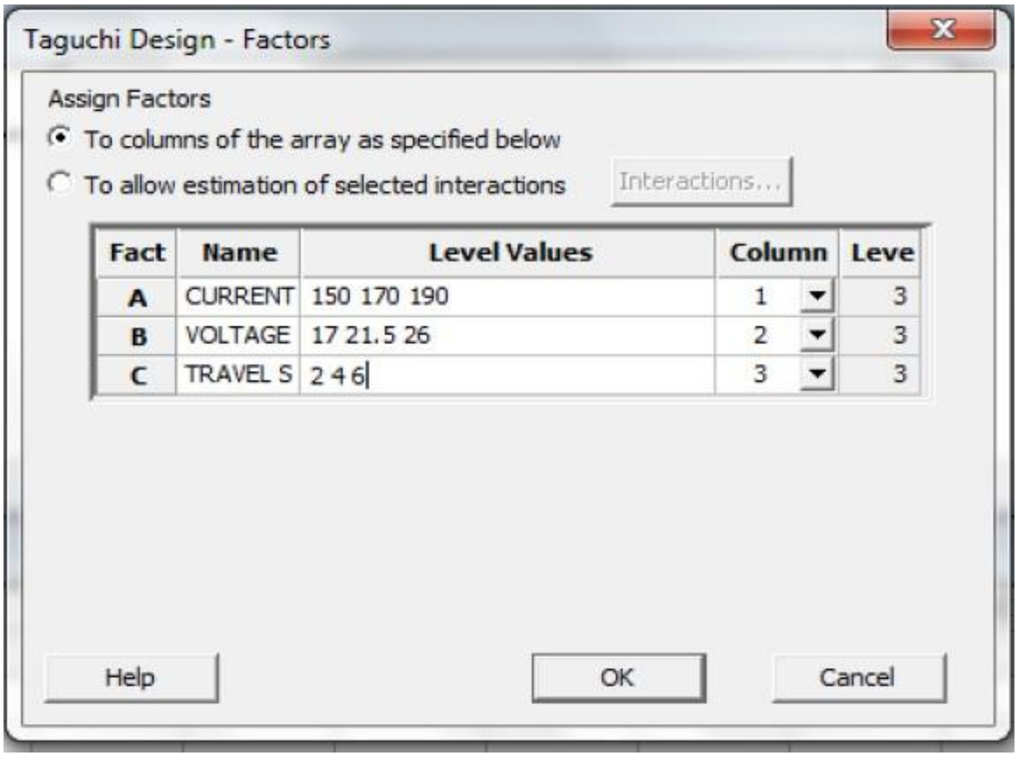



Figure 3.8 Fill The Data Collection

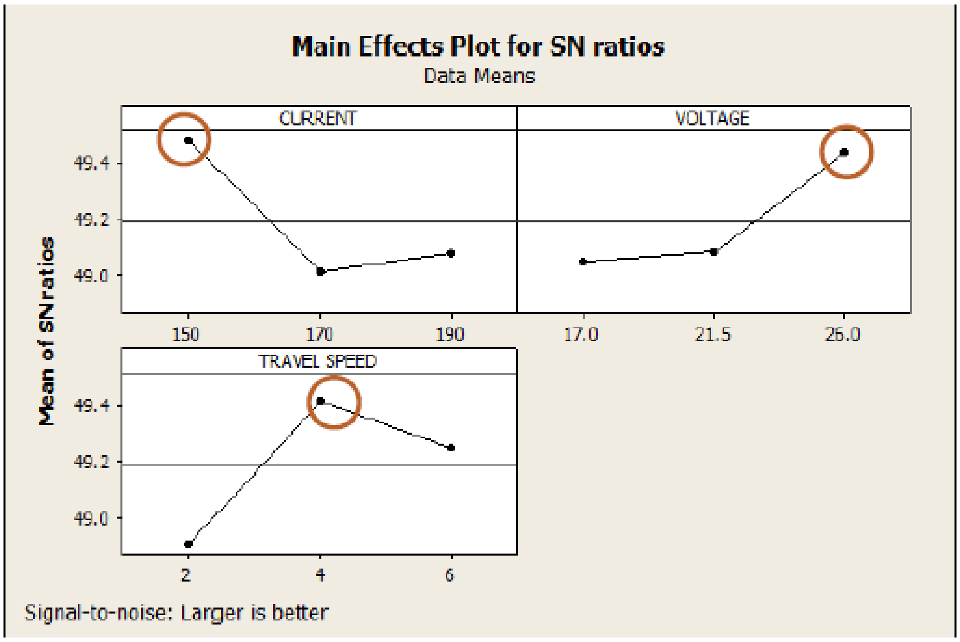



Figure 3.9 The Validation Result

## 3.5 SUMMARY

In conclusion, the optimisation planning for this project that has been applied in the assembly line process is possible with all the support data collection. The assembly line layout will be designed through the Arena simulation that generated the three layout design with the different arrangement of the assembly line sequence. In addition, the data collection for this project is following the reference layout model. The attributes in the assembly line is already defined and will be applied in the Taguchi method. By using the Taguchi method, the three assembly line layout of the remanufacruing system in the automotive industry will be validate and produce the final result of optimization.

# CHAPTER 4

## RESULT AND DISCUSSION

### 4.0 INTRODUCTION

This project aims to optimise and improve the effectiveness of the use of all the processes in the remanufacturing system and improve the efficiency of the services. This chapter has discussed and analysed all the data collection obtained from the testing as mentioned in this project. As an overview of this chapter, there are THREE (3) significant parts expressed from the objective in Chapter 1.

I. The analysis and discussion on the proposed layout design characterisation.
II. The analysis and discussion of the data collected are based on the Taguchi method analysis and relation with the validation test and mean analysis.
III. The simulation and discussion of the designed layout are based on the Arena simulation.

### 1. LAYOUT DESIGN

1. Proposed Layout Model (1)

The layout design of the remanufacturing system that is focusing on the assembly line in the automotive industry. Proposed layout design is an essential phase to give a clear vision of the assembly line to form similar to the industry's actual situation. The assembly line is the sequence arrangement of several stations starting from the welding stations, painting station, assembly frame station (wiring, engine, & roof lining), inspection station, the repair process station, and vehicle quality station (Ismail, 2020). Proposed layout model (1) is a reference layout based on the literature study in Chapter 2. Figure 4.1 show the reference layout that will be made as a proposed layout model (1).

