CYCLE TIME IMPROVEMENT IN WIRING HARNESS ASSEMBLY PROCESS

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Engineering Management
Regional Centre for Manufacturing Systems Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2015

การปรับปรุงเวลารอบในการผลิตสำหรับกระบวนการประกอบสายไฟรถยนต์

นายณัฐวัฒน์ ฉันทนโพธิ์กุล

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาการจัดการทางวิศวกรรม ภาควิชาศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2558

Thesis Title	CYCLE TIME IMPROVEMENT IN WIRING HARNESS ASSEMBLY PROCESS
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Field of Study	Engineering Management
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ณัฐวัฒน์ ฉันทนโพธิ์กุล : การปรับปรุงเวลารอบในการผลิตสำหรับกระบวนการประกอบสายไฟรถยนต์ (CYCLE TIME IMPROVEMENT IN WIRING HARNESS ASSEMBLY PROCESS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: รศ. ดร. ณัฐชา ทวีแสงสกุลไทย, 182 หน้า.

ในอุตสาหกรรมการผลิตสายไฟรถยนต์ในปัจจุบันประสบปัญหาเรื่องอัตราผลิตภาพแรงงานที่ต่ำ ต้นทุนค่าแรงที่เพิ่มสูงขึ้น และ การขาดแคลนของแรงงาน ทำให้หลายบริษัทจำเป็นต้องหันมาใส่ใจในเรื่องของการลดต้นทุนในกระบวนการผลิตเพื่อที่จะลดปัญหาการสูญเสียกำไร ดังนั้นงานวิจัยจึงมีวัตถุประสงค์เพื่อหาวิธีการลดต้นทุนและเพิ่มผลผลิตให้กับโรงงานในอุตสาหกรรมรถยนต์ โดยใช้โรงงานประกอบสายไฟรถยนต์เป็นตัวอย่างในการวิจัย โดยในการวิเคราะหเบื่องต้นพบว่า โรงงานตัวอย่างมีกำลังผลิตสายไฟสำหรับรถยนต์ OEM อยู่ที่เฉลี่ย 55 ชิ้นต่อวัน หรือประมาณ 7 ชิ้นต่อชั่วโมง ในช่วงเวลาการทำงานปกติ (แปด ชั่วโมง) แต่ความต้องการของลูกค้าในปัจจุบันอยู่ที่ 70 ชิ้นต่อวันในช่วงเวลางานปกติ ในการวิเคราะห์ปัญหาได้ใช้เครื่องมือของ Lean และ Work study เพื่อที่จะค้นหากิจกรรมหรือกระบวนการที่ไม่ก่อให้เกิดคุณค่า หลังจากนั้นได้ทำการประเมินโดยใช้ Matrix Diagram เพื่อพิจารณาเลือกแนวทางที่มีความเป็นไปได้และเหมาะสมที่สุด ซึ่งหลังจากสรุปการวิจัยแล้วมีทั้งหมด สองแนวทางหลักในการแก้ปัญหา โดยในสองแนวทางหลักที่นำมาแก้ไขได้แก่การใช้รถเข็นในการเคลื่อนย้ายวัตถุ และ ไม้ลำเลียงชิ้นส่วนเพื่อช่วยเคลื่อนย้ายวัตถุขนาดเล็ก โดยที่ทั้งสองแนวทางได้ถูกเลือกเพื่อนำไปดำเนินการสำหรับการพัฒนาเวลาในการผลิต และได้สามารถลดเวลาการผลิตจากสูงสุดที่ 504 วินาทีต่อรอบ ลดลงเหลือสูงสุดที่ 405 วินาที ซึ่งได้ลดไป 19.6% และภายในช่วงสองเดือน (พฤษภาคม 2558 ถึง เดือน มิถุนายน 2558) หลังการปรับปรุงเวลาผลิตและประกอบสายไฟรถยนต์ ผลผลิตสามารถเพิ่มได้ขึ้นจากเดิมที่เฉลี่ย 1454 ชิ้นต่อเดือน เป็นเฉลี่ยที่ 1836 ชิ้นต่อเดือน หรือ 26.5% เพิ่มขึ้นจากเดิม โดยที่อัตราการผลิตต่อชั่วโมงเพิ่มขึ้นจากเดิมที่ 7 ชิ้นต่อชั่วโมงเป็นเฉลี่ย 8.83 ชิ้นต่อชั่วโมง ซึ่งทำให้ส่งผลต่อการผลิตต่อวันที่เพิ่มขึ้นจากเฉลี่ยที่ 55 ชิ้นต่อวันเป็น 70 ชิ้นต่อวัน ในเวลาการผลิตปกติที่แปดชั่วโมงงาน โดยที่กระบวนการพัฒนาทั้งหมดนี้ได้บรรลุเป้าหมายและทำให้บริษัทลดต้นทุนได้

ภาควิชา	ศูนย์ระดับภูมิภาคทางวิศวกรรมระบบการผลิต	ลายมือชื่อนิสิต ....
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สาขาวิชา	การจัดการทางวิศวกรรม	
ปีการศึกษา	2558	

5671224921 : MAJOR ENGINEERING MANAGEMENT
KEYWORDS: CYCLE TIME / WIRING HARNESS / SEVEN WASTE MANAGEMENT / WORK STUDY / ASSEMBLY PROCESS / LEAN TOOL / AUTOMOTIVE PARTS

NATTAWAT CHANTANAPOKUL: CYCLE TIME IMPROVEMENT IN WIRING HARNESS ASSEMBLY PROCESS. ADVISOR: ASSOC. PROF. NATCHA THAWESAENGSKULTHAI, Ph.D., 182 pp.

Nowadays Automotive Wiring harness industry has encountered problems of low production rate, higher labor cost and shortage of labors which has caused many companies to turn their interest on how to reduce the cost in order to sustain their profit margins. Therefore, this research study has been developed with the objective to study on improvement of wiring harness's production process. The current survey and observational analysis on the case study company shows that the production capability of wiring harness to OEM client have an average of 55 pieces per day or 7 pieces per hour during normal working-time, which accounts for a working period of eight hours. However, the demand of customers is at 70 pieces per day. This demonstrates a gap between the ability of the case study company to supply the required demand. The method of work study and lean tools will be used for analyzing the problems and general solutions. There are two main solutions that had been selected to be implemented, which are the use of Trolley for transferring parts and the use of Transferring board (Tofix board) for transferring smaller parts. In the pilot test that took place between May 2015 and June 2015, several interesting findings were determined, all pointing towards positive results. The results demonstrated that there was a significant reduction in the overall cycle time from 504 seconds per round to 405 seconds per round or 19.6% reduced. From two month experiment in May and June 2015, the output has increased from an average of 1,454 units per month to an average of 1,836 units per month whereas hour rate output has increased from 7 units per hour to 8.83 units per hour which give the daily production output to increase from 55 units to 70 units per day with in normal working time of eight hours. All of these implementation has no concern on other subjects except the methods and equipment added to the production process.

Department:	Regional Centre for Manufacturing Systems Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Engineering Management		
Academic Year:	2015		

ACKNOWLEDGEMENTS

Firstly, I would like to express my appreciation to my thesis advisor Professor Natcha Thawesaengskulthai who have guided and encouraged me throughout to achieve the requirements and objectives of the thesis with her valuable advisory. I must also extend my gratitude towards Professor Parames Chutima Ph.D., chairman of the thesis committee, and Assistant professor Oran Kittithreerapronchai, a member of the thesis committee, for their constructive suggestions.

I would also like to thank the company and their staff for providing information for the case study which was an essential part of my research study. Without their full support on all parts of implementation, the mission of the research would not have been successful.

Lastly, I would like to thank my family and friends for their support and encouraging me to thrive further in putting this thesis together.

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CHAPTER 1: INTRODUCTION

1.1 Background of Thesis

Automotive Industry is one of the main industries of Thailand which creates high value for the country. It accounts for 10% of the gross domestic products that are manufactured in Thailand and employs over 500,000 direct jobs of skill labor and above in 2012, not to mention related industries such as upstream industry, service industries such as financial, insurance and after sales, etc. In addition, Thailand is a leading area as a global automotive manufacturer, which ranks as the first amongst ASEAN countries. According to (B.O.I. 2015) the general structure for Thai automotive industry lies within 3 tiers. Firstly, the tier 1 are mainly foreign companies who have found their primary suppliers within the local market, however Tier 1 alone consists of nearly 709 auto-parts suppliers. The other local suppliers are tier 2 and 3 of the nationwide supply chain of automobile industries and accounts for nearly 1,700 companies. As stated by (B.O.I. 2015) "Of the top 100 auto parts manufacturers in the world, 50% have factories in Thailand. Thailand's production base is diverse enough to supply all necessary components, from tires to structural components". As further described by Thailand Automotive,(Institute 2012) that due to the complex nature of this supply chain, a lot of the primary processes in automobile manufacturing followed by the lower cost of production in ASEAN country, has resulted in Thailand being one of the main hubs for big brands such as Honda, Toyota, Mercedes Benz, Nissan, Isuzu, Hino Motors and General Motors. Many of the suppliers are small to medium sized companies that are struggling to meet the requirements of international giants, who expect nothing but beyond standard performance and delivery time. With Thailand increasing as a hub in the assembling of several major automotive brands, it is crucial that the industry players, both small and big, take a close consideration to the overall impact of their performance in this competitive industry. It is only based on these conclusive aspects, that the industry can be brought on an international scale and to be competitive in the international arena. Therefore, future challenges must be taken into careful consideration in formulating the strategies for every companies especially SME's that are playing a vital role in the industry. The growth of the company should be sustainable and well-planned. Therefore, cost reduction, quality control, increasing productivity are the primary concerns for the company in order to make company be able to sustain in the growing competitive markets.

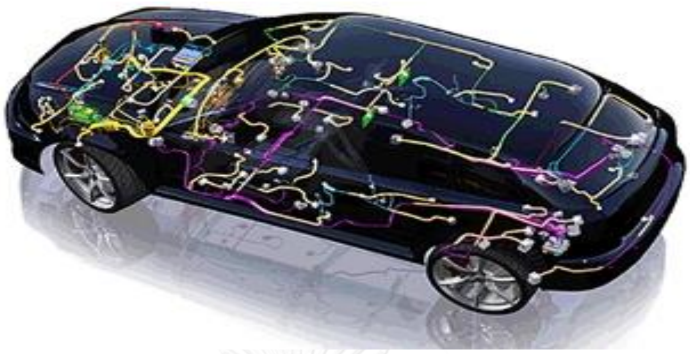

Figure 1: Wiring harness contain inside passenger vehicle

Figure 2: Main wiring harness in vehicles

The particular manufacturing focus of this thesis is on the production of automotive wiring harnesses. According to Sumitomo,(Electric 2012) “an automotive wiring harness is an assembly of electrical wires, connectors and other parts, or an electrical wiring system, used to convey information and energy in automobiles”. The role of these wirings are to ensure that one segment of the automobile’s electronic component is connected with other areas in order to fulfill its function as movement of energy and information. These wiring harnesses are created by various wires connected together in a board, which functions as to provide power, to signal a function, or even to transmit information. Automotive Wiring harness are a high-value product that serve in most parts of the vehicles. These products are necessary in both OEM and Aftermarket. The case study company sells for the OEM market at an average of 12 million baht per month during the year 2013-2014, and plans to increase its sales to 200 million baht within 2019 with an average of 10% increase per year. As shown in Figure 3 and Figure 4. The case study company wants to improve its capability of production in order to handle future trends of OEM market. Therefore, they are seeking for support of real information so that company can execute improvement plan appropriate to the current situation.

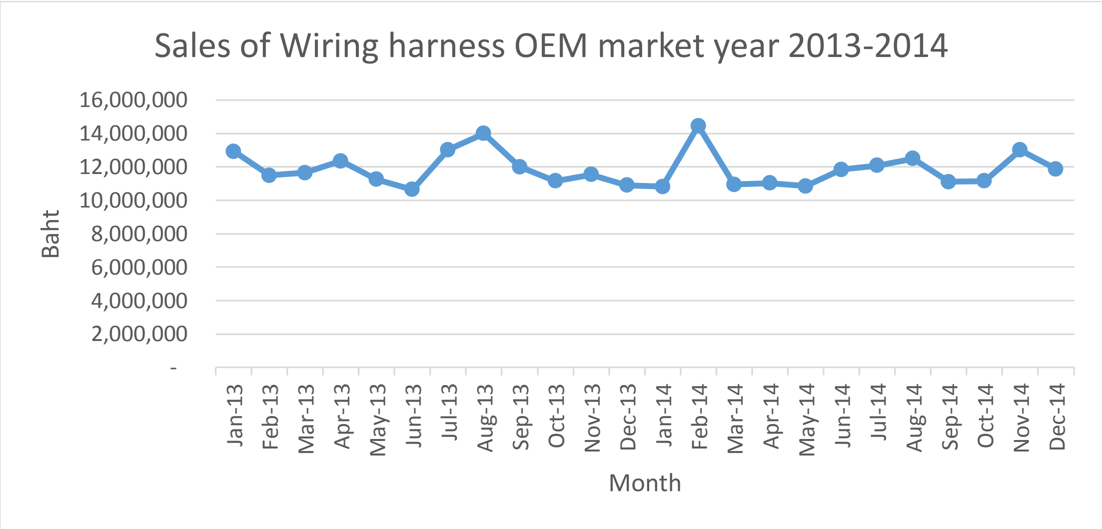

Figure 3: Sales of Wiring harness OEM market year 2013-2014

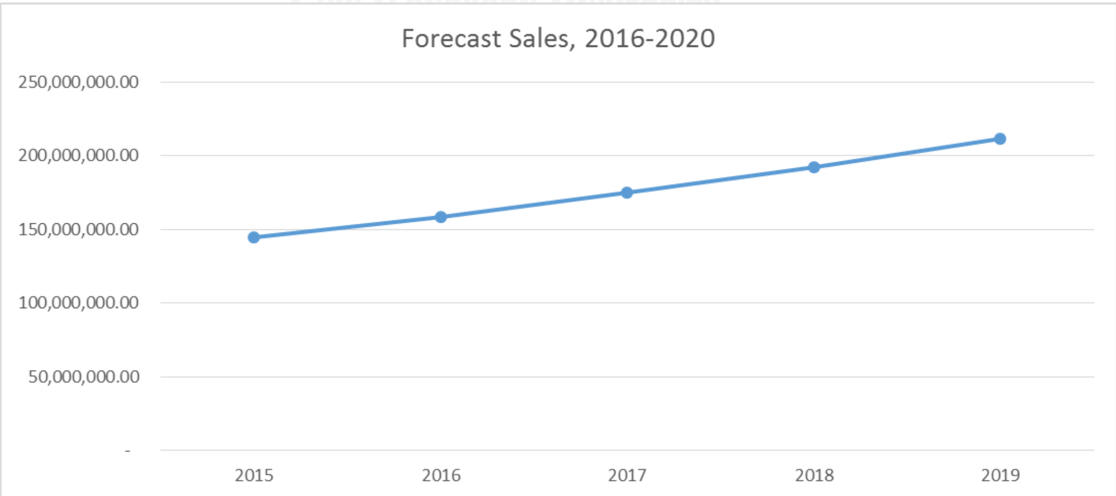

Figure 4: Forecast sales of Wiring harness OEM market year 2015-2019

1.2 Statement of Problem

There are two policies from Case Study Company and customers of the company. The main policy is to reduce manufacturing costs in order to make more sales and also be able to have more competitive advantage throughout the competitive markets, as shown in Table 1 and Table 2.

Table 1: Company policy in 2015

Company Policy
Policy: Increase Sales
1 Increase Sales by gaining new customers throughout new channels
2 Increase Sales by having more competitive price and reducing cost of manufacturing goods.
3 Increase Sales by enhancing quality and delivering customers delight

Table 2: Customer policy to supplier in 2015

Customer policy
Policy: Increase Capability
Increase Capability of daily output to at least 70 pcs per day

Based on the Company policy and Customer Policy, the part that the research and the team can control are on the elements of increasing sales by reducing cost of manufacturing goods and increasing the output by at least 25%. The remaining other goals are the responsibility of the other departments. The structure of the costs in 2015, is shown in Figure 5. It demonstrates the allocation of the costs for creating wiring harness. The main costs of wiring harness are from raw materials which accounts for 50%, whereas the labor costs accounts for 25%.

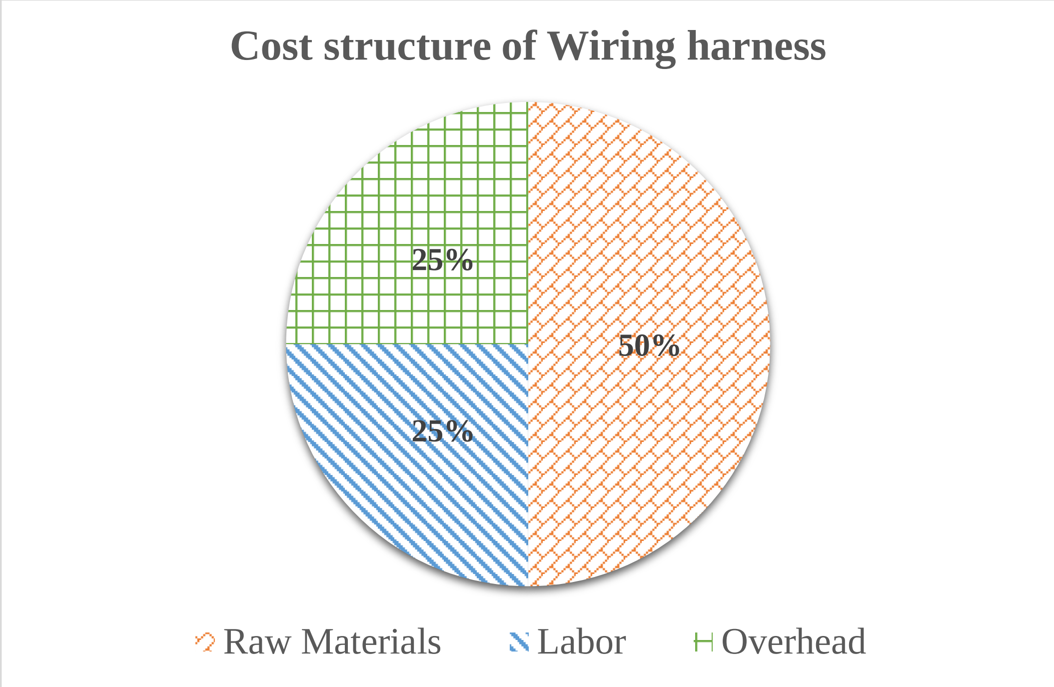

Figure 5: Cost Structure of Wiring harness

In terms of raw materials costs, the company have been suggested by customers in order to select the supplier for raw materials due to most of the raw materials are considered confidential and there are agreements between customers and supplier on using certain raw materials. Therefore, in the context of this case, the company cannot reduce the cost on the raw materials itself but can reduce the costs by managing the supply chain. Supply chain is viewed in from different perspectives and different ideologies depending on the area of focus. According to NC State University, Handfield (2011) states "The concept of Supply Chain Management is based on two core ideas". First is in relation to how the product reaches the end user or the consumer. It is an integrative effort from which a raw material is processed to final goods and then delivered to the consumer. This process is often seen as the heart and soul of the organization from some perspectives and a very vital one. The second idea is the idea of management. Supply chain management tends to ensure that the products that are delivered to the consumers are of the value that is and was initially established by the objectives, mission and vision of the organization. Therefore, being able to not only increase and improve consumer satisfaction but also to improve competitiveness.