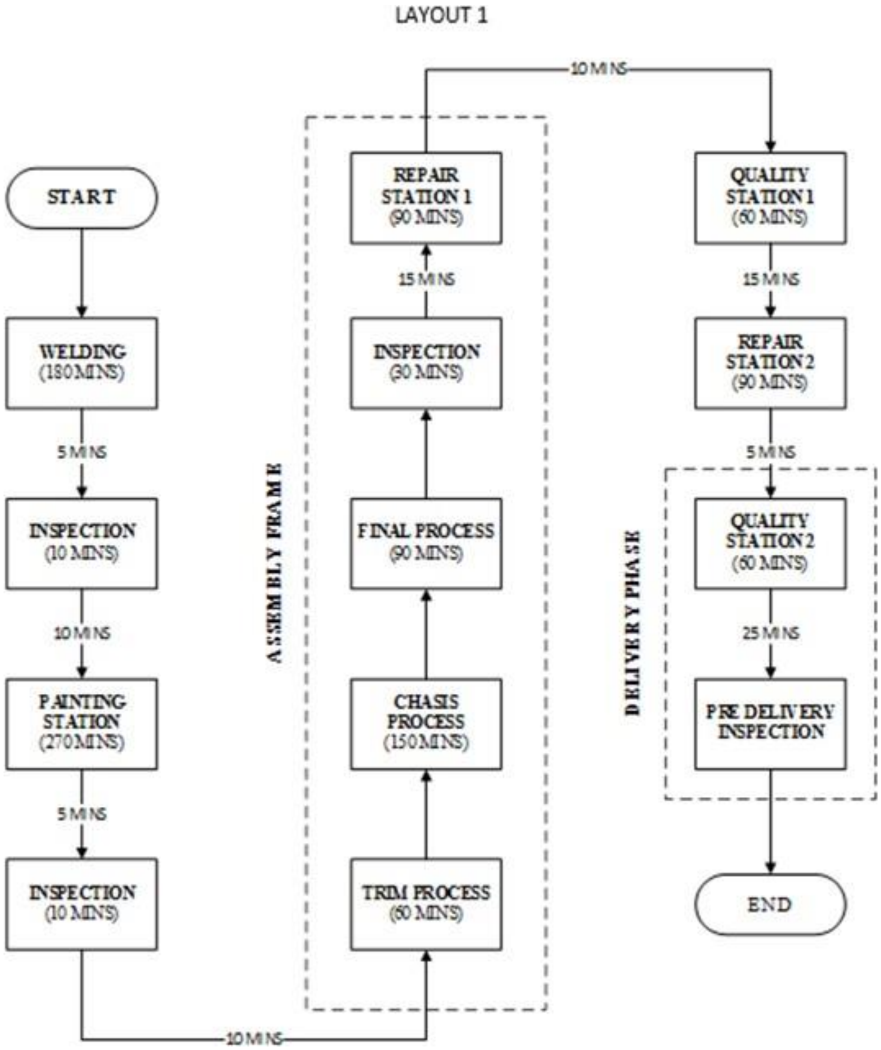



Figure 4.1 The Illustration of Proposed Layout Model (1)

From the reference layout, all the input parameters will remain similar for the proposed layout model (1) that has been used as a data collection for the Taguchi method analysis for level 1. If one of the stations having a problem during the production, this effect on the whole assembly line will facing the bottleneck situation (Ismail, 2020). The performance of the proposed layout model (1) has been indicated by using the simulation. Figure 4.2 shows the proposed layout model (1) is designed in the arena simulation that is used to determine the layout's performance.

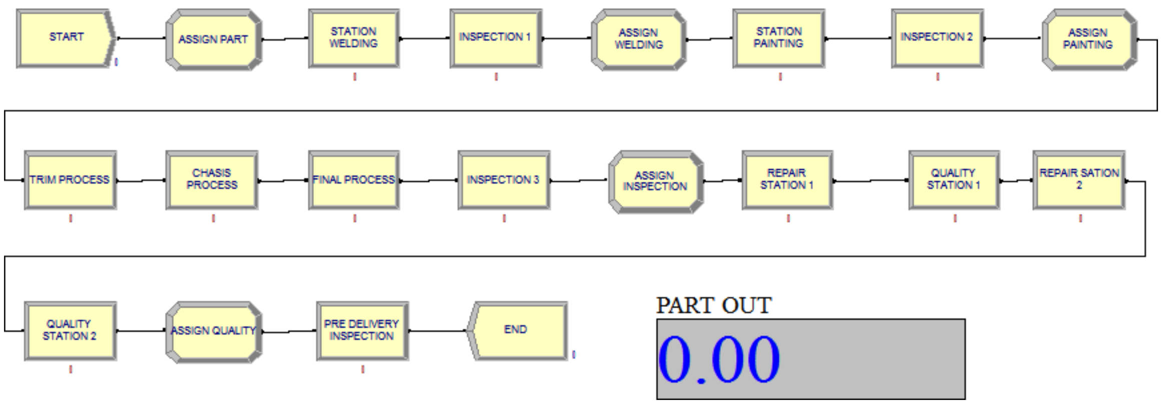



Figure 4.2 The Proposed Layout Model (1) in Arena Simulation

### 4.1.2 Proposed Layout Model (2)

From the proposed layout model (1), the layout design is made as a reference to generate the proposed layout model (2). Based on the literature study in Chapter 2, proposed layout model (2) is an improvement that has been made by combining the station. The combining process will be considered several possible conditions which are in the remanufacturing system in assembly lines has three types of conditions; human-operated station, semi-automated station, and automated station (Zhang et al., 2020).

The combining process is on the human-operated station and semi-automated station. The result obtained from the combining process is the decreasing waiting time that affected the total processing time. In the proposed layout model (2), the combining process. Besides that, from the round robin scheduling formula in equation (1), the waiting time of this combination process is 10 mins for the inspection station. Figure 4.3 shows the proposed layout model (2) after the combination process.

The Waiting time can be expressed by: ———————— Eqn (1)

Turn around time = Completion time – Arrival time

Waiting time = Turn around time – Burst time

| Inspection Station 1 | Inspection station 2 |
|---|---|
| Turn around time = 10 mins – 5 mins | Turn around time = 10 mins – 5 mins |
| = 5 mins | = 5 mins |
| Waiting time = 5 mins – 0 | Waiting time = 5 mins – 0 |
| = **5 mins** | = **5 mins** |

Total time = Inspection Station 1 + Inspection Station 2

= 5 mins + 5 mins

= **10 mins**

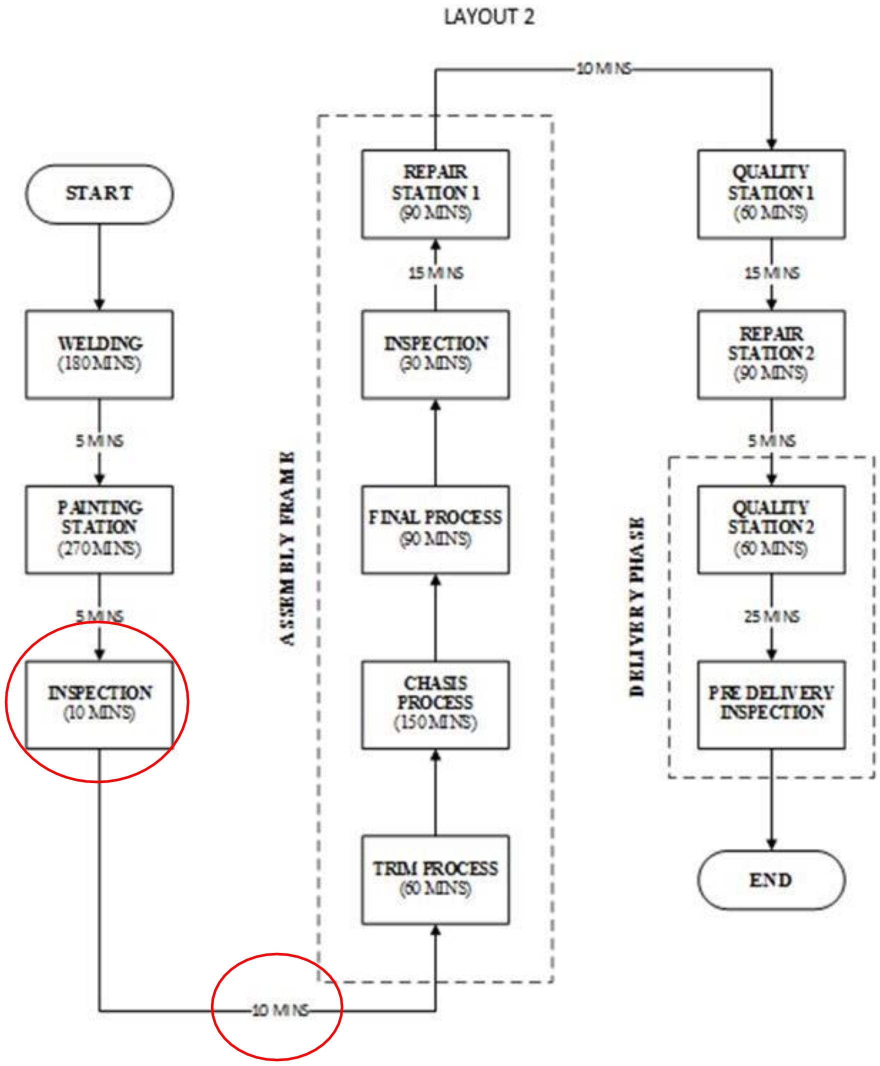



Figure 4.3 The Illustration of Proposed Layout Model (2)

In the real-world simulation, the activities assigned will be prioritised equally to assess the uncertainties of the activities included and prevent the pulling concept's implementation in the model (Zahraee et al., 2020). The performance of the proposed layout design (2) has been indicated by using the simulation after the combining process between inspection station (1) and inspection station (2). Figure 4.4 shows that the proposed layout model (2) is designed in the arena simulation used to determine the layout's performance.

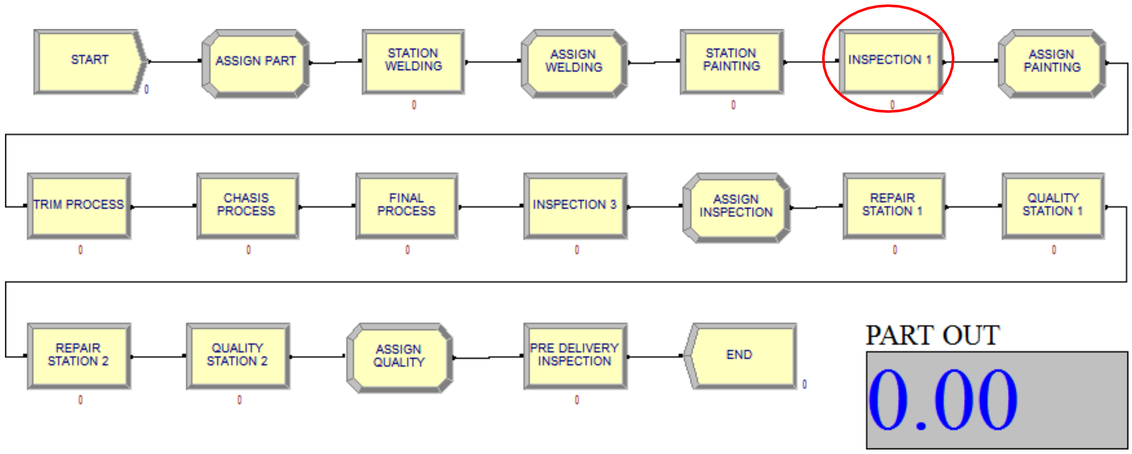



Figure 4.4 The Proposed Layout Model (2) in Arena Simulation

### 4.1.3 Proposed Layout Model (3)

Based on the reference layout and proposed layout model (2), the proposed layout model (3) is the contribution that optimizes the processing time by decreasing the waiting time in the uncertainties station on the assembly line. The combining process in the proposed layout model (3) also considered the human-operated station and semi-automated station factors based on the literature study in Chapter 2. The proposed layout model (3) is the continuity layout model that combination of the assembly frame phase between the inspection station (3) and repair station (1) and became a repair and inspection station. Figure 4.5 shows the proposed layout model (3) after the combination process.

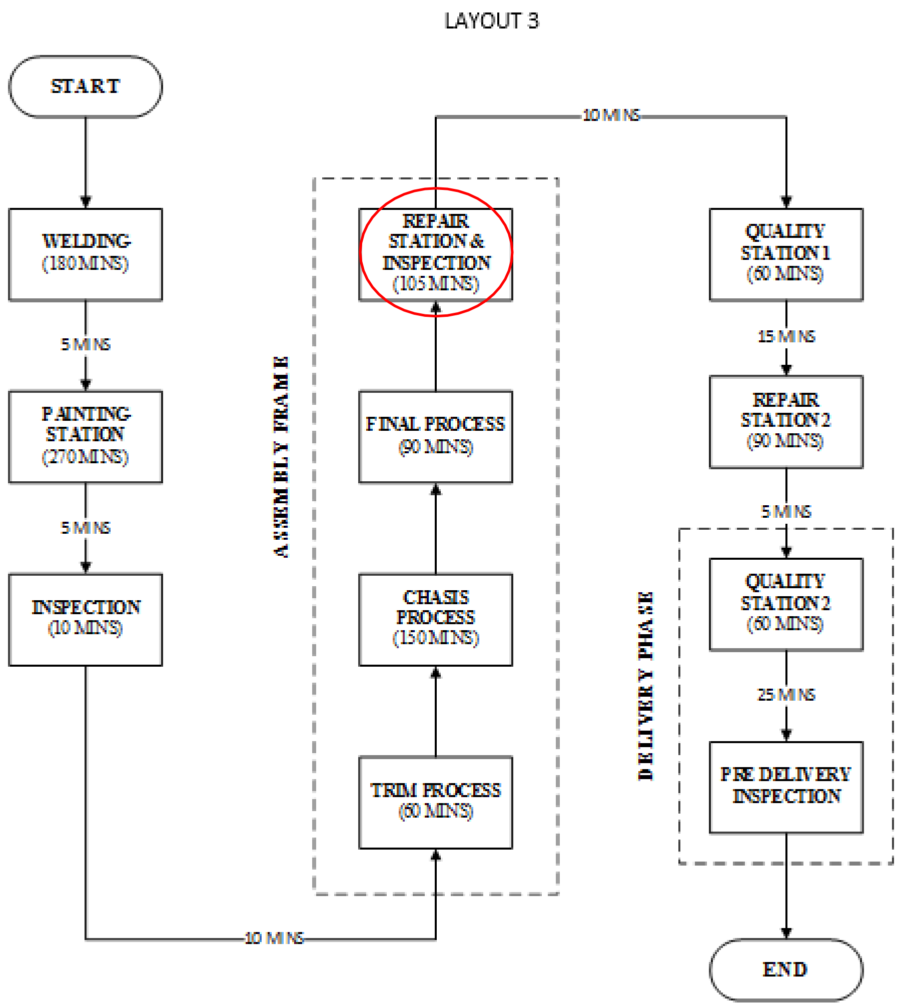



Figure 4.5 The Illustration of Proposed Layout Model (3)

Besides that, from the round-robin scheduling formula in equation (1), the waiting time of this combination process is 15 mins for the repair and inspection station. The Assembly frame phase is on the conveyor line, and every station will carry the fixed number of processing times. Waiting time in the conveyor line will affect the activities of the activities, and the execution time (Burst time) will be concentrated in the last activities (Ijomah & Childe, 2007). The waiting time will be included in the processing time in the combination process between the inspection station (3) and repair station (1). Figure 4.6 shows that the proposed layout model (2) is designed in the arena simulation used to determine the layout's performance.