The research will be focusing on labor costs and overhead costs which have been increasing sharply since year 2013. The government have been increasing minimum wages to 300 baht/hour. The company used to pay wages at an average 150 baht per day, which mean the costs of labor have increased 100% since the year 2013. This event have significantly affected the company, especially for overtime costs that company has to pay 1.5 times more from original cost. However, this mandatory gain in wage has not been able to replenish the productivity improvements that were required as the workers see this mandatory wage increase as the wage they deserve for the work they are performing. In general however, wages have a huge impact on the way people work. Increase in salary or in wage can increase the individual's motivation to work and get more involved with the company. Money sometimes may have this kind of impact on workers, however in some cases the amount of money is irrelevant when it comes to motivating workers to work harder (Osterman 2005). Shread also believes that motivation of workers comes from building strong relationship between the employer and the employees. With having a strong relationship with one another, the worker/employee feels more involved with the company and the work itself.

Regarding this occurrence, the company need to adapt and plan for improving its productivity on the production line in order to compensate the amount of money that is paid on wages to get the best out of the productivity each day and improve efficiency.

This research will focus on the Wiring harness manufacturing process, which, for the most processes, relies on labor intensive work. The bottle neck of the process are mainly from feeding components in to the assembly line which causes the overall process to slowdown. In conclusion, the company is currently uses inappropriate working method in the process which results in the effective usage of labors and inefficiency in the production line. This is limiting the company from achieving the highest productivity in the production process.

1.3 Objective of Thesis

The objective of this research is to increase the production output of Wiring Harness production by using Lean tools and work-study concept to analyse and improve the current process.

1.4 Scope of Study

This research focuses on the cycle time improvement for car wiring harness assembly's process where the elements that research will be controlling to remain the same, that are, Man, Machine (not included tools and equipment) and Material whereas method will be the variable element that can be changed. The Lean tools will included ECRS and Seven Waste management.

1.5 Research Methodology

Concept of Lean management will be applied in this research due to it being a well-known concept with clear steps and systematic methods that help to track the problems with precise data analysis in order to execute the implementation from research. As for DMAIC from Lean will be approach as a concept framework along with other tools that will be applied in each section of methodology. DMAIC process will aid identifying the causes and effects and prevent the problem.

Table 3: Methodology of research

Steps	Detail process description	Tools and Method
1. Define	-Define the scope and boundaries of the project -Define the current situation problem -Define team charter to identify process definition, critical –to-quality parameters, benefit impact, key milestone activities with dates, support required and core team member as well as estimate the impact of the project in monetary term.	-Process flow chart -Current State Analysis -Interview and Survey

Steps	Detail process description	Tools and Method
2. Measure	-Map process and identify the process inputs and outputs -Establish baseline process capability and measure system capability -Conduct cause and effect analysis -Establish the data collection plan	-Value Stream Mapping -Cause and effect Diagram -TAKT Time & Cycle Time Analysis
3. Analyse	-Gather data and identify possible sources of variation that causes problem -Perform cause and effect analysis to identify parameters that most significantly affect the process. -Analysing Work study of the process	-New 7 management tool - Process activity chart -Work study
4. Improve	-Perform Tree diagram and Matrix diagram for selecting the alternative solution. -Compare and contrast Process activity chart.	-New 7 management tool -Prototype building -Implementation plan -TAKT Time & Cycle Time Analysis
5. Control	-Plot control charts to establish new process capability -Develop a control plan to sustain improved quality.	-Tracking/Checklist -5S organization -Work instruction

1.6 Expected Results

1. Improve outputs in wiring harness production process
2. Reduce cycle time of the bottle neck process.
3. Innovates solution for increasing productivity for wiring harness assembler.

1.7 Expected Benefits

1. The company can implement the improvement plan on reducing costs and increase productivity.
2. The company can gain competitive advantage
3. The company will have more knowledge on analyzing information and create solutions for solving problems in the long-term.

CHAPTER 2: LITERATURE REVIEW

This chapter reviews the theories and concepts associated and relevant to the present study. The first part of literature review will examine productivity improvement theory and Work study that are used in problem analysis. Then the second part will review the theory of Lean on creating alternatives for solutions. The last part will review on work instruction and discuss about the results and analysis from solutions proposed in the research.

2.1 Introduction

Giese and Cote (2002) was able to provide a context-specific definition for customer satisfaction. They were able to conclude that the customer satisfaction definition is subjected to several different aspects. The broad definition that they were able to provide stated that customer satisfaction is “a summary affective response of varying intensity…time-specific point of determination and limited duration…focal aspects of product acquisition and/or consumption… (Giese 2002)” (pp. 2) that results in the ability of the consumer to approve, disapprove or moderate their feelings towards the company and the product. (Oliver 1997) suggested that consumer/customer satisfaction is a response to a process of assessment on the acceptability of the product. Others have provided a rather emotional-level of definition, which suggested that customer satisfaction is directly proportion to how the consumer using the product feels about the product after and before using which can extend their feeling towards the company producing that particular product (Westbrook 1983). The reason why customer satisfaction provides a very good justification in the literature review in this topic is because the ultimate changes that would be done in the case study company is to achieve maximum customer satisfaction and avoid them from changing their loyalty.

Several academic authors have explained about productivity improvement methods and frameworks that may adjusted based on the requirements and the process associated with a particular study. The literature review section will discuss the productivity definition followed by the understanding on the work study. Activities that add no-value or non-value activities are to be identified/located in this study by the use of the concept called process activity mapping, along with the use of seven waste observation by lean theory. The alternatives suggested by the team members will be conducted by lean tools guideline. This will be followed by work instruction in order to enhance the process and make use for the long term for the case study company.

2.2 Definition of Productivity

Sakamoto (2010) suggested that in order to enhance the expectation for everyday comforts by lessening working time and raising wages, organizations will acknowledge the increment in wages if efficiency gets higher. The expanding efficiency will comes about on expanding of representative's standard, work fulfillment, enhance upper hand, offering lower costs to shoppers and enhancing the adequacy of capital speculations for the organizations. Productivity and efficiency are categorized as two very similar phenomenon and very significant to all sectors associated with manufacturing a required quantity of products in order to keep the demand satisfied Haskel,(J 2007). Haskel,(J 2007) further suggested that innovation does not have to be technological advancement in all cases, in fact some of the innovation can be as little as changing the manufacturing arrangements in the organization, in order to reduce time. As stated by (Gruen 2012) structural changes in the manufacturing line can enhance productivity of an organization. It is believed by these two researches that by implemented a design management or even the catering the need for the remove of waste processes can be seen as an innovative advancement for the organization, as the result of these innovative changes are often improvement in productivity and efficiency. There are numerous approaches to enhance efficiency, for case expanding generation utilizing same or rather similar assets or decreasing the assets while keeping up the creation rate (Gaither, 1980). (Rijravanich 2000) suggested that profitability is gotten from yield isolated by info, or the amount of items delivered partitioned by the assets utilized. Profitability is utilized to quantify the yield that happens from a given data. What's more, it is anything but difficult to quantify if the yield and information can be set up.

$$\text{Productivity} = \frac{\text{Output}}{\text{In put}}$$

(Kanawaty 1992) suggested that there are 5 elements in which the inputs can be classified and this is represented in the figure below.

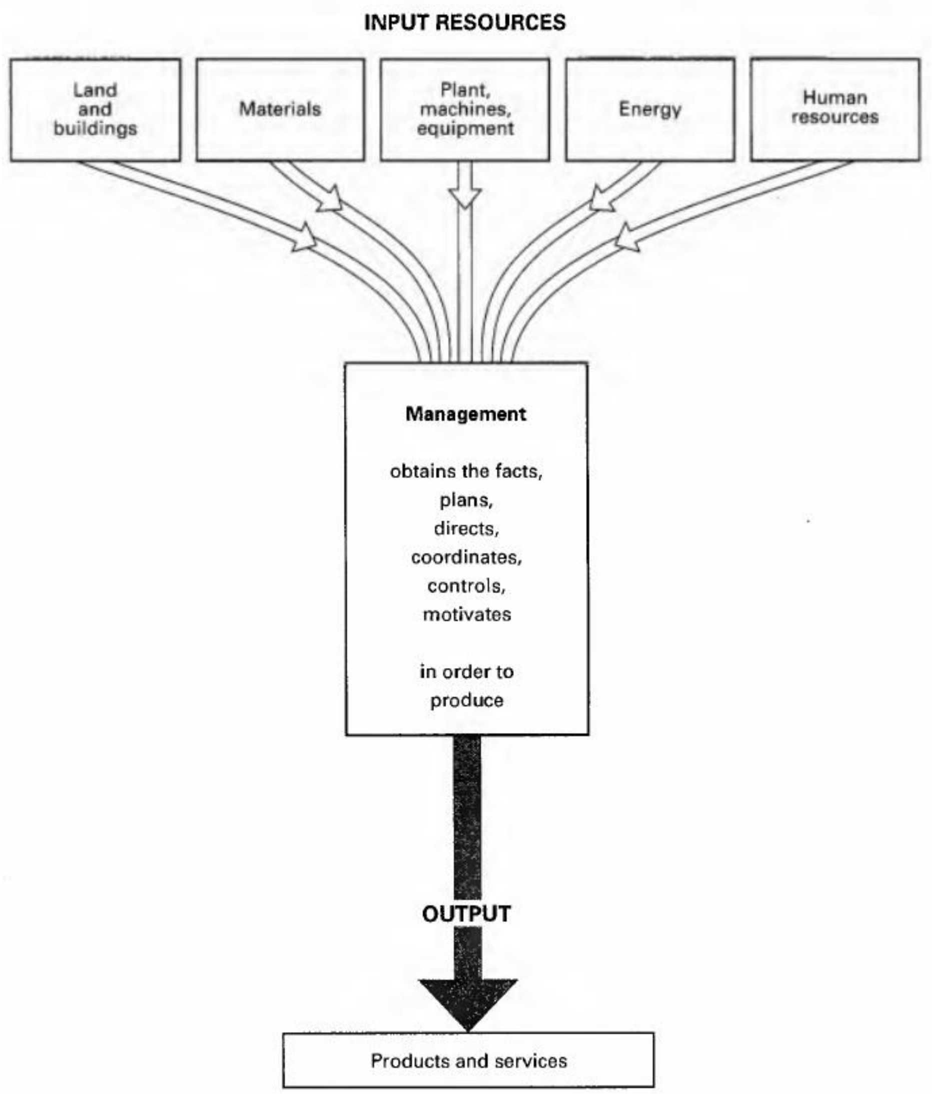

Figure 6: Inputs resources and output products and services

[Source: Kanawaty 1992]

Figure 8 illustrates the output and input factors in an enterprise, and it demonstrates 5 vital input resources, which are:

- Land and buildings which refer to location that are convenient and appropriate to the size of the company
- Materials refers to those that converted in to the products or services to be sold.
- Energy concerns on the usage of energy whether it is effective and efficient or not.
- Machinery and equipment includes whether the machines is fit for the process or not and if the machine is being used at its optimum capacity with highest efficiency.
- Human resources refers to the usage of labor that may not add value to the output which might cause from the working environment, inappropriate work movement or a bottle neck with in the process.

(Farell 1957) states “when one talks about the efficiency of a firm one usual means its success in producing a large as possible an output from a given set of inputs. Provided that all inputs and outputs were correctly measured, this usage would probably be generally accepted”. He stated that therefore, efficiency and productivity is a measurement based on the relative output based on the relevant input and the ultimate time that is consumed in the process of doing so.

2.3 Sample size

According to (Sigma 2008) expressed that to demonstrate that a procedure has been enhanced, you must gauge the procedure capacity previously, and then after the fact upgrades are executed. In the event that information is not promptly accessible for the procedure, the measurement or method might be inaccurate and lead to wrong information. Therefore, determining the size of the sample is an imperative issue in light of the fact that specimens that are too huge may waste time, assets and cash, while samples that are too little may prompt off base results, that is, they may be inaccurate or indecisive. As a rule, we can without much of a stretch decide the base example size expected to appraise a procedure parameter, for example, the populace mean μ.

$\bar{x}$ is calculated when the sample data is fully collected. This is very different from the population mean classified by μ. The existing disparity that is between the mean of the population and the mean of the sample is what we see and defines as the level of error. The margin of error E, or the margin of error is considered to the ultimate difference that exist between the population mean μ and the mean of the sample that is being observed $\bar{x}$.

$$\mathrm{E} = z_{\alpha/2} \cdot \frac{\sigma}{\sqrt{n}}$$

Where:

$z_{\alpha/2}$ is the critical value that is derived from the positive z over the boundary with the area of $\alpha/2$.

σ Standard deviation in the population

n size of the sample

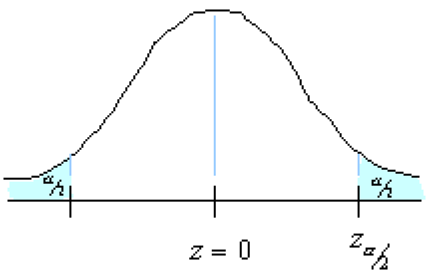

Figure 7: Normal Z distribution

Revamping this equation, we can explain for the example size important to deliver results exact to a predefined certainty and room for give and take.

$$n = \left[\frac{z_{\alpha/2}\sigma}{\mathrm{E}}\right]^2$$

Once you are aware of σ then this formula can be utilized when you are in need to know what the required sample size is and to establish that there is a confidence of $1-\alpha$ of $\pm E$ and the mean value μ. In other circumstance this formula can be still used when the standard deviation of the population is still unware, and the mean of the population is low.

2.4 Lean

The demonstration of Lean has established in 1988, which was noted in the "Triumph of the Lean Production System" article yet it is not prominent. The book called "The Machine that Change the World" and "Lean Thinking" made the wide use of Lean. The beginning stage of Lean was in sixteenth century when the ceaseless stream process and institutionalized term were created by the Venetian Arsenal. Therefore, the entire boat was created in under 60 minutes. After that, amid the Napoleonic Wars, that resulted in the change in system and institutionalized procedure methods has led to the quick convey broadside to against the contenders. In the nineteenth century, the Pareto guideline was built up. It was found that 20% of individuals possesses 80% of the area in Italy. Henry Ford and others organizations utilized the persistent stream for their plant from the idea of Lean. Meanwhile, the idea of takt time has introduced by the German flying machine. The creation of fuselage was control by this idea which implies the generation of every procedure must not more than takt time. In the mid-1940s, Taiichi Ohno united these ideas so as to adjust for generation of Toyota, called Toyota Production System (TPS) which was created to be Lean later.

It is important as stated by (Flynn 1995) that many organizations aim for lean, however the significance of JIT (Just in time) and TQM (Total Quality Management) are also equally important. It is vital to ensure that the products although in a lean manufacturing section is able to meet the highest quality requirements. This was further elaborated by (Krafcik 1998) who suggested that the lean production system, as mentioned earlier, has been a great success in the industry of automobiles and even various other industries. In addition, there seem to be a close relationship with JIT system and Lean system, as both involves meeting the spot on demand of the consumers.

In light of clients' prerequisite and needs is when the idea of LEAN was introduced as means to improve the organization and its ability to spot-on meet the needs of the clients. Everything that’s not increase the value of the client is resolved as waste so the objective of Lean is waste end to convey the greatest worth to the clients He expressed that the foundation of Lean idea is TPS which is concentrating on waste end. Additionally, the capacity to convey the required yield is likewise engaged in TPS idea on the grounds that if the squanders are dispensed with and right values are conveyed, it could promise that the assets are used and generation is smooth and adaptable. The top of Toyota Production System house in Figure 10 indicates both interior and outer qualities, which are quality, fetched, conveyance, wellbeing, and spirit, are given to the clients. In the nick of time and Jidoka idea bolster the quality in the rooftop (Eaton 2013) The idea of Just-In-Time is about creating the required amount of item when it is required while 23 Jidoka idea concentrates on the generation and item quality. Another four stages make the solid house as demonstrated below:

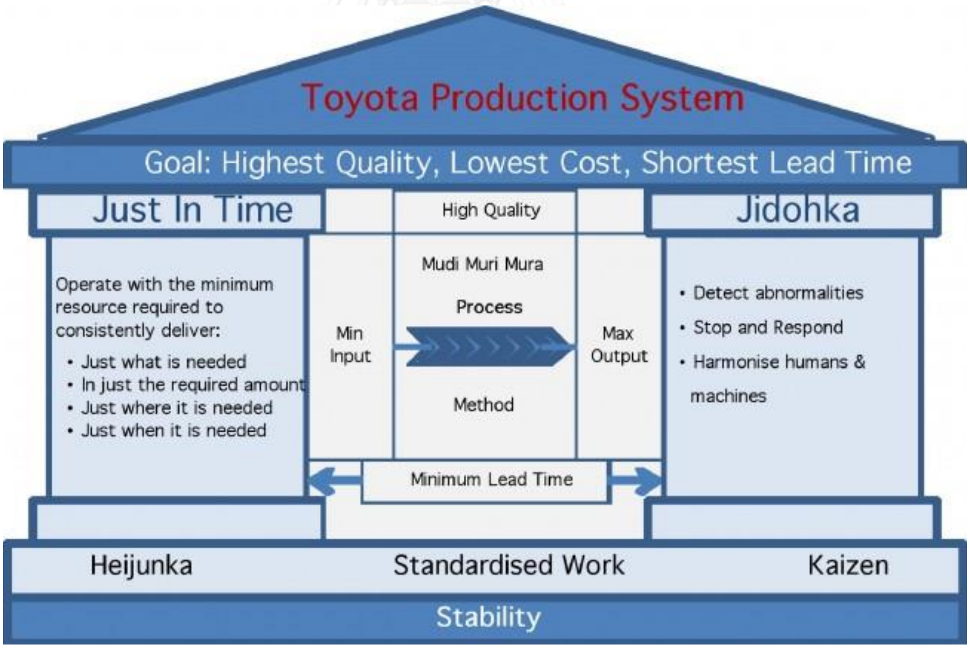

Figure 8: The Toyota production system (TPS) House

[Source: Eaton, 2013]

The TPS as suggested by (Liker 2006) can be subjected to four different areas and with over 14 principles. The 14 principles and 4 areas are demonstrated in the following section below, ranging from the philosophy, process, people and partner and problem solving. In terms of philosophy, it is the ultimate foundation and it involves the first element that is the decisions that should be made immediately in order to achieve long-term sustainability and strategy.

The process is the second area, and it involves 8 elements. The first element is all about creating the right flow of movement of goods between people and the processes and to achieve maximum efficiency. Second element is the Kanban system alongside with the pull system that is used to help the organization from achieving overproduction, and therefore, excessive waste. The third element is to use Heijinka that is to make the workload stable. Fourth element is the make sure that the production is within the required quality, as with good quality several problems can be avoided. Fifth element is regarding making sure the tasks are standardized and that they have processes that are considered to be best practices that allows the constant and rapid improvement of both the processes and the employees knowledge – a good example as mentioned before is via the use of learning organization. A concept that be applied in this scenario as well. The sixth element is the visualization of the problems, and controlling it. Seventh element is the use of the right technology to improve workplace efficiency.

The third area is people and partner. This is the area that is associated with the improvement of the people and the various stakeholders that can help in adding value to the product/service and the entire organization. This involves 3 elements. The first element is on the leaders and this would involve the use of working processes that helps in transferring and teaching people within the organisation. The 2nd element is regarding the establishment of a team that is able to work harmonically with one another and uplift the organizational goals and objectives. The third element is aiding the partners, especially the suppliers in achieving maximum efficiency and collaboration.

The forth area is problem solving. This is a vital area in the TPS as it involves not only solving surface problems, but to identify the root problems and solving it. This involves 3 elements as well. First element is about trying to under the problem and then to consider the problem from the first-person perspective. Second element is about making the decisions while considering the consequences and benefits of each alternatives that are provided. Finally, the last element is to focus the organization to not stop at solving one problem, but also to continuously improve the solution to achieve maximum efficiency (Christopher 2011)

There are five standard of Lean from the mix of fourteen guideline of TPS and the seven squanders created by Eaton (2013), Figure 11. Toward the starting, it is important to characterize the client's qualities on the grounds that Lean is to dispense with squanders or nonvalue included movement so this standard assists the association with understanding what ought to be killed. At the point when the quality is resolved, it should be conveyed into the procedure by utilizing worth stream. Building up the stream without bottlenecks, defers, holding up and revamp is the following step. In addition, the force framework ought to be embraced. The generation will begin when there is the interest from client. The last rule is the flawlessness, which implies the procedure should be enhanced constantly, similar to how an organization needs to learn continuously. As stated by (Tran T. T. and Wongsurawat 2011) and (Limpibunterng 2009) that an organization that is capable of learning, is likely to have its supply chain processes improved continuously, and indefinitely, as it factors in new forces and new factors for better outcomes

Figure 9: The five Principle of Lean

[Source: Eaton, 2013]

2.5 Seven Waste Management

It is believed by several authors that the more optimization of the process is achieved, the more value-adding can be done in the organization and the finished product for the customers (Bowersox 1993, John 2008)

Non-value adding (NVA) – They are general aspect of activities that should be eliminated first as it is considered as an unnecessary action, and they are seen as pure wastes.

Necessary but non-value adding (NNVA) – These are activities that are necessary for the process but does not add value to the finished products for the customers. Therefore, when changing this, it is important that they take careful consideration as these changes ca neb very big and can affect the operational layout and etc.

Value-adding (VA) – “As the company has to produce value-adding product or service to the customer, the activity in this type is necessary for the product or service” provided.

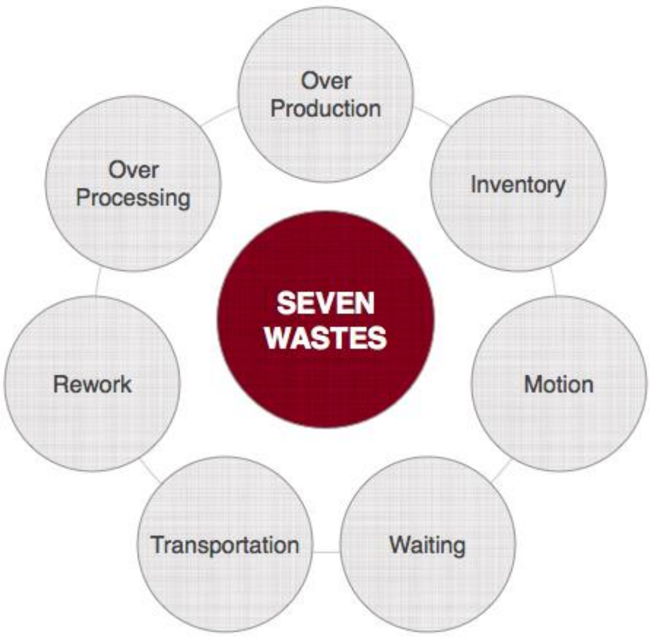

Figure 10: Seven Wastes
(Adapted from Warwick Manufacturing (Group 2014))

In Figure 12 illustrated seven types of wastes that help define where waste can occurs and support guidance for generating alternatives for improvement (Cheewapanyaroj 2001); Productivity Press Development Team 2006.

1. Over-production

This waste is the creation of a greater number of items than requested, or delivering them and keeping them for quite a while. Generally, makers have attempted to deliver however much as could be expected in every procedure without considering WlP, which is waste.

Issues of over-creation include:

- Loss of work and asset in delivering past interest.
- Loss of space for capacity of WIP — a few organizations lease or purchase storage room for WIP
- Transportation misfortune
- Cost of capital
- Production issues, for example, stoppage time and diminishments in apparatus proficiency, which are disguised in light of the fact that there is a ton of extra item or WlP,

Options for development include:

- Carry out deterrent support of apparatus to enhance creation, and urge representatives to utilize the aggregate profitable upkeep idea and fix the issues without anyone else's input.
- Decrease machine setting up time by work study
- Upgrade a bottleneck procedure to diminish process duration.
- Encourage workers to become multi-gifted.

2. Stock waste

This waste occur from purchasing a considerable measure of crude materials and supplies to guarantee that there is sufficient for generation constantly.

Issues of remaining stock composed of:

- Stocks consumes up room, which influences rental or purchasing expenses for the space.
- Expense of capital
- Stock may break down
- Resources are utilized to deal with the stock.

Options for development include:

- Define the perfect stock level and re-request point. Control the amount utilizing visual control to make it straightforward and watch.
- Use the first-in-first-out idea.
- Use the force idea to oversee stock.
- Reduce change after some time or the sin

3. Transportation waste

Transportation does not increase the value of the item so this action is waste Time and exertion are spent in moving items around the processing plant as an aftereffect of poor design (Amitabh S. Raturi 2005)

Issues of transportation can be identified as below:

- Cost
- Lost generation time
- Accidents amid transportation

Choices for development include:

- Changing the format of the creation line
- Reducing copy transportation
- Using proper hardware for transportation

4. Movement waste / Motion waste

Movement waste results from unseemly movement, for example, twisting the body to pick an item, which will prompt administrator exhaustion.

Issues of movement contain:

- The separation moved reasons lost generation time
- Fatigue and push
- Accidents
- Wasted time and assets

Ways to improve this involves the following:

- Options for Motion study and using ergonomic techniques
- By having working conditions that suit the workers and the environment
- To utilize technology and other aspects that help with the work load.
- Providing fitness activities to keep the workers on full fit and capabilities.

5. Wrong process waste

This waste includes work which enhances the item or does not enhance item precision and quality, for example, the review process.

Issues of unseemly waste can be explained as below:

- Unnecessary generation costs
- Loss of space where unseemly work is did
- Using apparatus and work without increasing the value of the item

Choices for development include:

- Analyzing the generation procedure utilizing an Operational Process Chart
- Using less asset serious different options for accomplish the same result. For example, computerization.

6. Postponement waste / Delay waste

Postponement waste is time lost when a machine or administrator needs to quit attempting to sit tight for something, for example, sitting tight for crude materials, holding up because of hardware breakdowns, or sitting tight for single moment downtime.

Issue of postponement waste is considered as following:

- Unnecessary expenses
- Lost open doors
- Problems with worker spirit.

Choices for development include:

- Good organizational planning that are appropriate

- Making sure that the equipment and other utilities are in tip-top conditions.
- Ensuring the works and task tasks are well balanced.
- The utilization of SMED
- Planning and apportioning proper assets to venturing up creation

7. Imperfection waste / Defect waste

Imperfections or defect occurs when things are not doing work effectively at the first time which can effect time and cost.

Issues of imperfection waste contains:

- Increased crude material and work costs
- Loss of space to store flawed items
- Duplication of work to repair an imperfection when a large portion of the generation line is not accessible
- Lost chance to offer the item to the client
- Cost of taking out the deformity

Choices for development include:

- Setting principles for crude materials to control their utilization
- Requiring administrators to allude to work directions to guarantee that they utilize the right strategies
- Using mistake-proof procedure to decrease botches
- Training administrators to have a feeling of value through an energy about a quality culture and educating them of the downsides and organization misfortunes from imperfections
- Ensuring an arrangement of brisk reactions to quality issues with a specific end goal to avoid them raising on the creation line.

Having distinguished waste all the while, incline apparatuses assume an essential role in ensuring that the production line improvements can be made.

2.6 Value Stream mapping (VSM)

According to (M.I.T. 2012) ,slide 4" value is defined by customer in terms of specific products and services…whereas a value stream is the map out all end-to-end linked actions, processes and functions necessary for transforming inputs to outputs to identify and eliminate waste". Therefore, value steaming is all about making the right flow, which involves the removal of waste and addition of value steps. If the step does not add value but is crucial to the production, then it should stay within the flow, however if the step is simply a waste of time, then it should be removed and possible replaced by a value adding step. Although, value adding is important, it is also important to understand that some of the product standards does not require additional value based on the price and quality standards (Kortum&Eaton 1999). In addition, VSM or Value Stream Mapping is also seen to be a very crucial tool that can enhance the productivity of a manufacturing line and division. VSM is one of the incline apparatuses that used to imagine material and data move through the creation process. Material stream is engaged in the normal creation yet the incline assembling centers both material and data stream similarly in light of the fact that the data stream offers administrators some assistance with knowing what part/item if they make including amount and next errands/forms (Rother 1999). Additionally, the reasons of VSM advancement are to build up stream, take out waste, and including quality. (Singh 2009) stressed that the more squanders generation has, the more assets are expended without including quality for the client. The squanders are found in the creation as well as could be found in each exercises including approaches and techniques. The entire procedures are attracted a bit of paper so as to picture the creation stream in every stride. It contains all fundamental information, for example, process duration, work in procedure (WIP), quality, and execution of gear. The lessening of lead time, stock, quality enhancing and on-time conveyances, and asset use are the result of utilizing VSM. (Goriwondo 2012). They brought up that there are five fundamental strides of VSM to enhance the creation line gets to be incline as takes after.

1. Characterizing the Value – The client's qualities must be distinguished in this stride.

2. Recognizing the Value Stream – All worth included and non-quality included activities are distinguished in this stride. Besides, it demonstrates the orderly operation with the subtle elements of every procedure. The present state guide will demonstrates the present data and material stream all through the assembling procedure. It will help the producer retrieve the view and comprehend the need of progress. Figure 11 inspects the present state map.
3. Stream the Product – The objective of VSM is the stream so the non-esteemed exercises must be wiped out or minimized while esteem exercises must be expanded.
4. Pull – The item should be pulled by client's requests on the grounds that it is the idea of produce the right item to serve to the client as fast as could be expected under the circumstances.
5. Take a stab at Perfection – The initial four stages must be checked on in light of the fact that the generation will have capacity to deliver the item that client need with the proper expense. In addition, the interior economy could be spared in light of the diminishment of mix-up, scrap, and general cost in production.

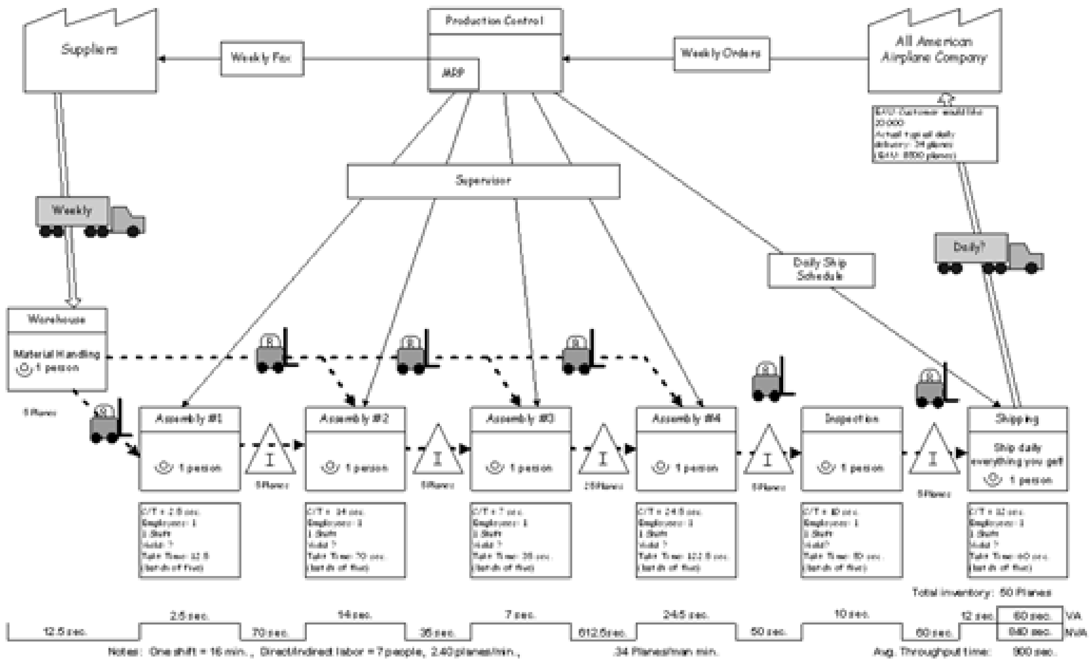

Figure 11: Example of Value Stream mapping (VSM)

[Source: John et al., 2008]

Referring to VSM, takt time is the key stride of creating future state map. The count bases on the client's necessity so accessible work time per movement will be isolated by client interest rate per shift. This number is the pace of generation for occurrence, the creation line is worked 8 hours for each movement and client demands 80 engines a day so takt time is 12 moment/engine. This implies every engine ought to be delivered 12 minutes keeping in mind the end goal to have capacity to serve the interest.

2.7 Line Balancing

The line in production in sequential construction system that is executed by the Lean standard since the reason for Lean is to take out squandered and non-worth included exercises from the line of production. In spite of the fact that squanders are decreased, the process duration and workload of every workstation that is not appropriate or not within the needs, then it can be viewed as a waste or even as an obstacle to the efficiency production of the product. Case in point, there will be the high sit out of gear time if the process duration of joined procedure is huge distinction. (Kumar 2009) specified that line adjusting strategy adjusts all workstations in the creation keeping in mind the end goal to expand the stream. Consequently, the adjusted workload prompts unmoving time lessening. The generation line comprises of numerous workstations to create a measure of item and every workstation contains numerous assignments to complete the procedure. There are various strides for computation and usage line adjusting as takes after.

1. The generation succession of every item is diverse so it is important to indicate the relationship of procedure using so as to group priority outline.

2. Workstation process duration or takt time must be ascertained by isolating general generation time out from required yield. To do line adjusting, the process duration of all workstation must be lower than this number in light of the fact that it can be ensured that the organization has capacity to deliver item to take care of client demand.

3. The base number of workstations is ascertained by isolating the aggregate errand time with takt time. Be that as it may, practically speaking, the quantity of workstations may be higher than this number relies on upon situation, for example, approach, design, and number of capable administrators.

4. Select an essential standard by which undertakings are to be allocated to workstations, and an auxiliary guideline to break ties.

5. The undertakings will be doled out to every workstation. At the point when the aggregate errand time at first workstation comes to takt time and no doable undertakings can be allocated, the assignments will be relegated to the following workstations. This stride will be rehash until all undertakings are doled out.

6. The parity proficiency can be figured by partitioning aggregate tsk time with genuine number of workstations duplicate by takt time.

Kumar and Suresh (2009) prescribed that numerous alternatives should be figured and dissected keeping in mind the end goal to contrast the equalization productivity with locate the suitable line adjusting for the creation line. In any case, re-format should be considered in the event that it could build the productivity and parity of the creation line.

2.8 Work Study

According from (Kanawaty 1992, Rijravanich 2012), there are composing of eight stages in a work study, from selecting the employment or procedure to be concentrated on to keeping up the new standard.

Eight stages of work study consists of:

Stage 1: Pick the procedure or occupation

Stage 2: Record the work technique

Stage 3: Examine the work strategy

Stage 4: Enhance the work technique

Stage 5: Measure the work

Stage 6: Devise the new working standard

Stage 7: Support utilization of the new working standard

Stage 8: Follow up the new working technique.

2.8.1. Picking the procedure or occupation to concentrate on

In this stage, three components help in the decision of procedure to concentrate: Firstly, financial contemplations, for example, a bottleneck process: furthermore, specialized contemplations, for example, handling a procedure without specialized issues to begin with, so as not to set aside quite a while in examining the dangers and impacts of specialized changes; and thirdly, thought of work responses in light of the fact that the accomplishment of a work study depends for the most part on 'about so its impact on the work power ought to be considered as staff might not respond decidedly to change, invalidating any advantages.

2.8.2 Recording the work system

Before dissecting and enhancing the procedure or work technique, the information must be recorded. For good investigation and change, the information ought to be right and precise; in this manner, record the work technique is a critical stage. The work technique can be spoken to with five images, as appeared in Figure 12.

Symbol	Description
	Operation
	Transportation
	Inspection
	Delay/Waiting
	Storage

Figure 12: Description and symbol of recording work method (Rijravanich 2012)

An activity chart can be used to record the work method, showing the timescale, transportation distance and description of each activity, as shown in Figure 13.

Process Activity Chart							
No.	Sheet no. Of		Summary				
Subject Charted:	Packing		Activity	Present	Propose	Saving	
Activity:							
	Packing						
Method	Present	Proposed	Distance				
Location			Time				
			Charted by		Date		
			Approved by		Date		
	Factory						
Description			Time (sec)	Distance (M)	Symbol	Type of Activity	Type of Waste
Total							

Figure 13: process activity chart for work method

[Source: Rijravanich, 2012]

The strategy for recording the work methods of the process can be separated into seven stages:

Stage 1. Study and plainly comprehend the work strategy
Stage 2. Define the begin and end purposes of the work strategy
Stage 3. Record the action utilizing images from begin to end
Stage 4. Portray the point of interest of every action alluded to by the images
Stage 5. Examine the information and data and contrast and real perception
Stage 6. Request that an outsider read the record with a specific end goal to check the data and information
7. Record different points of interest

2.8.3 Analyzing the work system

This stage includes dissecting the record created in the past stage utilizing the 5W1H strategy. The examination takes two methodologies:

1. Ask "what", "who", "when", "where" and "how" inquiries to examine the objective and extent of every movement, the individual doing every action, the area, work arrangement and work technique.
2. Recognize opportunity to get better utilizing "why" questions. Why isn't that right? Is there a distinct option for accomplishing it?