The Waiting time can be expressed by: ———————————— Eqn (1)

Turn around time = Completion time – Arrival time

Waiting time = Turn around time – Burst time

| Inspection Station 3 | Repair station 1 |
|---|---|
| Turn around time = 30 mins – 10 mins | Turn around time = 90 mins – 15 mins |
| = 20 mins | = 75 mins |
| Waiting time = 20 mins – 20 mins | Waiting time = 75 mins – 50 mins |
| = **0** | = 15 **mins** |

Total time = Inspection Station 3 + Repair Station 1

= 0 + 15 mins

= **15 mins**

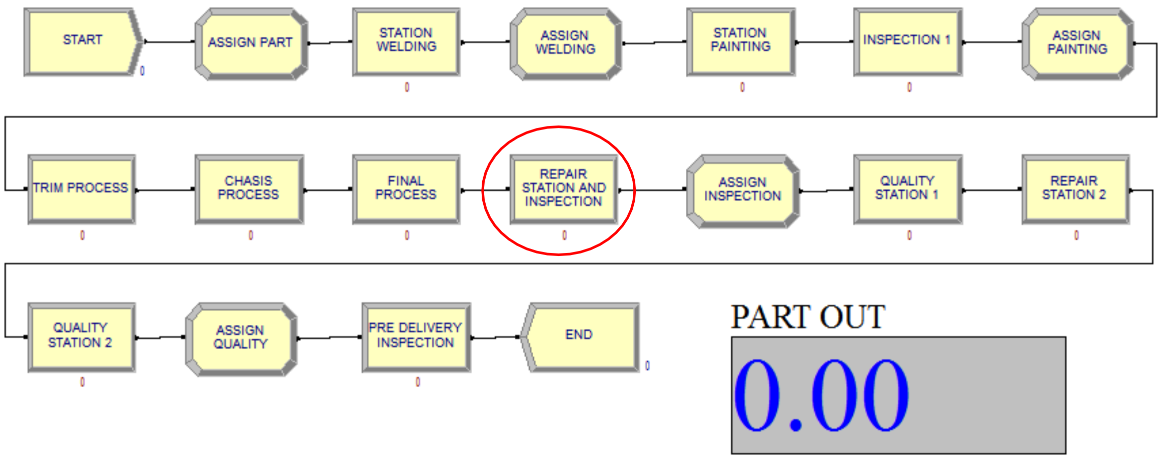



Figure 4.6 The Proposed Layout Model (3) in Arena Simulation

## 4.2 TAGUCHI METHOD ANALYSIS

This study aims to propose the model by using the Taguchi method because Taguchi method analysis is the fundamental statistical model of the design of experiment (DOE) method that will obtain the optimized condition based on the parameter given. Taguchi methods are statistical methods developed by Genichi Taguchi to improve the quality of manufactured goods and, more recently, also applied to engineering (Semioshkina & Voigt, 2006). The parameter value is on the data collection in the layout design phase. Table 4.1 shows the parameter value for the Taguchi method analysis.

Table 4.1 The Attributes For Assembly line layout

| **Parameter** | **Level 1** | **Level 2** | **Level 3** |
|---|---|---|---|
| Processing time | 1200 Mins | 1180 Mins | 1150 Mins |
| Number of Station | 13 | 12 | 11 |
| Waiting time (Response) | 100 mins | 90 mins | 75 mins |

The analysis started by selecting the parameter in this study involved processing times and the number of stations as a factor, and waiting times is a response in this Taguchi method analysis. Based on the article of an overview of Taguchi method, the parameter requirements is at least three, which is two is the factor and one is a response (Semioshkina & Voigt, 2006). The orthaghonal array (OA) of nine is the number of analysis run in the taguchi method and expressed the result obtained in the S/N ratio graph and mean graph. Based on the S/N ratio graph,

Taguchi analysis results show that level 3 (Proposed layout model (3)) is the most optimized layout design following to the smaller number is a better condition in Figure 4.7. The value of S/N ratio is -37.0252 decibels (dB) at the run number nine is the optimal condition of the processing times is 1150 mins, the number of stations is 11, and the waiting time is 71 mins on level 3 of the Taguchi method parameter. Level 2 is the average between level 3 and level 1, which is generally expected as an improvement layout model with a small gap in optimization contribution.

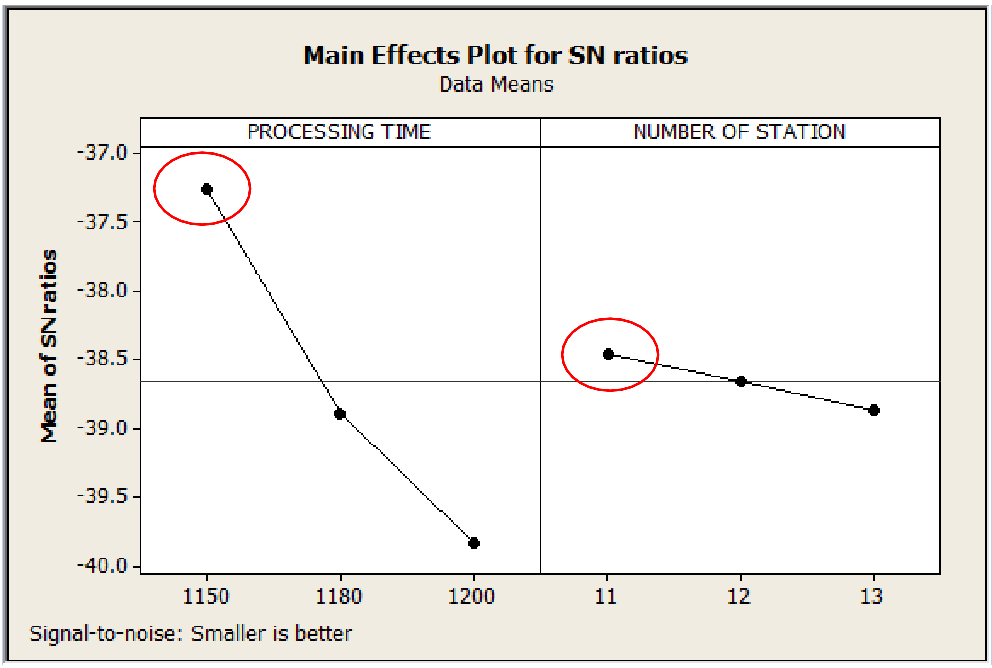



Figure 4.7 The S/N ratio graph by Taguchi method analysis

### 4.2.1 Validation Test

Based on the result obtained from the Taguchi method analysis, the validation test determines the error for all numbers of the run orthogonal array (OA) that can be expressed in the percentage value. The lowest number of errors is the most significant value to the actual condition and the validation test generated the equation based on the response has been selected (Semioshkina & Voigt, 2006).

The equation is typically the contribution of factors that became a dependent value and the response is the independent value that generally affects the number of improvements. From this analysis, the equation (1) generated for the waiting time and the value of the error will be compared with the actual value following the level of the Taguchi parameter. The run number nine is the lowest number of errors with 5.63 percent and the predicted value generated from this equation is 71 mins. The percentage error of the model is 9.24 percent and considering 90 percent level of confidence the model is valid . The prediction value is significant with the value generated from the S/N ratio graph. Table 4.2 shows the values of error from the comparison with the predicted value and actual value.