Questions for analysing activities during recording can be explained in Table 4.

Table 4: Questions for analysing the work method (Rijiravanich 2012)

	Group 1 Question	Group 2 Question
Target and scope of work	What to do?	Why do like this ? Can it change?
Employee	Who does it?	Why these people ? Can it change?
Location	Where to do it?	Why this location ? Can it change?
Work sequence	When to do it?	Why do it at that time ? Can it change?
Work method	How to do it?	Why doing it using this method? Can it change?

2.8.4 Advancing the work method

The work activity can be improved using the ECRS technique: eliminate, combine, reduce, simplify. In the event that the movement is redundant, it can wiped out. Be that as it may, if the movement can't be dispensed with, it may be consolidated with different exercises, prompting a diminishment in a few exercises. On the off chance that the movement is perplexing, the working steps or exercises may be streamlined. Besides, the work may be did all the more effortlessly and speedier utilizing gear and devices, for example, a dance or installation for backing. ECRS technique will be used for supporting company on brainstorming session that need to generate alternatives for problems solving.

2.8.5 Measure the work

The current and proposed working systems are contrasted with distinguish which is better, for instance as far as lessening time or separation.

2.8.6 Setting the new working standard

To guarantee that administrators will apply the proposed strategy, the new working standard ought to be set and used to prepare the administrators and the framework ought to be recorded to forestall bending.

2.8.7 Encouraging utilization of the new working standard

In this stage, administrators are urged to get tied up with the new working strategy, and it is clarified and imparted that the new technique is less demanding and more profitable, and that specialists won't lose any advantages. There are numerous progressions to support purchase in, from the endorsement of top administration, correspondence with administrators, preparing administrators and controlling the procedure until everybody can accomplish the objective.

2.8.8 Monitoring the working system

It is important to keep up the new working system and guarantee persistent change. This stage includes catching up and watching that the administrators 'working technique is the same as the new standard to guarantee that the new strategy is economical.

2.9 Matrix Diagram of New Seven administration instrument

In 1976, the Union of Japanese Scientists and Engineers (JUSE) saw the requirement for instruments to advance development, impart data and effectively plan significant undertakings. A group looked into and built up the seven new quality control instruments, regularly called the seven administration and arranging (MP) devices, or basically the seven administration devices. Not every one of the devices were new, but rather their accumulation and advancement were. Lattice Diagram demonstrates the relationship between two, three or four gatherings of data and give data about the relationship, for example, its quality, the parts played by different people, or estimations (Oklahoma 2015).

CHAPTER 3 PROBLEM ANALYSIS

This chapter will be providing the information about the wiring harness company in details and also the process flow from raw materials received, manufacturing the goods and until the finish goods has been attained. In the process, the study will identify each process by applying work study method to analyse in detail on problems that occur in the production line. The concepts of using work study method is to identify the wastes that must be eliminated or improved in order to reduce the cycle time of manufacturing wiring harness.

The company is currently running production based on customer orders because the company's type of business is made-to-order business however the trend of orders are stable throughout the years with slightly fluctuation during December 2014 through February 2015 and again on April 2015. The outputs are slightly down because these months contain many holidays and low working days as stated in production hours in Appendix 1. The Figure 14 shows the trend of outputs deliver to customers from March 2014 – April 2015 with the average of 1629 units throughout the period.

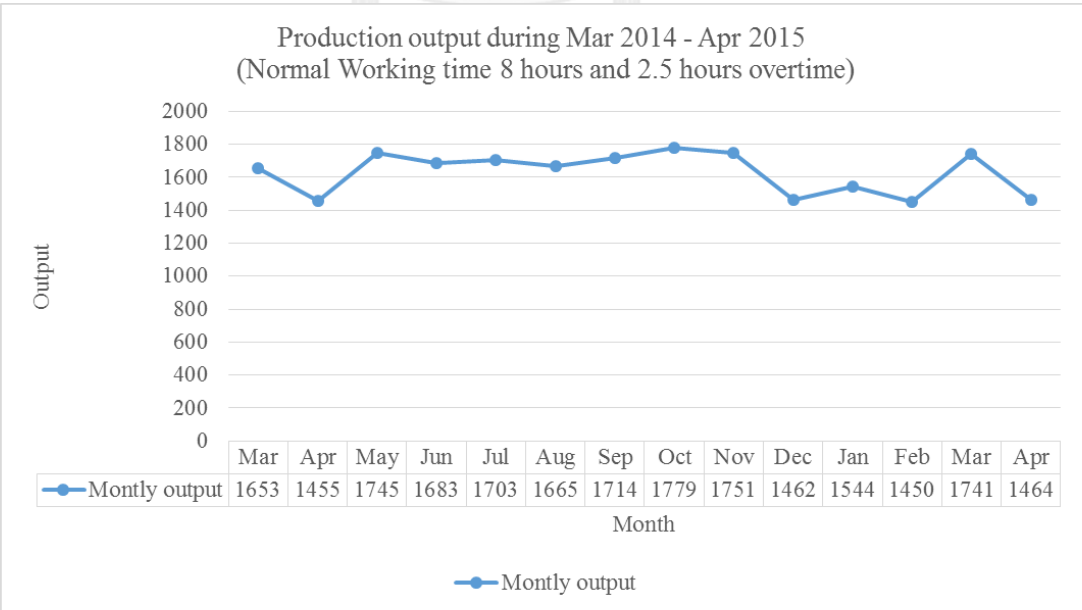

Figure 14: Production output during March 2014 – April 2015 in normal working time and overtime combined

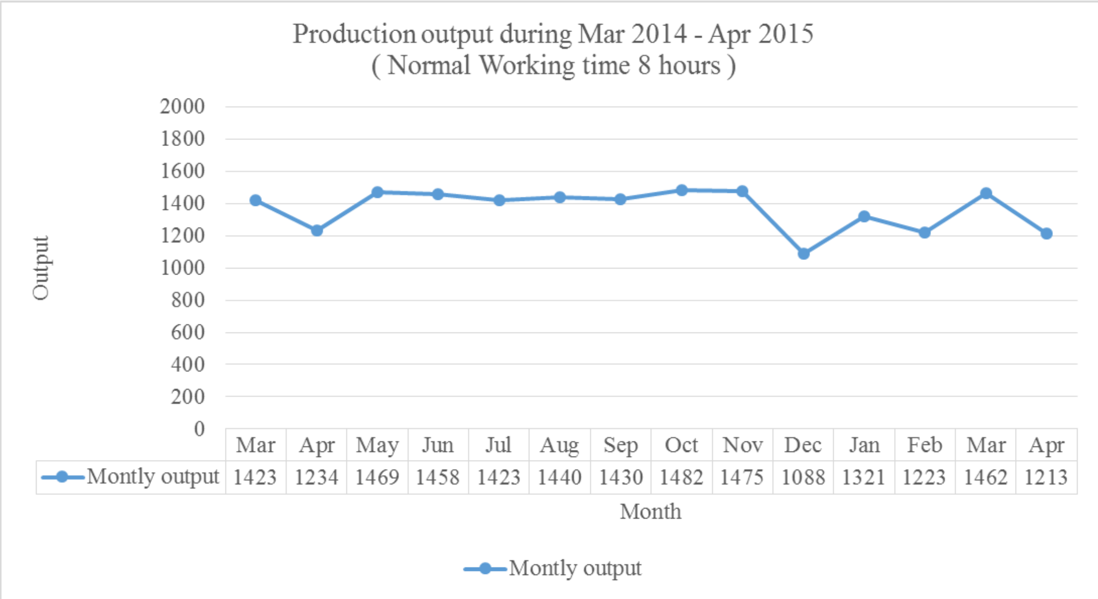

Figure 15: Production output during March 2014 - April 2015 in normal working time

Figure 15 demonstrates the outputs that the company can produce during normal working time of eight hours. However, due to the customer's policy, the company needs to improve productivity in order to keep up with the demand of customers. Otherwise, customer may consider changing their supplier for supporting their production.

Based on the graph in Figure 15, the production output during normal working hours have an average of 1,374 units throughout the year with daily working hours of 8 hours. The company must increase production output to an average of 70 units per day throughout the year in order to gain higher average monthly units.

Therefore, process analysis will be taken by the improvement team. The improvement team will conduct investigation on each process of production and analyse any waste that can improve or eliminate in order to improve productivity in the company.

3.1 Wiring harness Company

3.1.1 Organisation

The wiring harness case study company has one production department manager and four section managers. Production section one will be in charge of manufacturing wiring harness for OEM Car manufacturer (tier 1), which is where the main stream revenue is feeding to the company. Production section two and three will be responsible in manufacturing electronic harness and aftermarket wiring harness products where customers are tier 2. In the section - Process engineer -, the manager will be in charge of checking and improving equipment to support production line in order to keep it operating and running smoothly and fixing the ones that are broken during the process. In each four sub department, there will be one key manager that would be responsible for monitoring the tasks in order to reach the goal target. The KPI's are divided in to four categories: quality, cost, delivery, and output. The research will be focusing on the department of production section one (Figure 16) that are the main revenue stream of the company and need to be improve according to customer's requirement.

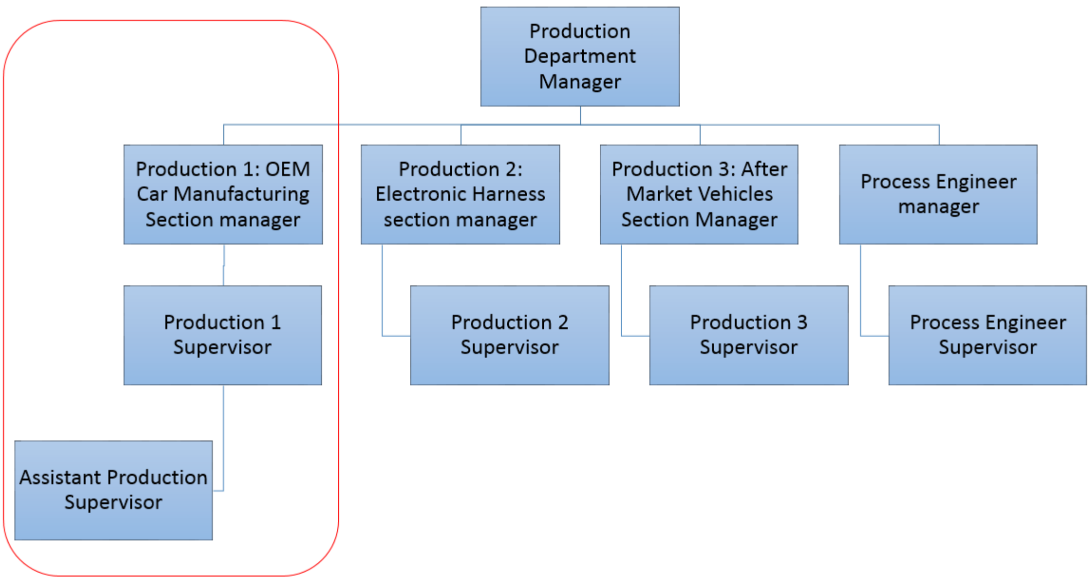

Figure 16: Production department organizational Chart

3.1.2. Research Team

This research is the major project with in production department. The project will need the team and experienced workers along with managers to execute the cycle time improvement project. The team includes ten members of workers that have been decided by top-level management. The lists of name and positions are as following in Table 5.

Table 5: Team members name and position.

No.	Position
1	Production department Manager
2	Production one section manager
3	Production one supervisor
4	Assistant Production Supervisor
5	10 years' experience worker
6	10 years' experience worker
7	10 years' experience worker
8	Process engineer Manager
9	Process engineer Supervisor
10	Consultant (Author, Nattawat Chantanapokul)

The author role in the team are collecting the data, analysing the results before implementation and after implementation as well as supporting during implementing the solutions.

3.1.3. Production Process

Wiring harness process flow can be divided mainly in to seven main processes, as shown in Figure 18. It starts from Wire Assembly process and end at packing process. Lay wire and Lay part are different processes, although, it takes place at the same period of time. Regardless of both these processes taking place in the same timeframe, they are considered as two very distinctive processes. Moreover in Figure 19, the production line layout demonstrates the location of each process and the size of production line.

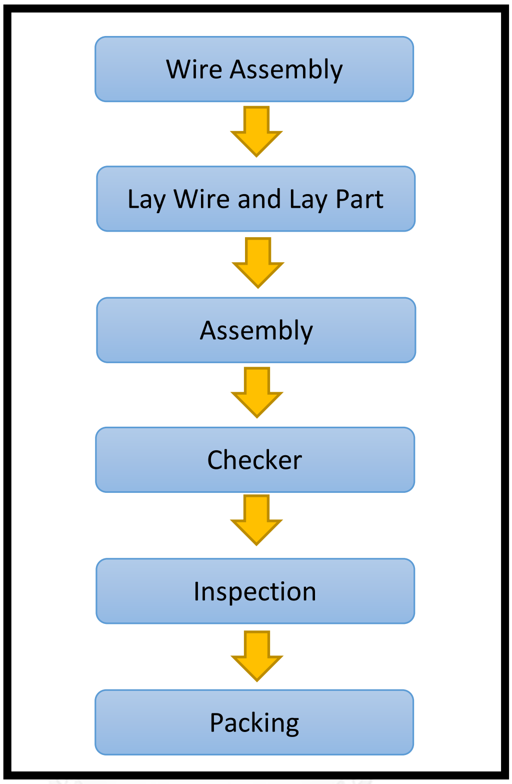

Figure 17: Manufacturing Process of Wiring Harness Assembly

The production process in Figure 17 shows the manufacturing wiring harness process from Wire Assembly to Lay wire and Lay part station. Then all the parts and components will be on assembly board where assembly worker will assemble the harness. The Assembly Station will compose of various processes such as taping, inserting cot, inserting tube and grommet. After all parts are assembled, the loom will be transferred to checker station where the electronic circuits of the loom will be checked to confirm the connector’s connection. Then inspections will take place afterwards for visual inspection of the overall loom. Lastly, after all the harness have been checked and confirmed for delivery, the packing station will pack the looms into the box and will be sent to the warehouse department.

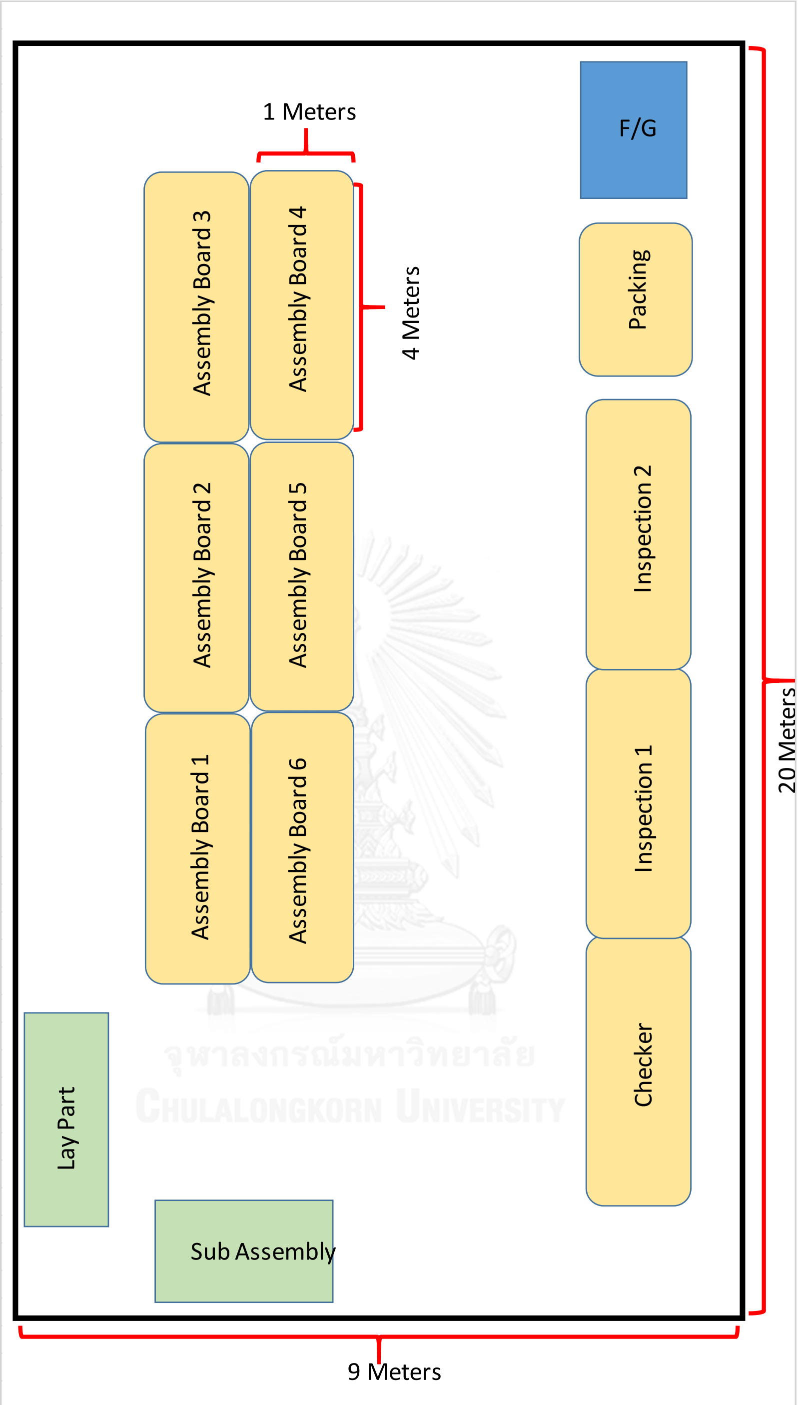

Figure 18: Production line Layout

For the process that take place in Assembly board 1-6, the operators that operate at the assembly board will move once they have finished assemble. For example; if operator of Taping station finished taping at Assemble board 1, the operator will then move to Assembly board 2 to start taping again.

Process 1: Wire Assembly

After raw materials have delivered to the production area, Wire Assembly process will be the first process to start manufacturing products. In this process the wires and components will be pre-assembled before feeding in to the assembly line.

Figure 19: Operator is pre-assembling process of the wires

Figure 20: Wires before pre-assembly

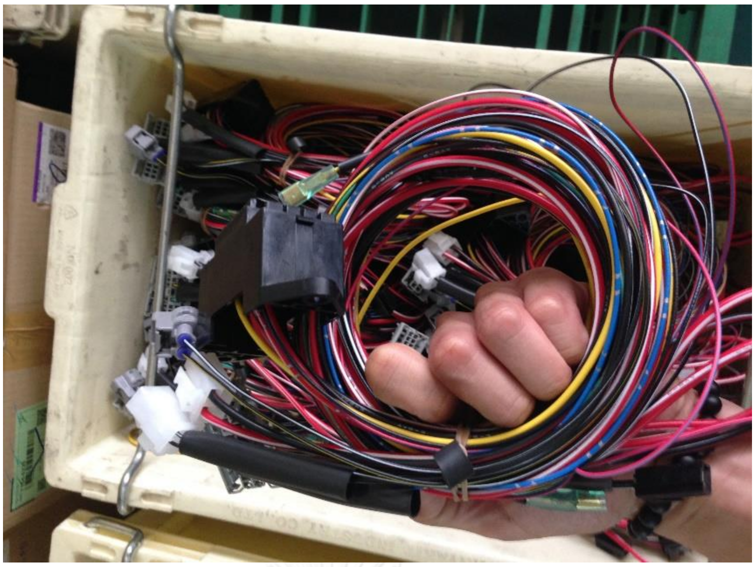

Figure 21: Wires after Assembly

Process 2: Lay part

In process of lay part, parts and components besides wires are arranged on the lay part board called "WASU board" (Common name for using in Japanese standard JASO). Wasu board is the board that is used for transferring the components to the assembly line. The operator will be carrying five Wasu boards to the assembly line for further stages in the production process.

Figure 22: Operator is laying the components on the WASU board

Figure 23: Lay pat station

Process 3: Lay Wire

This process station will be taking wires from Wire Assembly and laying them out on the assembly board. The wires need to be ready on the board before the assembler comes and assembles it.

Figure 24: Operator is laying the wire

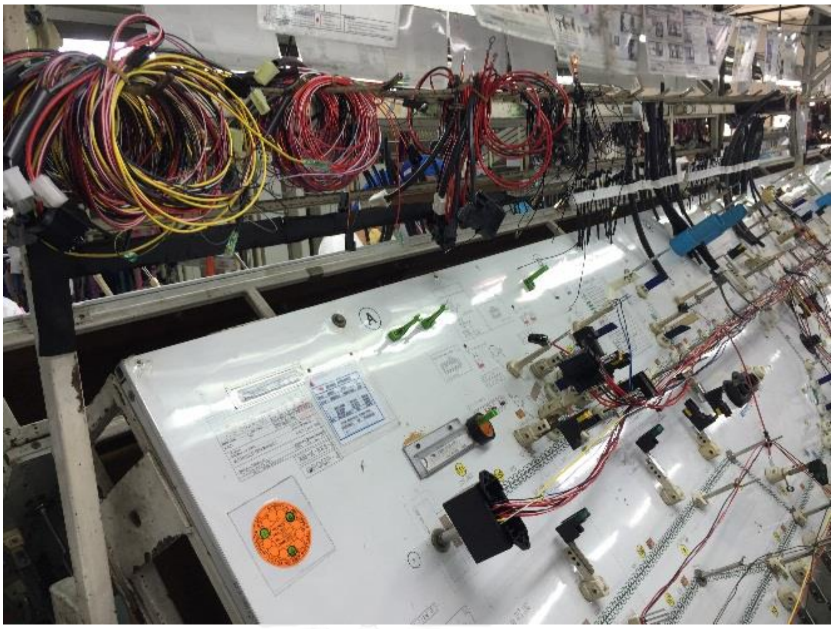

Figure 25: Wires hanging on the bar of assembly board

Process 4: Assembly on the board

In this process, all the components and wires are assembled. The process will run from taping the wires, assembling the tubes, assembling the corrugate (COT), assembling the clip and Inserting the Grommet.

Figure 26: Operator is taping the wire with components

Figure 27: Operator is clipping the loom

Figure 28: Operator is inserting Grommet

Process 5: Checker

This process is about checking the circuits of the wire harness that are fully assembled. The wire harness or finished loom must be tested the circuit in order to confirm the right wire and components are in the correct position. The circuit testing machine will be used in this process.

Figure 29: Operator is checking the loom with circuit testing machine

Process 6: Inspection

In this process, after the checker has done circuit checking, the finished loom will be inspected by two more process. The first inspection will be checking the clips and pulling test of the loom. The second inspection will be about visual inspection process where the loom will be visualized according to the master sample given by the customer. The operator will then compared and contrast the loom.

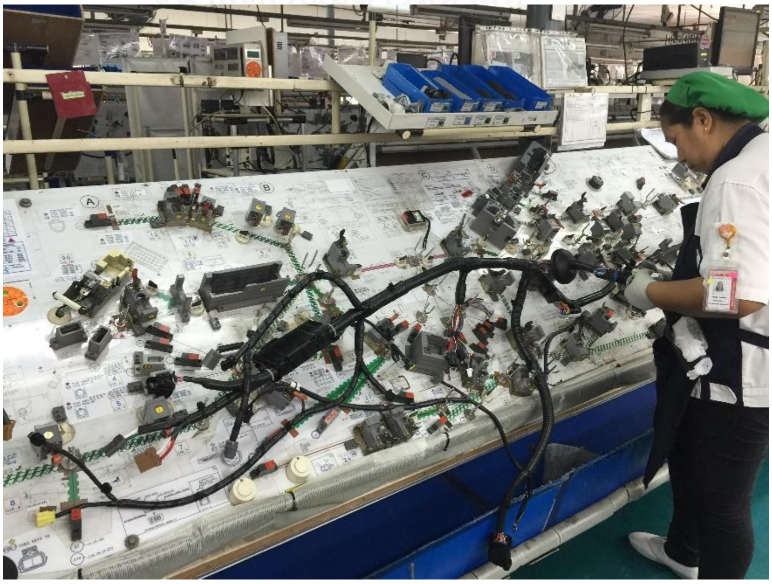

Figure 30: Operator is checking the clips of wiring harness

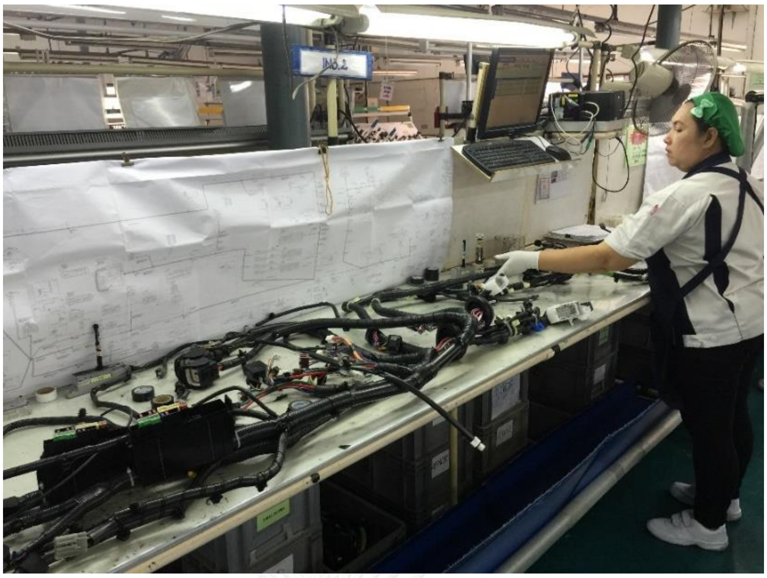

Figure 31: Operator is checking the finished loom with master sample

Process 7: Packing

This process will be packing the harness in to the correct form in order to protect the damage occurring during the transportation to customers.

Figure 32: Operator is putting finished test loom in to the box.

3.2 Process Analysis

Process analysis have been analysed by team members and operators. The supervisor will be the leader for this task because they are familiar with every stations and have the ability to recognize the details in the process. The time keeping will be for measuring each activities and each task. The time keeping will be divided into two sessions. The first session will be from 8.00 until 11.00 and second session will be from 14.00 until 17.00, where each task will also be measured twice. The process of time keeping took place in March where the maximum working days are allowed and the time keeping method has been conducted by the following "determining sample size" equation:

$$\mathrm{E} = z_{\alpha/2} \cdot \frac{\sigma}{\sqrt{n}}$$

Where:

$z_{\alpha/2}$ is known as the critical value, the positive z value that is at the vertical boundary for the area of $\alpha/2$ in the right tail of the standard normal distribution.

σ is the population standard deviation.

n is the sample size.

Rearranging this formula, we can solve for the sample size necessary to produce results accurate to a specified confidence and margin of error.

$$n = \left[\frac{z_{\alpha/2}\sigma}{\mathrm{E}}\right]^2$$

This formula can be used when you know σ and want to determine the sample size necessary to establish, with a confidence of $1-\alpha$, the mean value μ to within $\pm\mathrm{E}$. You can still use this formula if you do not know your population standard deviation σ and you have a small sample size. Although, it's unlikely that you know σ when the population mean is not known, you may be able to determine σ from a similar process or from a pilot test/simulation.

3.2.1 Wire Assembly Station

There are one operator that work on this Wire Assembly station. Observation reveal that throughout the work from 8.00 am in the morning until 5pm in the evening, the operator carry out activities steps as below:

Step 1: The operator will sub Assemble the components to get pre-assembled wire.

Figure 33: Operator is pre assembling wire

Step 2: The operator will roll the wire in to circle form stated in work instruction and tie wires up with elastic band to maintain the form.

Step 3: Then operator will hang the wire on the bar provided in order to wait for operator form next station to collect it.

Figure 34: Pre-assemble harness is hanging on the bar at Wire Assembly station

The activities will continue to repeat from step1 to step 3 until four pre-assembled wires got hang on the bar. Having identified activities in the Wire Assembly process station, process activity mapping can be defined as shown in the Table 6:

Table 6: Process activity chart Wire Assembly process

Process Activity Chart						
No.	Sheet no.	Of	Summary			
Subject Charted:	Wire Assembly		Activity	Present	Propose	Saving
Activity:	Wire Assembly		○	4		
			⇨	8		
			□			
			D			
			▽			
Method	Present	Proposed	Distance(m)	0.8		
Location			Time (sec)	468		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Sub-assemble the wire with components to get Pre Assemble Wire 1	91		●	VA	Process
2. Roll the wire in to circle shape and tight up with elastic band	21		➡	NVA	Motion
3. Hang the wire no.1 on the bar	3	0.2	➡	NVA	Motion
4. Sub-assemble the wire with components to get Pre Assemble Wire 2	92		●	VA	Process
5. Roll the wire in to circle shape and tight up with elastic band	22		➡	NVA	Motion
6. Hang the wire no.2 on the bar	3	0.2	➡	NVA	Motion
7. Sub-assemble the wire with components to get Pre Assemble Wire 3	94		●	VA	Process
8. Roll the wire in to circle shape and tight up with elastic band	21		➡	NVA	Motion
9. Hang the wire no.3 on the bar	3	0.2	➡	NVA	Motion
10. Sub-assemble the wire with components to get Pre Assemble Wire 4	93		●	VA	Process
11. Roll the wire in to circle shape and tight up with elastic band	22		➡	NVA	Motion
12. Hang the wire no.4 on the bar	3	0.2	➡	NVA	Motion
Total	468	0.8			

Therefore the verifying time method must be implemented. According to the process activity chart, the results show that the process of pre-assembling wire 3 has the highest average time of 94 seconds. Therefore, we have selected this process to verify the time keeping method for the sample size of 20 is reasonable for further analysis.

Table 7: Collected time samples in process of Wire Assembly station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	92	84	95	85	92	102	95	103	94	104
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	84	95	87	92	97	95	103	94	104	82

At confidence level of 95.5%, and the Error at + - 5%

$$n = \left[\frac{z_{\alpha/2}\,\sigma}{E}\right]^2$$

E = 5

σ = 6.98

$z_{\alpha/2}$ = 1.96

Therefore n = 7.48, which means the sample size collected is enough for confidence level at 95.5%

3.2.2 Lay Wire station

Wires from Wire Assembly station will now be transferred to the assembly board for assemble. The process in this station will focus on putting the finished pre-assembled wire from Wire Assembly station and move them to the assembly board in order to assemble the wires with more components.

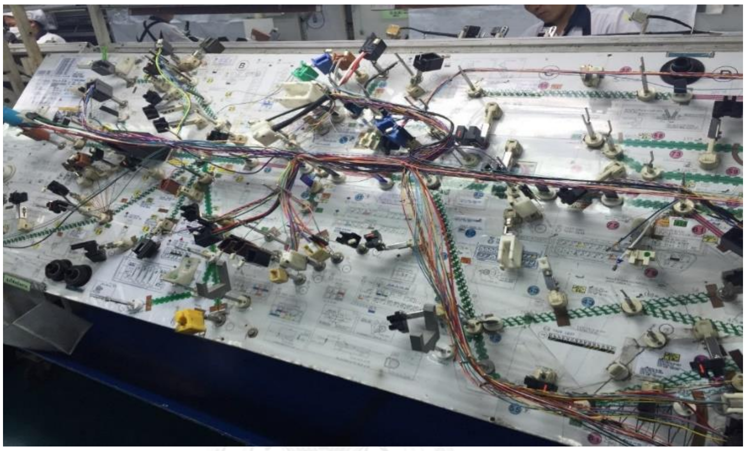

Figure 35: Wire harness on the assembly board

Step 1: The operator will grab all the harness from Wire Assembly station and move to the assembly board.

Step 2: The operator will hang the harness on the hanging bar at the assembly board.

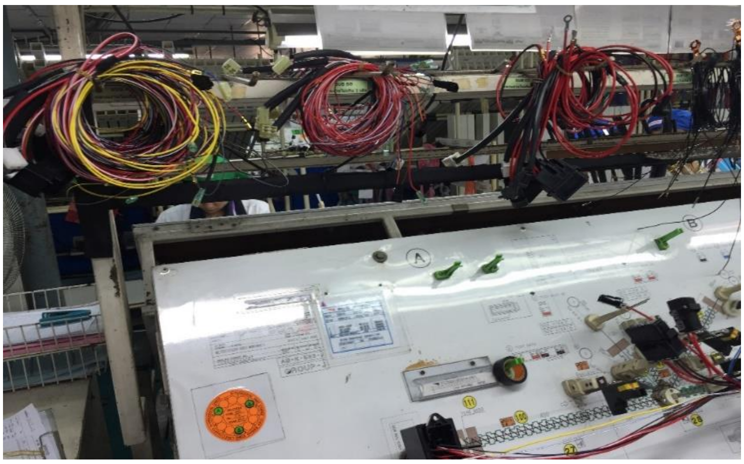

Figure 36: Pre assemble wires are hanging on the bar at assembly board.

Step 3: The operator will grabs the wire and untied it from the elastic band.

Step 4: The operator will lay down the wires on the assembly board

Steps will continue same as step 3* and 4* until four wires have been laid on the assembly board.

The process activity map can be described as following:

Table 8: Process activity chart of Lay wire station

Process Activity Chart						
No.	Sheet no.	Of	Summary			
Subject Charted:	Lay Wire		Activity	Present	Propose	Saving
Activity:	Lay Wire			4		
				8		
Method	Present	Proposed	Distance (m)	23		
Location	Factory		Time (sec)	504		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to Hanging Bar of Wire Assembly Station	13	11		NVA	Transportation
2. Pick up the Wire Assembly Wires	8			NNVA	Motion

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
3. Walk to Assembly Board Station	13	11	➡	NVA	Transportation
4. Hang all the Harness on the Bar on the Assembly board	10	0.2	➡	NVA	Motion
5. Take off Wire no.1	24	0.2	➡	NVA	Motion
6. Lay wire no.1 on the assembly board	91		●	VA	Process
7. Take off Wire no.2	23	0.2	➡	NVA	Motion
8. Lay wire no.2 on the assembly board	92		●	VA	Process
9. Take off Wire no.3	24	0.2	➡	NVA	Motion
10. Lay wire no.3 on the assembly board	93		●	VA	Process
11. Take off Wire no.4	23	0.2	➡	NVA	Motion
12. Lay wire no.4 on the assembly board	90		●	VA	Process
Total	504	23			

Therefore, verifying time method must be implemented. According to the process activity chart, the results show that process of pre-assembling wire 3 has the highest average time of 93 seconds. Therefore we have selected this process to verify the time keeping method for this sample size of 20 is reasonable for further analysis.

Table 9: Collected time samples in process of Lay Wire station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	82	83	96	104	102	84	86	103	100	85
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	87	103	89	83	81	94	102	105	90	100

At confidence level of 95.5%, and the Error at + - 5%

$$n = \left[\frac{z_{\alpha/2}\sigma}{E}\right]^2$$

E = 5

σ = 8.75

$z_{\alpha/2}$ = 1.96

Therefore n = 11.77, which means the sample size of 20 times collected was enough for further analysis.

3.2.3 Lay Part station

This process will occur parallel to the Lay Wire station. The process will be focusing on preparing the sub parts and components that need to be assembled on the wiring harness. The components on each board are described as in the Figures below

Figure 37: Wasu board one with components

Figure 38: Wasu board two with components

Figure 39: Wasu board three with components

Figure 40: Wasu board four with components

Figure 41: Wasu board five with components

Lay part station is the station where operator will need to move from lay part station to different Assembly board. The layout in Figure 42 demonstrates the pattern of worker that has to walk from Lay part station to assembly boards. The blue arrows demonstrate the walking direction of workers between assembly board and the Lay part station.