Waiting Time = - 526 + 2.00 (Number of Station) + 0.50 (Processing time) —— Eqn (1)

= - 526 + 2.00 (11) + 0.50 (1150)

= 71 mins (Predicted value)

Waiting Time = 75 mins (Actual value)

$$\text{Validation} = \frac{[\,71 - 75\,]}{71}$$

= 0.0563 x 100

= 5.63%

Table 4.2 The results of Validation Test for the waiting time errors

| **Run** | **Actual Waiting rime** | **Error (%)** |
|---|---|---|
| 1 | 100 | 40.84 |
| 2 | 98 | 38.02 |
| 3 | 96 | 35.21 |
| 4 | 90 | 26.76 |
| 5 | 88 | 23.94 |
| 6 | 86 | 21.12 |
| 7 | 79 | 11.26 |
| 8 | 77 | 8.45 |
| 9 | 75 | 5.63 |

### 4.2.2 Mean Analysis

ANOVA analysis was performed to determine the mean value generated by using a similar parameter with the taguchi method analysis. The ANOVA generated the 95 percent confident interval for mean to indicated the gap between those levels. The purpose of ANOVA is to investigate which process parameter significantly affected the properties and may be used to estimate the process performance at optimum conditions from the confident interval gap (Shahavi et al., 2016). From this study, the one-way types have been used to obtain the mean value and compare the mean graph value of the Taguchi method analysis. The analysis is expressed in each factor which is the waiting time between processing time and the waiting time between the number of stations.

The mean graph analysis from the Taguchi method shows the optimal value of those levels is 73.00 for processing time and 84.33 for the number of stations on level 3 of the Taguchi parameter that is presented on a mean graph in Figure 4.8. Figure 4.9 shows the analysis between waiting and processing times obtained the 95 percent confident interval for mean to indicate the gap between three levels following the Taguchi parameter. The gap between level 3 and other levels is most significant. Based on Table 4.3, level 3 contributes the smallest value of the mean, which is 73.00 for the standard deviation value of 2, similar to the mean graph value from Taguchi method analysis and the smallest value of mean is the optimal condition of the activities.

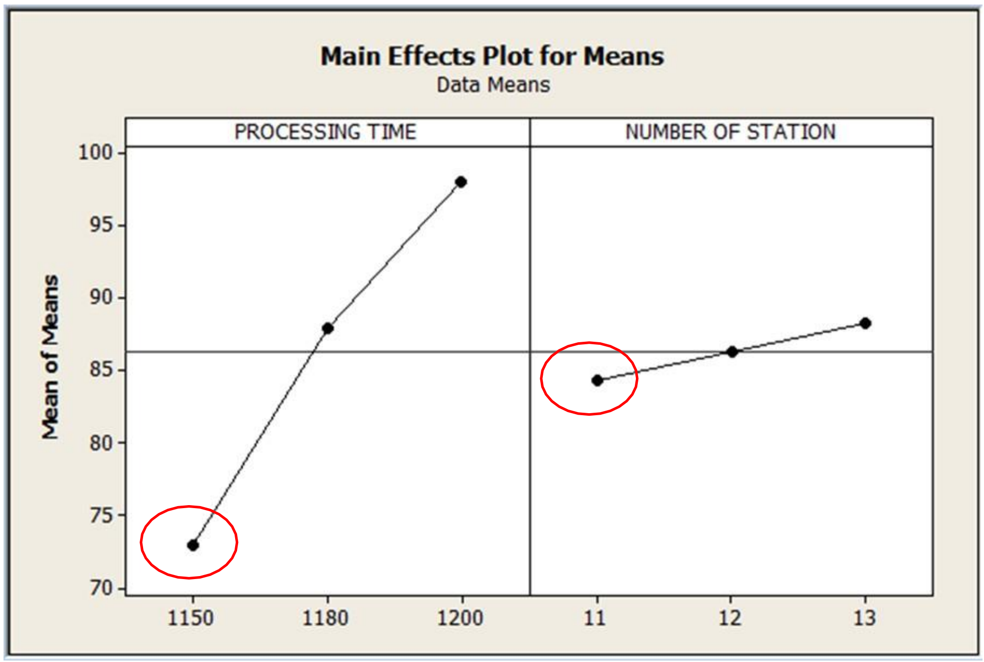



Figure 4.8 The Mean graph by Taguchi method analysis

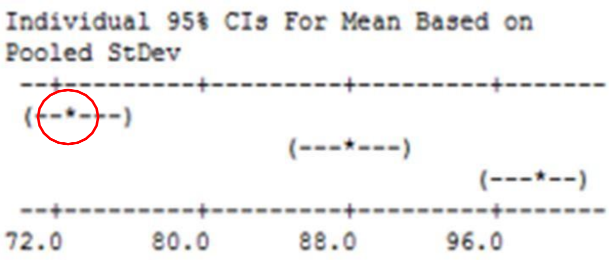



Figure 4.9 The 95 percent Confident Interval for Processing time by ANOVA

Table 4.3 The Mean value for Processing time by ANOVA analysis

| Level | Processing time (min) | Mean | Standard deviation |
|---|---|---|---|
| 1 | 1200 | 98.00 | 2 |
| 2 | 1180 | 88.00 | 2 |
| 3 | 1150 | 73.00 | 2 |

The analysis of the mean value between the waiting time and the number of stations is similar to the analysis of processing time previously. The ANOVA generated the 95 percent confident interval for mean to indicated the gap between those levels. The gap of the confidence interval for the number of stations shows in the Figure 4.10 is clearly in a consistent form which is the gap is not too far between three-level. Level 3 is an optimal condition based on the result obtained for the mean value of the number of stations. The smallest number between the three levels is 84.33, with a standard deviation of 12.58. Table 4.4 shows the mean value for the number of station that generated by using one-way ANOVA. By comparing the mean value between the Taguchi method, the mean analysis using ANOVA contributes a similar value between the two analyses method.

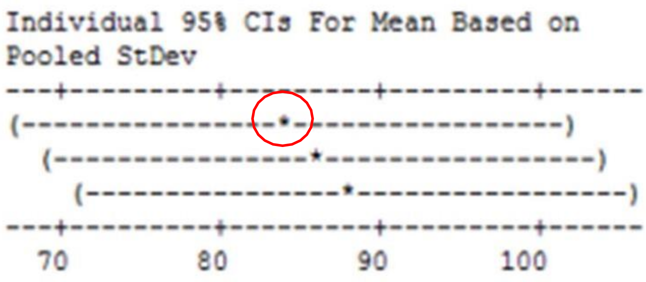



Figure 4.10 The 95 percent Confident Interval for the Number of stations by ANOVA

Table 4.3 The Mean value for the Number of stations by ANOVA analysis

| Level | Number of Station | Mean | Standard deviation |
|---|---|---|---|
| 1 | 13 | 88.33 | 12.58 |
| 2 | 12 | 86.33 | 12.58 |
| 3 | 11 | 84.33 | 12.58 |

## 4.3 ARENA SIMULATION

This study aims to analyze the performance of the remanufacturing system after applying the Taguchi method mentioned in the objective in Chapter 1. Based on the proposed layout model, the simulation design is generated using the Arena simulation that indicated every layout model's performance with the specific number input. Besides that, They determined the output progress to develop data collection that generated the significant study between the analysis and simulation phases

The simulation phase will contribute based on the proposed layout model which is three layout model. The input for this simulation follows the proposed layout model and data collection based on the actual situation of the assembly line. Arena software was used to simulate the given system to assess its significant output, such as a number of output, number of input, and work in progress (Kamrani et al., 2014).

### 4.3.1 Simulation Layout (1)

The simulation layout (1) follows the designed layout model (1) and parameter from the Taguchi method analysis of level 1, which is the reference layout. The perfomace generated will be set as a benchmark to indicated the gap between the other level of the proposed layout model. Figure 4.11 shows the simulation result obtained of simulation layout (1) after running the assembly line for 20 hours with the arrival of parts every 7 hours. The assembly line can produce up to 200 parts for fully running (Ismail, 2020).

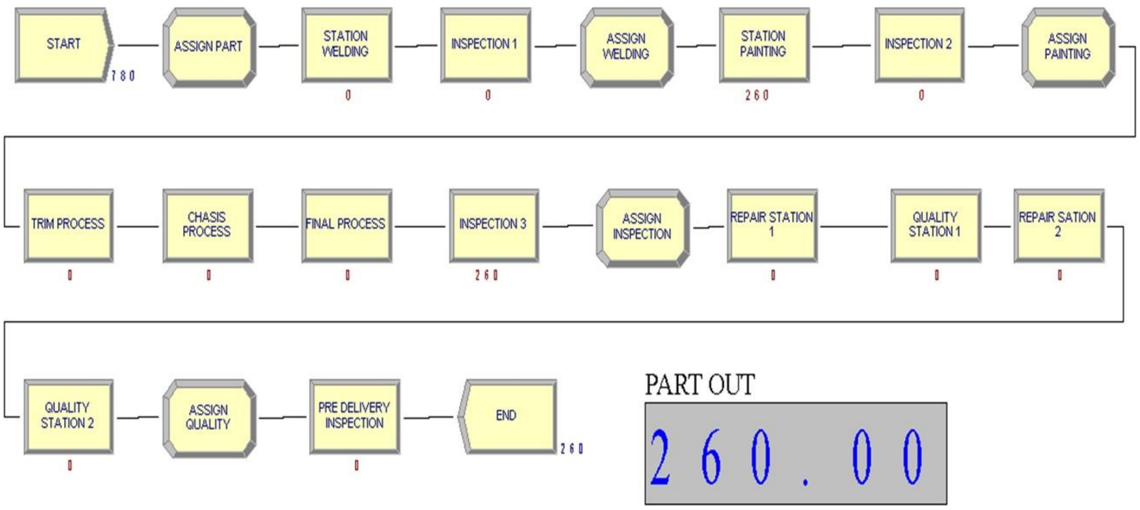
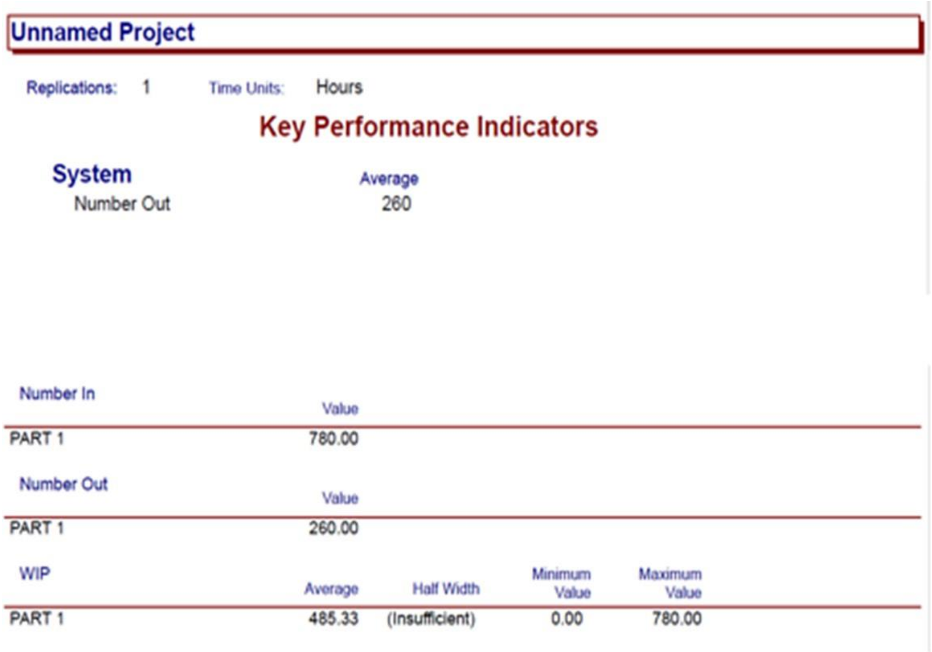



Figure 4.11 The Simulation Layout (1)

The simulation progress will be presented the performance report of the layout model that obtained the significant output value based on the input value. Based on the performance report in Figure 4.12, the number of part out that generated from this layout model is 260 parts, the number of the part in is 780 parts for arrival every 7 hours, and the work in progress (WIP) is 485.33 parts that painting station and inspection station (3) is the contribution to the numbers work in progress. Besides, the painting station has the longest processing time and the inspection station (3) is the last station of conveyor lines before the execution to another station.


Unnamed Project

Replications: 1 Time Units: Hours

Key Performance Indicators

| System | Average |
| --- | --- |
| Number Out | 260 |

| Number In | Value |
| --- | --- |
| PART 1 | 780.00 |

| Number Out | Value |
| --- | --- |
| PART 1 | 260.00 |

| WIP | Average | Half Width | Minimum Value | Maximum Value |
| --- | --- | --- | --- | --- |
| PART 1 | 485.33 | (Insufficient) | 0.00 | 780.00 |

Figure 4.12 The Performance Report of Simulation layout (1)

4.3.2 Simulation layout (2)

The simulation layout (2) follows the designed layout model (2) and parameter from the Taguchi method analysis of level 2, which is the combination is made between inspection station (1) and inspection station (2). Figure 4.13 shows the simulation result obtained of simulation layout (1) after running the assembly line for 20 hours with the arrival of parts every 7 hours. Based on the Taguchi method analysis, the smallest value is better that expressed in the SN ratio and mean graph (Semioshkina & Voigt, 2006). The result shown in the simulation layout (2) increases the number of parts on the assembly line.

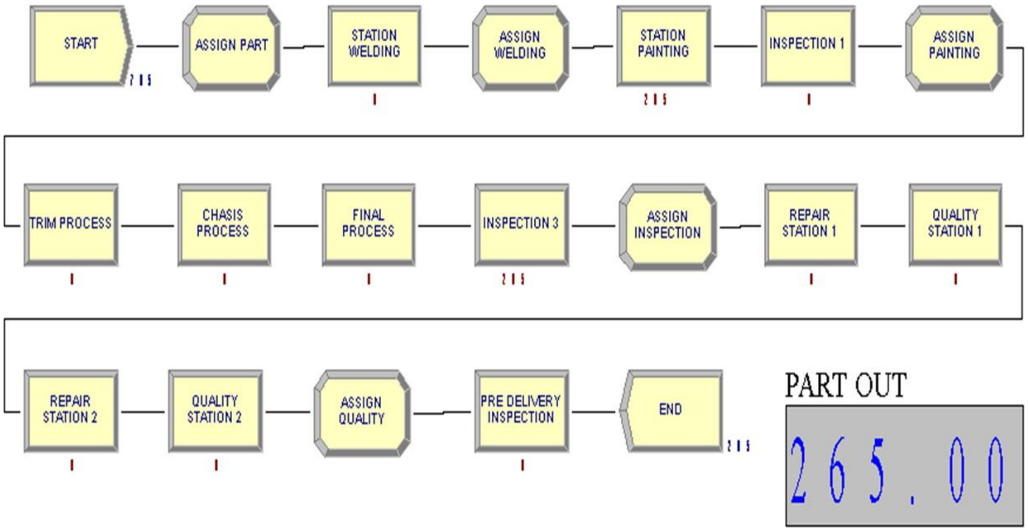



Figure 4.13 The Simulation Layout (2)

Based on the performance report in Figure 4.14, the number of part out that generated from this layout model is 265 parts, the number of the part in is 795 parts for arrival every 7 hours, and the work in progress (WIP) is 492.46 parts that painting station and inspection station (3) is the contribution to the numbers work in progress. The result has shown the simulation layout (2) increasing the number of parts in non-drastically form. Besides, based on the taguchi method analysis data collection, the designed layout model (2) is between level 1 and level 3, contributing to the non-drastically form of performance.