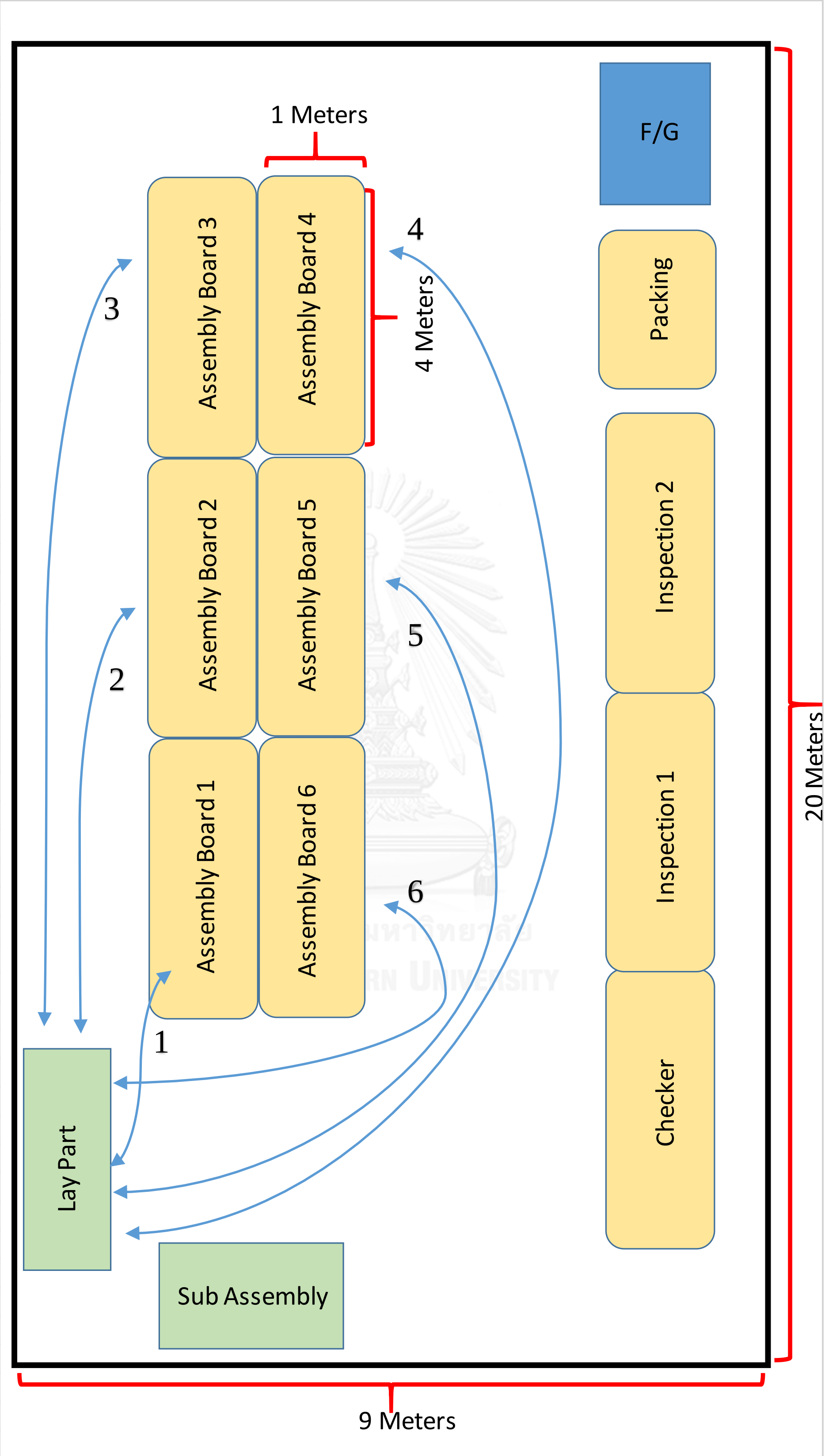

Figure 42: Walking pattern of workers in Lay part station

The average of distance between Lay part and six assembly boards can be described in steps as shown below:

Step 1. Starting from Lay part station to Assembly board 1 = 5 meters
Step 2. Lay part station to Assembly board 2 = 10 meters
Step 3. Lay part station to Assembly board 3 = 15 meters
Step 4. Lay part station to Assembly board 4 = 17 meters
Step 5. Lay part station to Assembly board 5 = 12 meters
Step 6. Lay part station to Assembly board 6 = 7 meters

Therefore the average of distance between lay part station and assembly boards could be calculated as following:
(5+10+15+17+12+7) / 6 = 11 meters

The process can be described in steps as following:
Step 1: Prepare "Wasu boards" on the bar in Lay part station.

Figure 43: Lay part station

Step 2: Set the Assembly components in the Wasu boards according to the label shown on each slots of the board.

Figure 44: Operator is picking up the components

Step 3: Operator will pick up full loaded Wasu boards from Lay part station

Figure 45: Operator is moving Wasu boards to the assembly line

Step 4: Walk to Assembly board.

Step 5: Set Wasu board on the Assembly board.

Step 6: Pick up empty Wasu boards on the Assembly board that has already been used previously.

Step 7: Walk back to the Lay part station.

Step 8: Put down the empty Wasu boards at Lay part station

Steps will now repeat from step 3 to step 8 until five Wasu boards have been delivered to the Assembly line.

Figure 46: Operator is moving fifth Wasu boards to the assembly line

Therefore, the process activity map can be described as the following:

Table 10: Process activity chart of Lay part station

Process Activity Chart							
No.	Sheet no.		Of	Summary			
Subject Charted:	Lay Part			Activity	Present	Propose	Saving
Activity:	Lay Part				5		
					15		
Method	Present		Proposed	Distance (m)	67.8		
Location	Factory			Time (sec)	472		
				Charted by		Date	
				Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Prepare Wasu board for the assembly board	15		●	NNVA	Process
2. Set the assembly components in the position of five Wasu boards	277		●	VA	Process
3. Pick up two Wasu boards from Lay part station	3	0.2	➡	NNVA	Motion
4. Walk to Assembly Board	13	11	➡	NVA	Transportation
5. Set Wasu boards on the Assembly board	19		●	NNVA	Process
6. Collect the two empty Wasu Board from Assembly board	5	0.2	➡	NNVA	Motion
7. Walk back to Lay part Station	13	11	➡	NVA	Transportation
8. Put down two spare Wasu boards on the Lay part station	5	0.2	➡	NNVA	Motion
9. Pick up two Wasu boards from Lay part station	5	0.2	➡	NNVA	Motion
10. Walk to Assembly Board	13	11	➡	NVA	Transportation
11. Set Wasu Boards on the Assembly board	20		●	NNVA	Process
12. Collect the two empty Wasu Board from Assembly board	5	0.2	➡	NNVA	Motion
13. Walk back to Lay part Station	13	11	➡	NVA	Transportation
14. Put down two spare Wasu boards on the Lay part station	5	0.2	➡	NNVA	Motion
15. Pick up one Wasu boards from Lay part station	5	0.2	➡	NNVA	Motion

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
16. Walk to Assembly Board	13	11	⇨	NVA	Transportation
17. Set Wasu Board on the Assembly board	20		●	NNVA	Process
18. Collect the one empty Wasu Board from Assembly board	5	0.2	⇨	NNVA	Motion
19. Walk back to Lay part Station	13	11	⇨	NVA	Transportation
20. Put down one Empty Wasu boards on the Lay part station	5	0.2	⇨	NNVA	Motion
Total	472	67.8			

With the implementation of the verifying time method, several outcomes can be depicted. The results show that process setting assemble components on Wasu boards has the highest average time of 277 seconds. Therefore, we have selected this process to verify the time keeping method for this sample size of 20 is reasonable for further analysis.

Table 11: Collected time samples in process of Lay Part station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	271	294	276	293	266	287	271	276	277	278
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	283	281	261	264	292	280	281	268	263	281

At confidence level of 95.5%, and the Error at + - 5%

$$n = \left[\frac{z_{\alpha/2}\,\sigma}{E}\right]^2$$

E $= 5$

σ $= 9.895$

$z_{\alpha/2}$ $= 1.96$

Therefore n = 15.047, which means the sample size of 20 times that was collected is enough for further analysis.

3.2.4 Taping Station

After Wasu boards and pre-assemble wires are set and ready on the assembly board, the operator of taping station will start the process of taping wires and taping components together.

The step can be described as below:

Step 1. The operator walks Assembly board.

Step 2. Tape will be picked up in order for using in assembly process.

Step 3. Operator tape the wires together according to the work instruction.

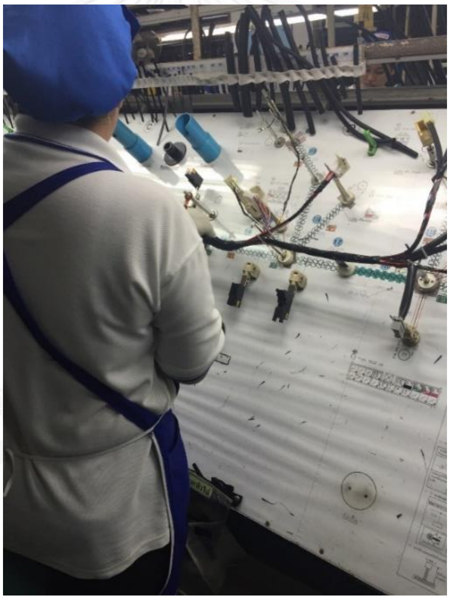

Figure 47: Operator is taping the wires together

Step 4. After tape is done, tape will be put back to its position.

The process activity map can be described as in Table 12.

Table 12: Process activity chart of taping station

Process Activity Chart					
No.	Sheet no. Of	Summary			
Subject Charted:	Taping	Activity	Present	Propose	Saving
Activity:	Taping		1		
			3		
Method	Present / Proposed	Distance (m)	4.6		
Location	Factory	Time (sec)	340		
		Charted by		Date	
		Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to the Assembly board	4	4		NNVA	Transportation
2. Pick up tape from tape position	3	0.3		NNVA	Transportation
3.Taping wires together	332			VA	Process
4. Put the back the tape to Tape position.	5	0.3		NNVA	Motion
Total	340	4.6			

Verifying time keeping method must be implemented in order to approve the time collected. According from the process activity chart, the results show that the process of taping wires has the highest average time of 332 seconds. Therefore we have selected this process to verify the time keeping method for this sample size of 20 is reasonable for further analysis.

Table 13: Collected time samples in process of Taping station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	341	330	352	324	334	321	330	342	324	331
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	312	352	324	334	321	330	352	324	331	331

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{\mathrm{E}} \right]^2$$

E = 5

σ = 11.01

$z_{\alpha/2}$ = 1.96

Therefore n = 18.62, which means the sample size of 20 times collected was enough for further analysis.

3.2.5 COT Assembly Station

In this station, operator will assemble the Corrugate (COT) to the wires. This process operator will assemble COT according to the label on the board. The label on the board will indicate the size of COT that need to be used and also the specific type of taping technique that need for assemble COT to the wires.

The process can be described as below:

Step 1. Operator walks to Assembly Board.

Step 2. Pick up tape.

Step 3. Pick up corrugate (COT).

Step 4. Assembly COT to the wiring harness.

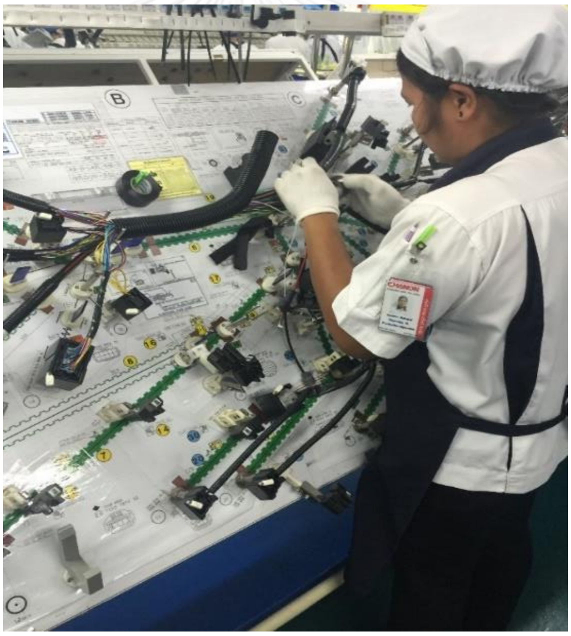

Figure 48: Operator is assembling COTs to the wire.

Step 5. Put the tape back to its position.

The process activity chart can be described as the following:

Table 14: Process activity chart of COT Assembly station

Process Activity Chart						
No.	Sheet no.	Of	Summary			
Subject Charted:	COT Assembly		Activity	Present	Propose	Saving
Activity:	COT Assembly		●	1		
			➡	4		
			▬			
			D			
			▼			
Method	Present	Proposed	Distance (m)	4.9		
Location	Factory		Time (sec)	362		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to Assembly Board	4	4	➡	NNVA	Transportation
2. Pick up tape from tape position	3	0.3	➡	NNVA	Motion
3. Pick up COTs from Wasu board	3	0.3	➡	NNVA	Motion
4. Assemble COTs with the harness	351		●	VA	Process
5. Put the tape back in to tape position	5	0.3	➡	NNVA	Motion
Total	362	4.9			

Therefore, verifying time keeping method must be implemented in order to approve the time collected. Based on the process activity chart, process assemble COTs with the harness has the highest average time of 351 seconds. Therefore, we have selected this process to verify the time keeping method for this sample size of 20 is reasonable for further analysis.

Table 15: Collected time samples in process of COT Assembly station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	351	359	350	339	358	341	339	370	334	355
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	358	351	350	349	361	363	355	341	344	352

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\,\sigma}{E} \right]^2$$

E = 5

σ = 9.27

$z_{\alpha/2}$ = 1.96

Therefore n = 13.20, which means the sample size of 20 times collected was enough for further analysis.

3.2.6 Tube Assembly

In this process, the operator will assemble the tube to the wires. This process operator will assemble tube according to the label on the board. The label on the board will indicate the size of tube that need to be used and also the specific type of taping technique that need for assemble tube to the wires.

Tube Assembly process can be described in steps as below:
Step 1. Operator walks to Assembly Board.
Step 2. Pick up tape.
Step 3. Pick up tubes.

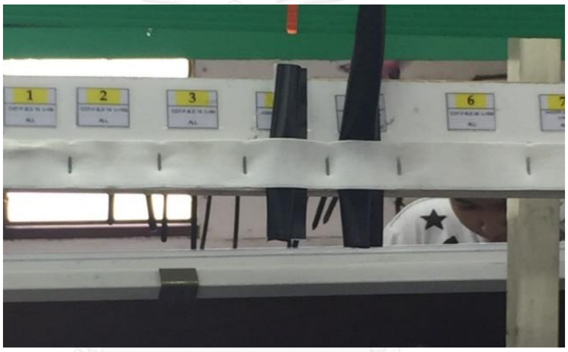

Figure 49: Example of Tubes that need to be assembled

Step 4: Assemble Tubes to the wiring harness.

Figure 50: Operator is assembling the tube on the wires.

Step 5: Put back the tape to its position

The process activity chart can be described as in Table 16:

Table 16: Process activity chart of tube assembly station

Process Activity Chart						
No.	Sheet no. Of		Summary			
Subject Charted:	Tube Assembly		Activity	Present	Propose	Saving
Activity:	Tube Assembly			1		
				4		
Method	Present	Proposed	Distance (m)	4.7		
Location	Factory		Time (sec)	360		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to Assembly Board	4	4		NNVA	Transportation
2. Pick up tape from tape position	5	0.2		NNVA	Motion
3. Pick up Tubes from Wasu board	5	0.2		NNVA	Motion
4. Assemble Tubes with the harness	345			VA	Process
5. Put the back the tape to Tape position.	5	0.3		NNVA	Motion
Total	360	4.7			

Therefore, verifying time keeping method must be implemented in order to approve the time collected. Based on the process activity chart in Table 16, the results shows that the process of assembling tubes with the harness has the highest average time of 345 seconds. Therefore, we have selected this process to verify the time keeping method for this sample size of 20 is reasonable for further analysis.

Table 17: Collected time samples in process of Tube assembly station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	360	344	350	339	358	341	332	360	325	355
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	352	351	350	349	334	327	355	341	333	347

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{E} \right]^2$$

E = 5

σ = 10.76

$z_{\alpha/2}$ = 1.96

Therefore, n = 17.80, which means the sample size of 20 times collected was enough for further analysis.

3.2.7 Clip Assembly

In the process, the operator will assemble the clips to the wire in order to lock harness to stay together and also cutting the tail of clips that are too long.

The process can be described as below:

Step 1. Operator walk to the Assembly board.
Step 2. Pick up clips from Wasu board.
Step 3. Assemble the clips to the harness.

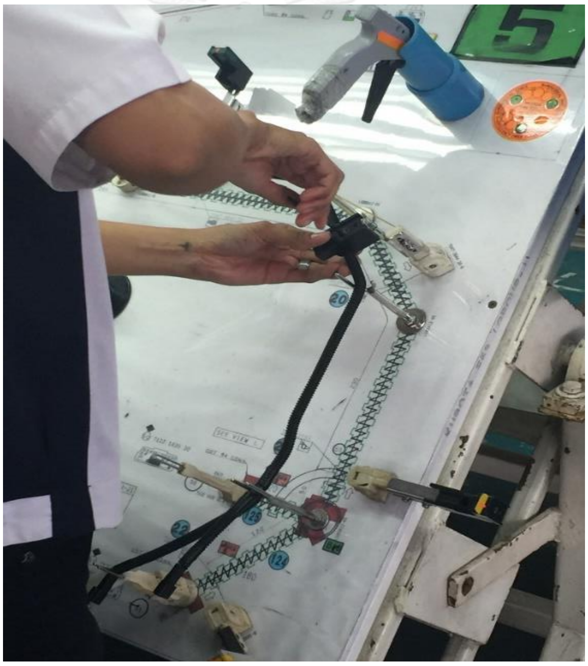

Figure 51: Operator is assembling clips.

Step 4. Pick up the guns from the gun position.

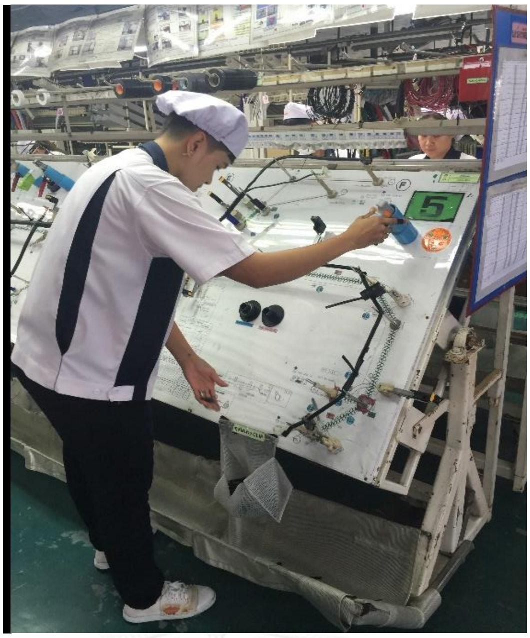

Figure 52: Operator is assembling clips.

Step 5. Cut the over tail of the clips.

Figure 53: Operator is cutting clips.

Step 6. Take all over tail to the bin.

Step 7. Take the gun back to the position.

Step 8. Disassemble the wiring harness from the assembly board.

Step 9. Take the wiring harness to Grommet Station.

Table 18: Process activity chart of Clip assembly station

Process Activity Chart						
No. Sheet no. Of			Summary			
Subject Charted:	Clip Assembly		Activity	Present	Propose	Saving
Activity:	Clip Assembly		●	4		
			➡	5		
			■			
			D			
			▼			
Method	Present	Proposed	Distance (m)	9		
Location	Factory		Time (sec)	370		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to Assembly Board	4	4	➡	NNVA	Transportation
2. Pick up the Clips from Wasu Board	5	0.2	➡	NNVA	Motion
3. Assemble the Clip to each positions of the loom.	220		●	VA	Process
4. Pick up the Gun Clip Cutter from the Gun position	5	0.2	●	NNVA	Process
5. Cut the Tail of the Clip on each positions	74		●	VA	Process
6. Take all the cut-off Clip's Tail and put in to the bin	5	0.3	➡	NNVA	Motion
7. Put the Gun Clip cutter back to its Gun position	5	0.3	➡	NNVA	Motion
8. Disassemble the harness from the Assembly Board	42		●	VA	Process
9. Take the Wiring harness to the Grommet Station	10	5	➡	NNVA	Motion
Total	370	9			

Therefore, verifying time keeping method must be implemented in order to approve the time collected. Based on the process activity chart in table 18, the results shows that the process of assembling the clip to each positions on the wiring harness has the highest average time of 220 seconds. Therefore, we have selected this process to verify the time keeping for sample size of 20 is reasonable to be further analysis.

Table 19: Collected time samples in process of Clip assembly station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	220	241	213	225	227	231	240	228	203	210
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	211	215	227	228	220	222	210	211	207	209

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{\mathrm{E}} \right]^2$$

E = 5

σ = 10.84

$z_{\alpha/2}$ = 1.96

Therefore, n = 18.05, which means the sample size of 20 times collected was enough for further analysis.

3.2.8 Grommet Assembly

Step 1. Operator will carry the wiring harness to the Grommet machine.

Figure 54: Grommet station

Step 2. Operator will install the wiring harness in to the Extending Grommet machine.

Figure 55: Operator installs the wiring harness to the extending machine

Step 3. Then the connectors will be put through the Extending grommet machine for inserting.

Figure 56: Operator is inserting connectors.

Step 4. Turn on the switch.

Step 5. After the machine is done, operator will take the harness out from the Extending Grommet machine.

Step 6. The wiring harness will be set on the assembly board at Grommet station.

Step 7. Grommet will be taped to strengthen the connections.

Figure 57: Operator is taping the grommet

Step 8. The harness will be hang on the bar at the Checker Station.

The process activity chart can be described as follows:

Table 20: Process activity chart of grommet assembly station

Process Activity Chart						
No. Of		Sheet no.	Summary			
Subject Charted:	Grommet		Activity	Present	Propose	Saving
Activity:	Grommet		●	5		
			➡	8		
			▭			
			D	1		
			▼			
Method	Present	Proposed	Distance (m)	13		
Location	Factory		Time (sec)	325		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Take harness to the Extending Grommet Machine	5	3	➡	NNVA	Transportation
2. Put the harness attach to the Extending Grommet Machine	55		●	NNVA	Process
3. Pick up the Grommet from Grommet position	10	0.3	➡	NNVA	Motion
4. Put the Grommet in to the Extending Grommet Machine	12	0.3	➡	VA	Motion
5. Pick up the Connectors and put through Grommet	60		●	VA	Process
6. Turn on the switch of the machine	5		●	NNVA	Process
7. Waiting for machine to done	31		D	NNVA	Waiting
8. Take off the harness form extending Grommet Machine	10		●	NNVA	Process

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
9. Put the harness on to the Assembly board of Grommet station	10	1	⇨	NNVA	Transportation
10. Pick up the Tape from Tape position	3	0.2	⇨	NNVA	Motion
11. Taping the Grommet with harness	112		●	VA	Process
12. Put the tape back to Tape position	3	0.2	⇨	NNVA	Motion
13. Take the harness to the Hanging Bar of Checker station	5	4	⇨	NNVA	Transportation
14. Walk back to Grommet Station	4	4	⇨	NVA	Transportation
Total	325				

Therefore, verifying time keeping method must be implemented in order to approve the time collected. Based on the process activity chart in Table 20, the results show that the process of taping the grommet with harness has the highest average time of 112 seconds. Therefore, we have selected this process to verify the time keeping for sample size of 20 is reasonable for further analysis.

Table 21: Collected time samples in process of Grommet assembly station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	95	109	98	125	104	113	105	123	108	120
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	106	106	128	99	124	121	108	119	122	109

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{\mathrm{E}} \right]^2$$

E = 5

σ = 9.93

$z_{\alpha/2}$ = 1.96

Therefore, n = 15.15, which means the sample size of 20 times collected was enough for further analysis.

3.2.9 Checker

Checker station is the process of checking the circuits of wiring harness in order to confirm every connectors and wires are connecting at the correct position.

The process can be described as below:

Step 1. Operator turn on the switch of YC-Checker.

Step 2. Once the Computer opens, the operator will insert the code in.

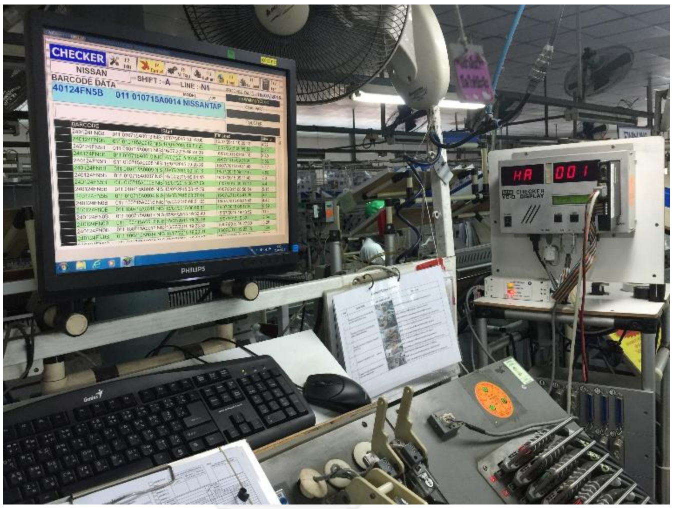

Figure 58: Computer at checker station has turned on.

Step 3. The operator will then carry the harness from the hanging bar to the checker board.

Step 4. Wiring harness will be laid down on the checker board.

Figure 59: Operator is laying down the harness on the checker board

Step 5. Wiring harness will be assemble to the fixture on the checker board

Figure 60: Operator is assembling the harness with checker board

Step 6. Operator will push “start” button to check the circuits of the wiring harness.

Step 7. After it has passed the checker, the operator will stamp “Ok/Checker” on the harness.

Step 8. Wiring harness will be disassembled from the checker board.

Step 9. Operator will take the harness to the hanging bar of inspection 1 station.

Figure 61: Inspection 1 hanging bar

The process activity chart can be described as the following:

Table 22: Process activity chart of checker station

Process Activity Chart					
No.	Sheet no.	Summary			
Subject Charted:	Checker	Activity	Present	Propose	Saving
Activity:	Checker		7		
			2		
			1		
Method	Present / Proposed	Distance (m)	5		
Location	Factory	Time (sec)	327		
		Charted by		Date	
		Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1.Turn on the switch of YC-Checker	2			NNVA	Process
2. Open computer and insert code of operator	15			NNVA	Process
3. Carry the harness to the Checker board	3	1		NNVA	Transportation
4. Lay the wire down on the Checker Board	27	1		NNVA	Motion
5. Assemble the harness on every position of Checker fixture	163			VA	Process
6. Click button "Start" to check the circuit of the harness	2			NNVA	Process

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
7. Waiting Checker to check the circuits	30			NNVA	Waiting
8. Stamp "OK/checker" on to the Name plate of the harness	15			VA	Process
9. Dissemble the harness from the Checker Board	65			NNVA	Process
10. Take the harness to the Hanging bar of Inspection station	5	3		NNVA	Transportation
Total	327	5			

Based on the process activity chart in Table 22, the results show that process assemble the harness on every position of checker fixture has the highest average time of 163 seconds. Therefore we have selected this process to verify the time keeping for sample size of 20 is reasonable to be further analysis.

Table 23: Collected time samples in process of Checker station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	167	156	146	166	161	150	160	171	161	173
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	170	152	156	168	168	175	162	169	172	158

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{E} \right]^2$$

E = 5

σ = 8.17

$z_{\alpha/2}$ = 1.96

Therefore, n = 10.26, which means the sample size of 20 times collected was enough for further analysis.

3.2.10 Inspection 1

Inspection 1 station is where the wiring harness will be inspected on the length and the strength of the clips that has been assembled. The process is described below:

Step 1. YC-Checker will be turned on.

Step 2. Computer will be turned on and the code will be inserted by the operator.

Figure 62: Computer of inspection 1

Step 3. Operator will inspect S/P before using.

Step 4. Wire from hanging bar will be carried to the inspection 1 board.

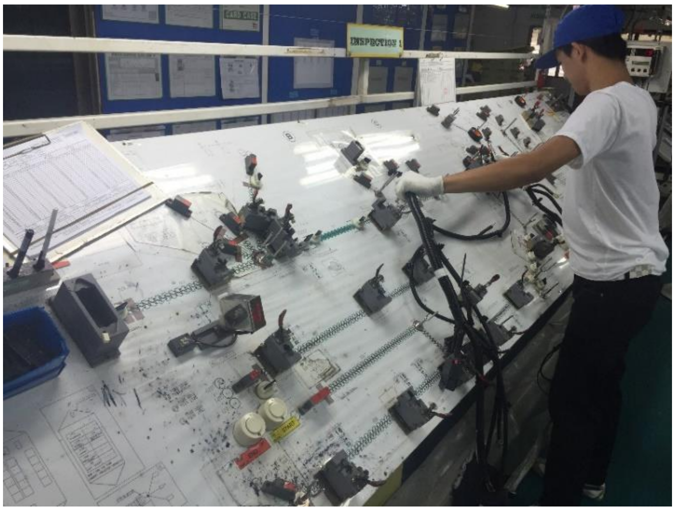

Figure 63: The operator is laying down the wiring harness on inspection 1 board.

Step5. Operator assemble clips of wiring harness with the inspection 1 board.

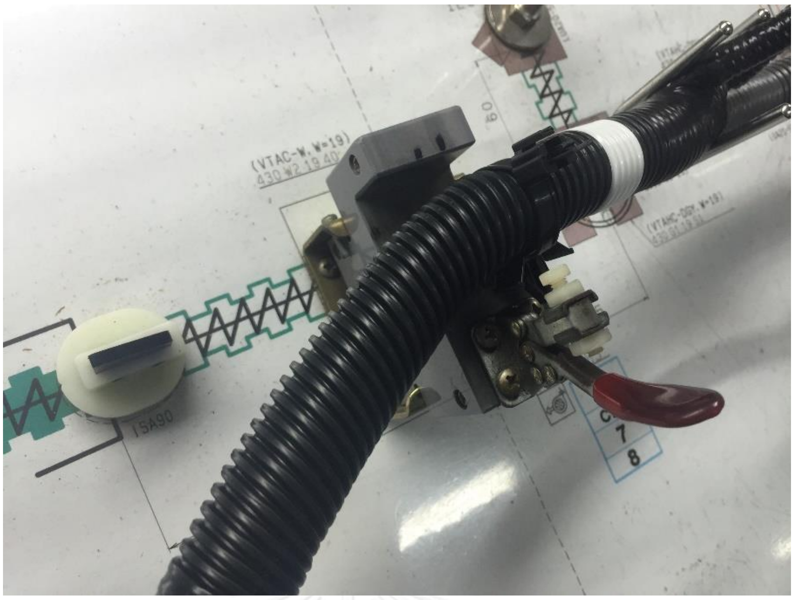

Figure 64: The wiring harness has been assemble at clip fixture

Step 6. Push “start” button to start checking.

Step 7. After wiring harness passed the test, Operator will stamp “ok/inspection1”.

Step 8. The harness will be tape on the branches by the operator.

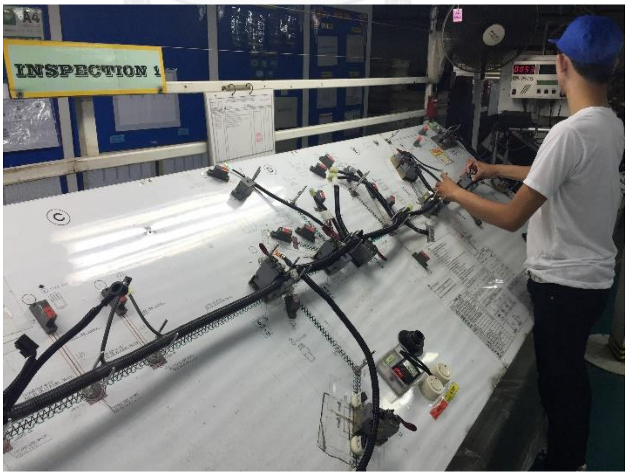

Figure 65: Operator is waiting for harness to be checked

Step 9. The operator will record the complete of inspection 1 on the check sheet.

Step 10. Harness will be de assemble from the board.

Step 11. The operator carry the harness to the next station.

Therefore, the process activity chart can be described as the following:

Table 24: Process activity chart of inspection 1 station

Process Activity Chart						
No. Sheet no. Of			Summary			
Subject Charted:	Inspection 1		Activity	Present	Propose	Saving
Activity:	Inspection 1		●	9		
			➡	5		
			▬			
			D			
			▼			
Method	Present	Propose	Distance (m)	8.4		
Location	Factory		Time (sec)	373		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Turn on the switch of YC-Checker inspection 1	2		●	NNVA	Process
2. Open computer and insert code of operator	15		●	NNVA	Process
3. Inspect S/P before using	25		●	VA	Process
4. Grab the Wire from hanging bar and put on the inspection 1 board	5		➡	NNVA	Motion
5. Assemble Clips to the YC-Checker inspection 1 board	175		●	VA	Process
6. Turn on "Start" to check the circuits	30		●	NNVA	Process
7. Stamp "Ok/inspection1" on the Name plate	5		●	VA	Process
8. Pick up the tape	3	0.2	➡	NNVA	Motion

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
9. Tape the wiring branches	35		●	VA	Process
10. Put down the tape in its position	3	0.2	➡	NNVA	Motion
11. Record the complete inspection 1 on the check sheet	10		●	VA	Process
12. Disassemble the wiring harness out form the YC-checker board	57		●	NNVA	Process
13. Take the wire to the Hanging bar of inspection 2	4	4	➡	NNVA	Motion
14. Walk back to the station	4	4	➡	NNVA	Motion
Total	373	8.4			

Therefore, verifying time keeping method must be implemented in order to approve the time collected. Based on the process activity chart in Table 24, the results shows that the process of assembling the clip to the YC-Checker inspection board has the highest average time of 175 seconds. Therefore, we have selected this process to verify the time keeping for sample size of 20 is reasonable for further analysis.

Table 25: Collected time samples in process of Inspection 1 station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	190	185	182	189	179	181	158	167	183	167
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	159	173	163	179	171	180	165	186	161	178

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{E} \right]^2$$

E = 5

σ = 10.23

$z_{\alpha/2}$ = 1.96

Therefore, n = 16.09, which means the sample size of 20 times collected was enough for further analysis.

3.2.11 Inspection 2

Step 1. The operator prepare the master sample of the wiring harness.

Figure 66: Master Sample of wiring harness

Step 2. The harness will be carried from hanging bar to the inspection table.

Step 3. Operator will put the harness comparing each position with the master loom.

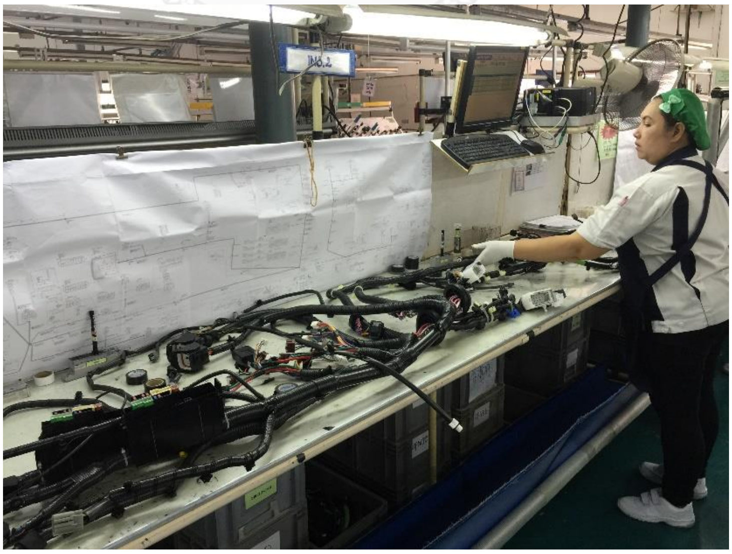

Figure 67: Operator is putting down the harness with master sample

Step 4. Operator will visually inspect on every positions of the loom.

Figure 68 : Operator is inspecting the harness

Step 5. If the loom pass, the operator will put a mark signed on the Name plate of the loom.

Step 6. The harness will be carried to the hanging bar of the next station.

The process activity chart can be described as the following:

Table 26: Process activity chart of inspection 2 station

Process Activity Chart							
No.	Sheet no.		Of	Summary			
Subject Charted:	Inspection 2			Activity	Present	Propose	Saving
Activity:	Inspection 2				4		
					2		
Method	Present		Proposed	Distance (m)	2		
Location	Factory			Time (sec)	337		
				Charted by		Date	
				Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Prepare the Master sample loom	32		●	NNVA	Process
2. Take the harness from the hanging bar to the Inspection table	5	1	➡	NNVA	Transportation
3. Lay the harness down and compare each position with the master sample	71		●	NNVA	Process
4. Inspect the harness visually on every positions	202		●	VA	Process
5. Put the mark signed on the Name plate for the Passed harness	22		●	VA	Process
6. Take the harness to the hanging bar of the Packing Station	5	1	➡	NNVA	Transportation
Total	337	2			

Therefore, verifying time keeping method must be implemented in order to approve the time collected. Based on the process activity chart in Table 26, the results shows that process of inspecting the harness visually on every positions has the highest average time of 202 seconds. Therefore, we have selected this process to verify the time keeping for sample size of 20 is reasonable for further analysis.

Table 27: Collected time samples in process of Inspection 2 station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	202	197	196	193	204	215	201	191	215	189
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	189	208	217	197	198	208	214	194	218	196

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{E} \right]^2$$

E = 5

σ = 9.68

$z_{\alpha/2}$ = 1.96

Therefore, n = 14.41, which means the sample size of 20 times collected was enough for further analysis.

3.2.12 Packing

Step 1. The Operate prepares the box for packing.

Figure 69: Operator is preparing the box.

Step 2. Operator rolls the harness with the correct formula.

Figure 70: Operator is rolling the harness in to correct form

Step 3. The harness will be tied up with rubber band.

Step 4. Put the harness in to the box.

Figure 71: The harness is being put in to the box.

Step 5. Close the box.

Step 6. Print the sticker no.

Step 7. Sign name and date on the sticker.

Step 8. Take the box to the pallet.