Unnamed Project

Replications: 1 Time Units: Hours

Key Performance Indicators

| System | Average |
|---|---|
| Number Out | 265 |

| Number In | Value |
|---|---|
| PART 1 | 795.00 |

| Number Out | Value |
|---|---|
| PART 1 | 265.00 |

| WIP | Average | Half Width | Minimum Value | Maximum Value |
|---|---|---|---|---|
| PART 1 | 492.46 | (Insufficient) | 0.00 | 795.00 |

Figure 4.14 The Performance Report of Simulation layout (2)

### 4.3.3 Simulation layout (3)

The simulation layout (3) follows the designed layout model (3) and parameter from the Taguchi method analysis of level 3, this layout model is the continuity from the previous layout model and the combination is made between inspection station (3) and repair station (1). Figure 4.15 shows the simulation result obtained of simulation layout (1) after running the assembly line for 20 hours with the arrival of parts every 7 hours. The result shows that the simulation layout (3) contributes to the most significant number of parts produced on the assembly lines than the other simulation layouts.

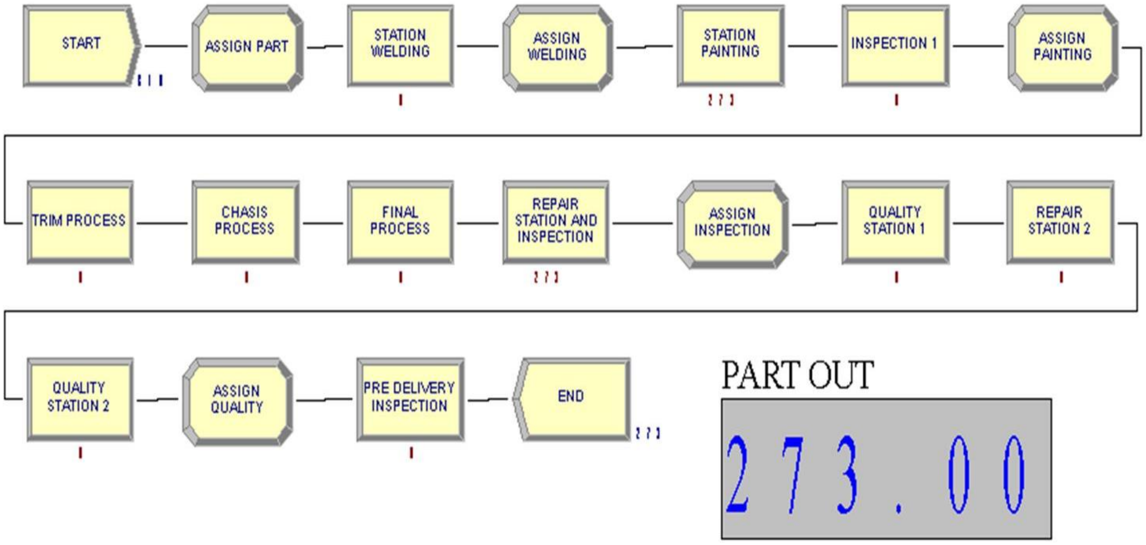



Figure 4.15 The Simulation Layout (3)

Based on the performance report in Figure 4.16, the number of part out that generated from this layout model is 273 parts, the number of the part in is 819 parts for arrival every 7 hours, and the work in progress (WIP) is 510.74 parts that painting station and repair and inspection station is the contribution to the numbers work in progress. Other than that, on the Taguchi method analysis, the optimal condition is level 3 generated from the SN ratio and mean graph. The result shows that the simulation layout (3) is in the optimum condition that produced the largest number of parts in, number of parts out, and work in progress.


Unnamed Project

Replications: 1 Time Units: Hours

Key Performance Indicators

| System | Average |
|---|---|
| Number Out | 273 |

| Number In | Value |
|---|---|
| PART 1 | 819.00 |

| Number Out | Value |
|---|---|
| PART 1 | 273.00 |

| WIP | Average | Half Width | Minimum Value | Maximum Value |
|---|---|---|---|---|
| PART 1 | 510.74 | (Insufficient) | 0.00 | 819.00 |

Figure 4.16 The Performance Report of Simulation layout (3)

## 4.4 SUMMARY

All in all, all the testing done in this section is to answer every one of the significant measures that stated in the objectives in Chapter 1. Based on this result for the Taguchi method analysis and Arena simulation, the data collection generated the significant of this study. The proposed layout model is completed by using the Arena simulation that contribution of three layout models there are layout model (1) is the reference layout, layout model (2) is a combination of inspection stations (1) and inspection station (2), and layout model (3) is a combination of inspection station (3) and repair station (3). The Taguchi method analysis generated results for data collection that determined the significant study on the validation test results and the mean analysis show in Table 4.4. Based on the Taguchi method analysis, the optimal condition is that the smallest number is better can increase the output (Semioshkina & Voigt, 2006). From this result shown in Figure 4.17, the smallest number of data from Taguchi method analysis will contribute to the increasing number of the production in the assembly line. The optimal condition is layout 3.

Table 4.4 The result of Taguchi method analysis

| **Result** | **Level 1** | **Level 2** | **Level 3** |
|---|---|---|---|
| Validation (%) | 40.84 | 26.76 | 5.63 |
| Mean (Processing time) | 98.00 | 88.00 | 73.00 |
| Mean (Number of stations) | 88.33 | 86.33 | 84.33 |
| S/N ratio (dB) | -40.00 | -39.08 | -37.02 |

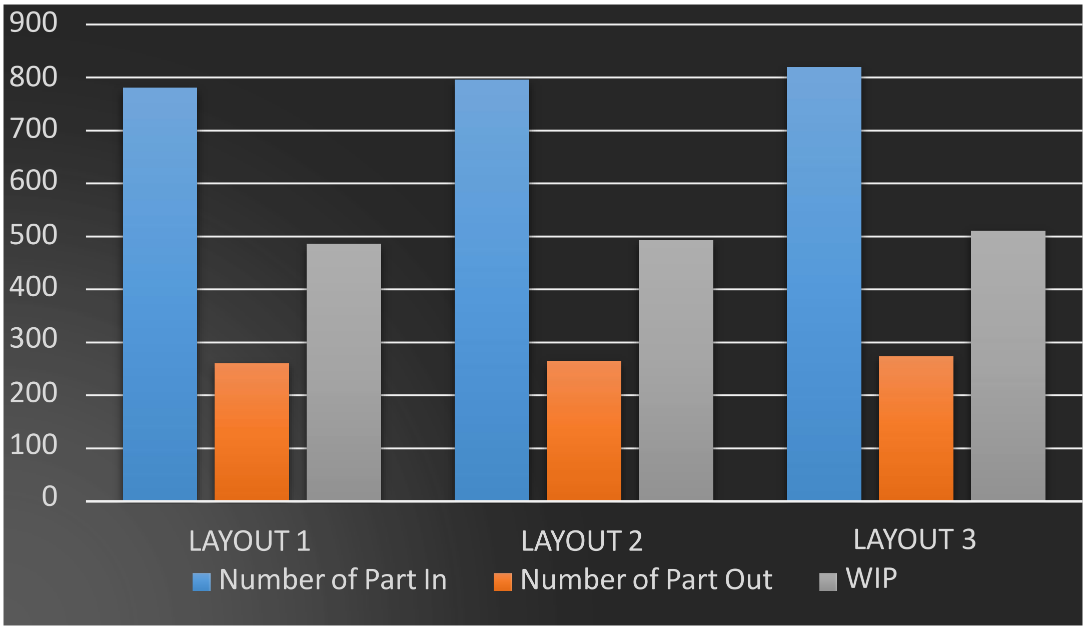



Figure 4.17 The result of the simulation layout by using Arena simulation

# CHAPTER 5

## CONCLUSION AND RECOMMENDATION

### 5.0 INTRODUCTION

This chapter summarized the importance of the study and the research findings in relation to the research objectives. This chapter also contains recommendations for further research and the improvement of this research.

### 5.1 CONCLUSION

In conclusion, this study is set of investigation the optimisation control process in the remanufacturing system focusing on the assembly line in the automotive industry has been selected. This project aims to establish strategies to improve efficiency and optimize the control process using the Taguchi method. Based on the literature study, the problem that obtains is due to the processing times in the remanufacturing system are unpredictable, the uncertain quality condition of used or waste products, and the inconsistent process in the remanufacturing system. Several attributes have been used in this study that generated the data collection for the analysis phase. Such as processing time, the number of stations, and the waiting.

The first objective of this study is to identify the problem of the current remanufacturing system. Based on the literature study, the current problem in remanufacturing is that the process involved in the assembly line is still in the research. The future solution is to standardized the remanufacturing system to sustain this sector. Also, processing time and the quality of product waste contribute to the largest number of the challenges in remanufacturing system activities. Other than that, the balancing supply and demand in remanufacturing system will generate through the uncertainties. The attribute is obtained based on the problem and challenges in the current remanufacturing system that resulted from the data collection of the observation in this study.

The second objective is to propose the model by using the Taguchi method. Based on the objective, the aims of this study are optimization control process, the assembly line layout model was completed proposed by using the reference layout from the literature study. The result shows, three proposed layout models were constructed the design in the Arena simulation. Proposed layout model (1) is the reference layout based on the literature study following with all the input given that able to apply in Taguchi method analysis. Next, the proposed layout model (2) is the contribution of the optimisation of the control process by combining the human-operated station, which is the possible station that carries the bottleneck in the assembly line is between the inpection station (1) and inspection station (2). Besides that, the proposed layout model (3) is the contuinity of the proposed layout model (2), which is the combination process between the inspection station (3) and the repair station (1). The input value at the proposed layout model has been used in Taguchi method analysis to generate the data collection. The Taguchi method analysis was completely performed the data collection using the S/N ratio graph that indicated the smaller number is better for optimizing the assembly line. The optimal condition is on the level 3, which is contributing the smallest value of S/N ratio which is -37.02 dB. Based on the validation equation, the validation test ultimately determines the execution number of errors between the predicted and actual values. The predicted value obtained in the Taguchi method and validation test is similar, which is 71 mins. The predicted value calculated with the actual value by following every layer number of run will be generated the errors. The smallest number of errors is the most significant condition with the actual value of waiting time that contributes to optimizing the whole assembly line process, which is the optimal condition is on the run number nine on level 3 with the errors of 5.63 percent. Based on the mean graph presented in the Taguchi method analysis, the mean analysis entirely finished this study's analysis phase to indicate the gap and similarity of the mean value. The results show that the optimal value is in level 3 with the mean processing time of 73.00 and the mean number of stations is 84.33. the data collected between the Taguchi method analysis and mean analysis is the most significant result.

The last objective of this study is to analyse the performance of the remanufacturing system after applying the Taguchi method. From this objective, the simulation phase will contribute based on the proposed layout model, which is a three layout model. The input for this simulation followed the proposed layout model and performed the simulation in Arena simulation. Based on the Taguchi method analysis, the optimal condition is that the smallest number is better can increase the output. The result obtained in the simulation layout (3), the input has been used is following the Taguchi method analysis level 3 is an optimal condition than another simulation layout. The simulation layout (3) that increases the number of production which is the number of parts out that generated from this layout model is 273 parts, the number of the part in is 819 parts for arrival every 7 hours, and the work in progress (WIP) is 510.74 parts.

All things considered, the most optimise condition for remanufacturing in the assembly line is the proposed layout model (3) that using the input of Level 3 in Taguchi method analysis with the drastically increasing number of production. Table 5.1 shows the result findings based this study.

Table 5.1 The result findings in this study

| No | Objectives | Result findings |
|---|---|---|
| 1. | To identify the problem of the current remanufacturing system | - **Processing times** in remanufacturing system are uncertainties.<br>- The **quality of the product** used is one of the challenges in the remanufacturing system.<br>- **Quantity and demand** is unbalanced in the remanufacturing system |
| 2. | To propose the model by using the Taguchi method | - Design layout are developed and presented that **consist of 3 layout**. By following the reference layout<br>- The optimal condition indicates that following the **smaller number is better.**<br>- **S/N ratio** value is **-37.02 dB**<br>- **Validation** value is **5.63%**<br>- Mean value for **processing times** is **73.00**<br>- Mean value for **number of station** is **84.33** |

| | | |
|---|---|---|
| | | - Based on the analysis that completely performed the **Level 3** is **the optimal condition.** |
| 3. | To analyse the performance of the remanufacturing system after applying the Taguchi method. | - Based on the proposed layout model the simulation design is generated using **Arena simulation.**<br>- The **simulation layout (3)** is **optimal condition** that increases the number of production drastically.<br>- Number of **Part In** is **819 parts**<br>- Number of **Part Out** is **273 parts**<br>- **Work in Progress (WIP)** is **510.74 parts** |

## 2. RECOMMENDATION

In view of the findings in this study, here are several recommendations that should be conducted to improve this research further**.**

a) To propose this layout can be applied to another industry that requires the remanufacturing system to be optimise that can help to reduce the uncertainties in the assembly line.

b) To propose the new idea by using the same attributes, applying to another analysis application (Design of Experiment method) to make a comparison between the result obtained.

c) For the future study, the quality of product need to be considered due to uncertainties in term of material is an important part in the remanufacturing system because it will affect processing time.

d) To perform this study with the full cooperation of remanufacturing company that can investigate the current situation based on the demand and requirement of remanufacturing industry.

## 5.3 SUSTAINABILITY

The main highlight of the remanufacturing system is to prevent the product from becoming waste and the end of life is on the landfill. Most companies focus on mass production and lack knowledge about the remanufacturing of their used or waste products. From this study, the investigation on the current problem remanufacturing system is mentioned. Thus, it will build up the sustainability esteem in the manufacturer and environment. Researchers can develop a new idea of substituting the raw material from waste and turning it into a product to support sustainability.

## 5.4 COMPLEXITY

The remanufacturing system environment is still fresh and most of the activities obtained in the system are still on the research and future will be standardized. Most of the remanufacturing systems follow manufacturing systems such as the assembly line, and the difference is on the disassembly phase. So the thrilling phase for this study, is to obtain the input or parameter from the literature study. Most of the research is in the surface phase and the data collection is still under the research phase.

## 5.5 ENGINEERING

The attributes for this research project are considered the newest idea in optimizing the control process in remanufacturing system that focuses on using the fundamental method, the Taguchi method analysis. The purpose of optimizing the assembly line will contribute to reducing the number of waiting times. Accidentally based on the optimal condition will contribute to the increasing number of products in the assembly line. This indirectly supports and promoted the remanufacturing industry as an important part nowadays.

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