The process activity chart can be described as the following:

Table 28: Process activity chart of packing station

Process Activity Chart							
No.		Sheet no.	Of	Summary			
Subject Charted:	Packing			Activity	Present	Propose	Saving
Activity:	Packing			●	6		
				➡	1		
				▬			
				D	1		
				▼			
Method	Present		Proposed	Distance (m)	11		
Location	Factory			Time (sec)	227		
				Charted by		Date	
				Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Prepare the box for packing	24			NNVA	Process
2. Roll the harness in to the correct form	82			VA	Process
3. Put the harness into the box	8	1		NNVA	Motion
4. close the box	34			NNVA	Process
5. Print the Sticker no.	30			VA	Waiting
6. Sign name and Date on the sticker	4			VA	Process
7. Stick the sticker on the box	15			NNVA	Process
8. Take the box to the Pallet and ready to ship	30	10		NNVA	Transportation
Total	227	11			

Therefore, verifying time keeping method must be implemented in order to the approve time collected. Based on the process activity chart described in table 28, the results show that the process of rolling the harness in to the correct form has the highest average time of 82 seconds. Therefore, we have selected this process to verify the time keeping for sample size of 20 is reasonable for further analysis.

Table 29: Collected time samples in process of Packing station

Time	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th
Sec	88	96	82	81	91	74	70	72	82	73
Time	11th	12th	13th	14th	15th	16th	17th	18th	19th	20th
Sec	89	78	91	88	84	82	82	86	71	81

At confidence level of 95.5%, and the Error at + - 5%:

$$n = \left[\frac{z_{\alpha/2}\sigma}{E} \right]^2$$

E = 5

σ = 7.35

$z_{\alpha/2}$ = 1.96

Therefore, n = 8.31, which means the sample size of 20 times collected was enough for further analysis.

3.3 Value Stream mapping

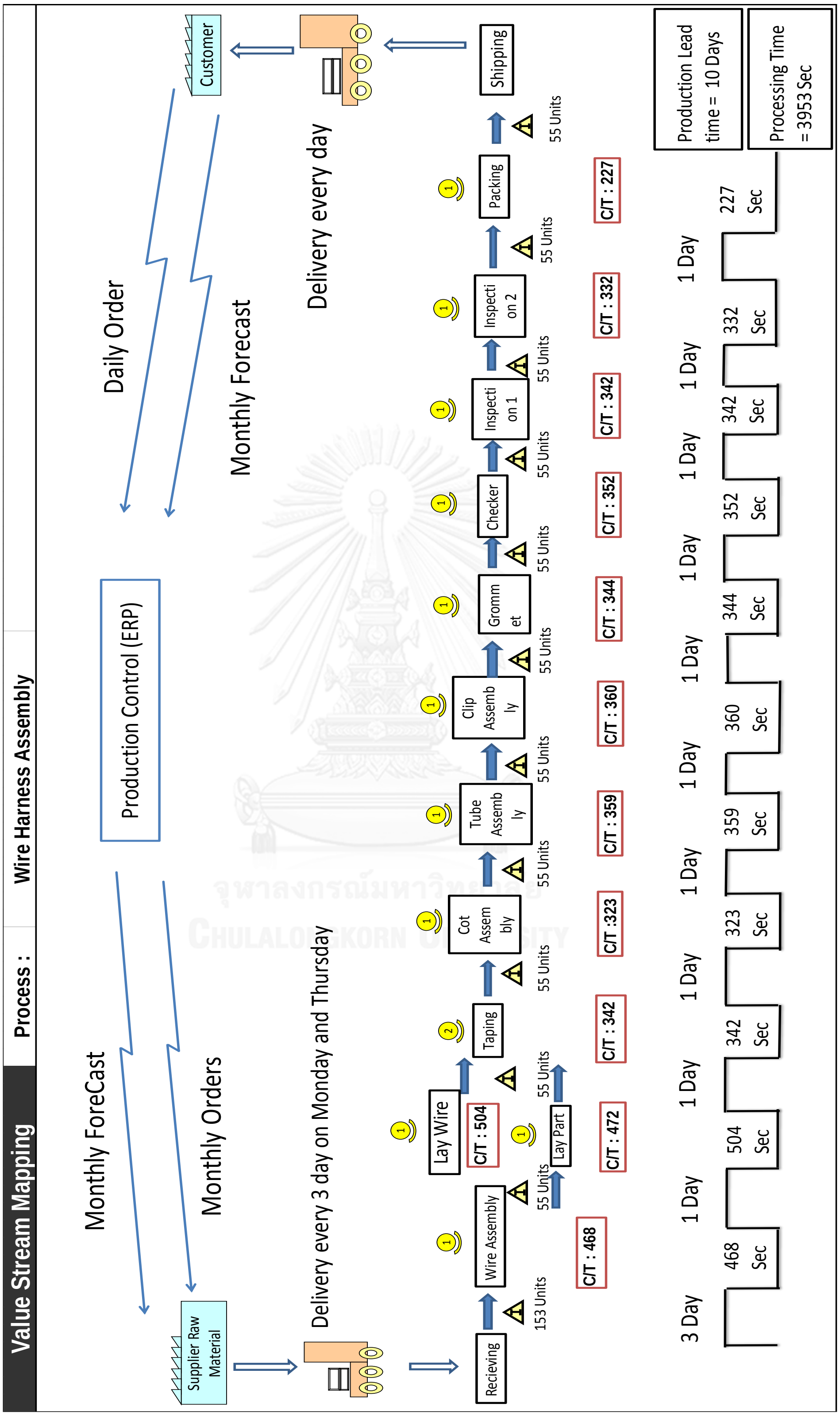

Figure 72: Value Stream map of Wiring Harness Case study Company

According from the Value Stream Mapping on the Figure 73, the Takt time can be calculated as demonstrated below:

Table 30: Calculating Takt time

Net Available Time		
Working Shifts/ Day	1	Shifts
Hours/Shift	9	Hours
Available Time/ Shift	540	Minutes
Break Time / Shift	20	Minutes
Lunch Time / Shift	40	Minutes
Planned Down time /Shift	0	Minutes
Net Working time/ Shift	480	Minutes
Net Working time/ Shift	28800	Seconds
Net Available time /day	32400	Seconds
Customer Demand/ Day	70	Pieces
Net Working Time / Day	28800	Seconds / Day
Takt Time	411	Seconds/ Pieces

The result of the takt time from calculation is 411 seconds in order for the company to produce 70 units per day within 8 working hour time period. Therefore, the process that has over process time than 411 seconds will be consider to look for improvement in process by eliminating or improving the waste. Based on the process analysis phase, we have discovered that there are three main stations that spend cycle time over 411 seconds. In the Figure 73 has shown the box plot diagram of the each process. The improvement team will analyse the wastes of process Wire Assembly, Lay Wire and Lay Part station as shown in the Figure 73.

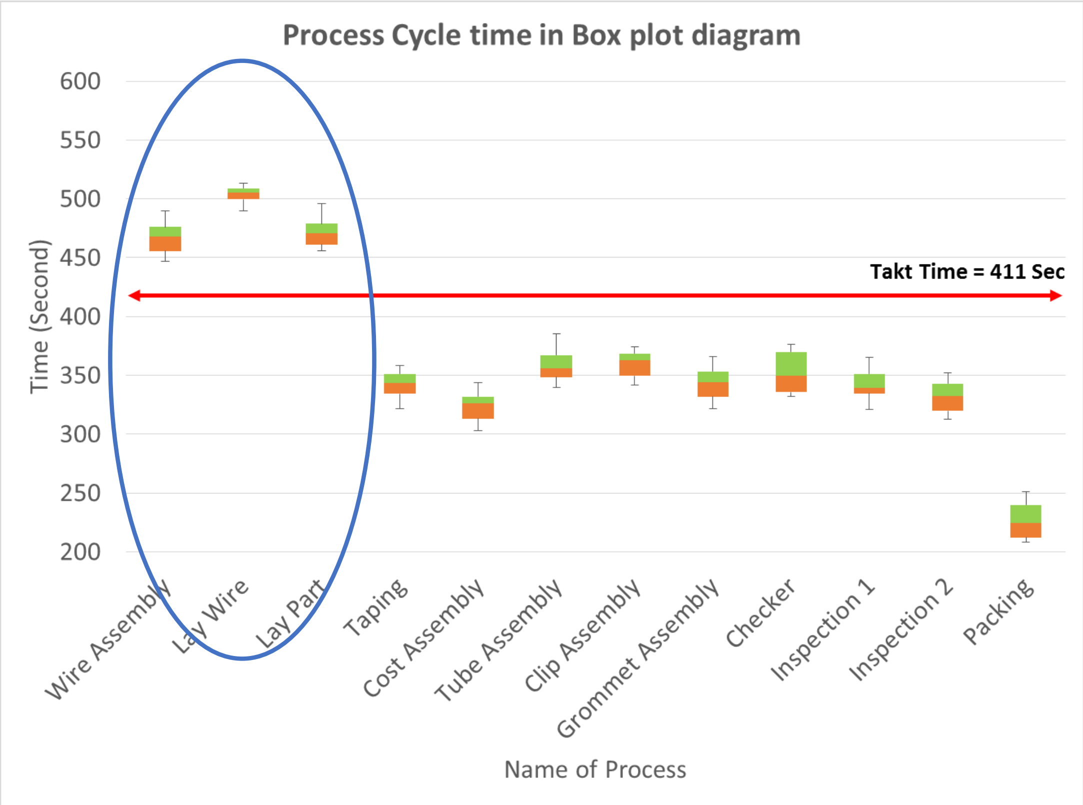

Figure 73: Process cycle time in Box plot diagram

3.4 Problem Observation

The purpose of observation was to identify the non-value added activities that exist in the production line. As stated in Chapter 2, Liker and Meier (2006) have introduced seven major types of wastes for discussion on the non-value added activities in manufacturing process. People that are responsible in the production line were assigned to walk through the production process and notice the wastes of each process by using seven-waste management. The results of the observation were concluded below:

1. Overproduction waste

There are no signed of overproduction waste occurred because the company is make-to-order for customers and will only produce if there are orders from customer in advance. The production schedule will determine how many goods will be made each day. Therefore, the problem of over-production is not detected in any of the processes.

2. Waiting

Waiting waste could be found in during inspection 1 and Checker process. These processes have to wait for the individual station to finish before they can continue to do the work.

3. Transportation

This type of waste are mostly found at raw material withdrawal from Warehouse and Feeding Assembly line. For instance, the transportation of parts from Lay part station to Assembly line has a long distance and the operator has to walk many rounds to transport the components in to assembly line.

4. Over-processing / Inappropriate process

Over processing has not been found due to most of the process has been required by customers as basic requirement. Therefore, the company has not input any over value added in to the process.

5. Excess inventory

There are no excess inventory due to the schedule have been fixed and that the inventory will not be carried for more than 1 day in the process.

6. Motion

Motion waste can be found in two stations which are Wire Assembly station and Lay wire station. Wire Assembly has motion waste during finishing the sub assembled wires where operators need to roll the wires. On the other hand, in the Lay wire station, motion waste occur during the time when the operator lay the wire on to the assembly board.

7. Defects

There are low defects of less than 0.01 ppm which mean defects are not usually occur in the Wiring harness manufacturing process. If the defect occur, it will be send back to rework.

Therefore the major wastes can be determined as following:

3.4.1 Transportation Waste

Transportation waste occurs mostly during the Lay part process because this process is concerned on feeding the materials into the Assembly board and the operator needs to walk back and forth between stations several times per round in order to keep the components ready on the assembly board.

In Lay part Station

1. Walk to Assembly board 11m (3 times)	39 seconds
2. Walk to Lay part Station 11m (3 times)	39 seconds
Total of Transportation Waste time	78 Seconds*

3.4.2 Motion Waste

Motion waste are mostly taking place in the Lay Wire process. The reason is because, most of the time the wire get caught with each other or bind on one another, causing the operator to spend more time on separating each wire out.

In Lay Wire station

1. Hang all the wires on the bar of assembly board	10 seconds
2. Pick up the Wire Assembly Wires	8 seconds
3. Taking off wire No. 1	23 seconds
4. Taking off wire No.2	22 Seconds
5. Taking off wire No.3	24 seconds
6. Taking off wire No.4	23 seconds
Total of Motion waste in Lay wire station	110 Seconds*

In Wire Assembly station

1. Roll the wire in to circle shape and tight up with elastic band (4 times) 86 seconds

2. Hanging the wires on the bar (4 times) 12 seconds

Total of Motion waste in Wire Assembly station 98 seconds*

Based on the identifying work study and waste, we can summarize the root cause of over cycle time in the process of assembling wire harness as in Figure 74

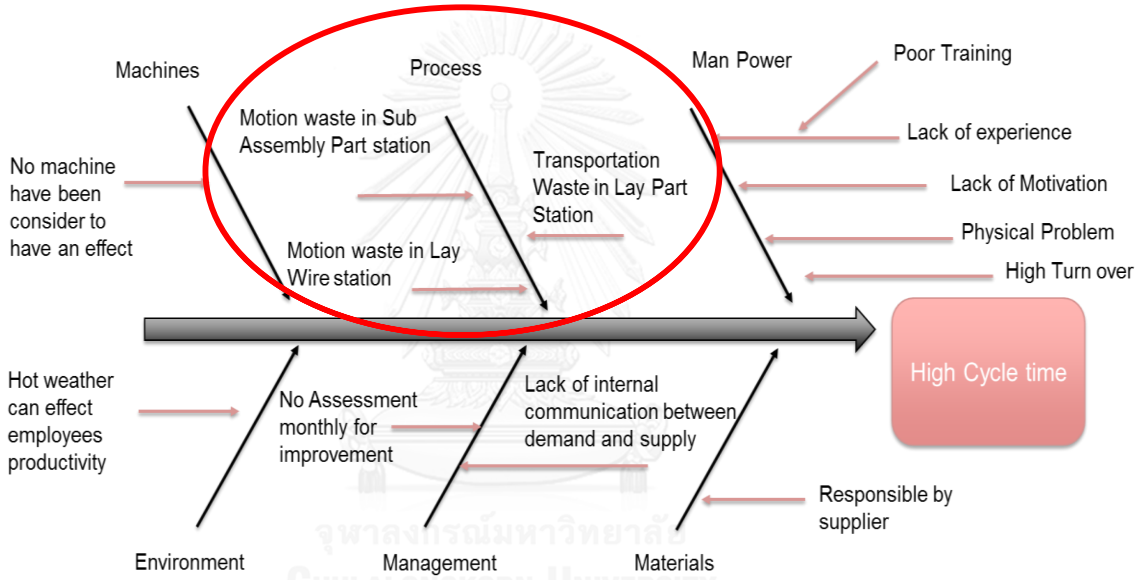

Figure 74: Cause and effect analysis diagram of High cycle time

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In the Figure 74, there are 6 mains factors that has been considered which are Machines, man power, process, environment, management and materials. Factors will be analysed as below:

1. Machines have low concern for the cycle time because it has low cycle time in the activity and it is not significant in the process according to the process activity chart.

2. Materials have no concerns because raw materials have been provided from supplier and the company has policy of keeping stock for 3 days stock on materials, so there are always available for the production line to run.

3. Environment have low impact on cycle time and it is not significant on the cycle time because the hot weather are seasonal and not appear every day. Environment is an uncontrollable factor.

4. Management have some impact on cycle time because there are no assessment of workers individually, therefore the company does not know how much skills of the workers have been improved or what skills should they improve in order to increase productivity.

5. Man Power have some impact on cycle time because according from no assessment had been took place in management perspective, workers tend to have poor training and lack the motivation of doing the job which sometimes it results in turnover of employees and no instant substitutes that can do the job immediately.

6. Process factor has the most effect on high cycle time according from the process activity chart because there are transportation waste and motion waste appear. The wastes need to be improve or eliminated immediately and therefore the root cause of high cycle time is the Process factor.

In conclusion, out of all six factors discussed earlier. The factor that is considered the root cause of high cycle time for manufacturing wiring harness is the process/method. The reason is because the wastes that has been calculated throughout process activity map has shown us the time spent on the wastes that overwhelm the takt time that company should've been processing.

CHAPTER 4: ALTERNATIVES EVALUATION

In chapter 3 the problems have been analysed in details in terms of seven waste management. The process activity map chart has illustrated us on which tasks has the highest cycle times. This chapter will explain about the process of generating alternatives and how to select the best alternatives for the solution of improving cycle time.

The alternatives suggested will be determined by Matrix score (1-5, where 1 is the lowest score and 5 is the highest score). The template form in Table 31 will be used for comparing and contrasting each alternatives with the criteria proposed by the team. The criteria that are used has been developed by the team where supervisor and production manager are the leaders on choosing the best one because these two individuals know the most about the product and the process. Table 31 shows the template of scoring sheet that used by the team for evaluating:

Table 31: Criteria for choosing alternatives

Team Members	Criteria					
	Productivity	Quality	Cost	Safety	Environment	Total (20)
Production department Manager						
Production one section manager						
Production one supervisor						
Assistant Production Supervisor						
10 years experience worker						
10 years experience worker						
10 years experience worker						
Process engineer Manager						
Process engineer Supervisor						
Consultant						
Average						

According to the Table 31, there are 5 majors' criteria that requires most attention by the company. Team members in this project will get to vote the scores of each alternative. The maximum total of score of each alternative that each member will get to score is 20 whereas the lowest score is 5.

In Table 32 will described how each criteria and score related. The details of score description has been analysed and agreed by the case study company to be used for selecting the best alternative however other companies may use different criteria for selecting alternative.

Table 32: Criteria and Score for assessing alternative solutions

Score / Criteria	**1**	**2**	**3**	**4**	**5**
Productivity (Expected output)	Less than 60 pieces	60-65 pieces	65 - 68 pieces	68 - 70 pieces	More than 70 pieces
Quality (Probability of Defects occurance)	More than 15%	11 % - 15 %	6 % - 10 %	1 % - 5 %	0%
Cost (Investment fund)	More than 500,000 Baht	100,000 – 500,000 Baht	50,001 – 100,000 Baht	10,000 – 50,000 Baht	Less than 10,000
Safety (Probability of unsafety)	No probability of unsafety	Low probability of unsafety	Medium probability of unsafety	High probability of unsafety	Very high probability of unsafety
Environment (probability of environment impact)	Non-impact	Low impact	Medium impact	High impact	Very high impact

1. Productivity – the output of finish products that are increasing. If the productivity gets a higher score than the maximum will be at 5 where the goal of productivity is at least 70.

2. Quality – the alternative that are used will not create any issues regarding the quality. If the alternative tends to effect the quality in negative ways, it will be considered with a lower score. The lowest score of 1 will mean more than 15% of probability of defects because the company can't tolerate more than 15% probability of defects that may occur in the assembly line. The highest score of 5 will mean no probability of defects.

3. Cost – The more costly in the implementation of the alternative, the lower the score it will be given, because there is a certain amount of budget for this implementation. The cost will be an estimated value where it could be vary according to experience of voters.

4. Safety – the alternative have to be safe for the operator to use. Safety is highly concerned and important. It will also include ease of use and ergonomic design for workers to be able to handle safely and easily. The score will be rank based on the safety handling of the solutions. The score of 5 will mean no probability of safety issues. The score of 1 will mean high chance of unsafety can occur.

5. Environment – The alternative is creating pollution or not. The more pollution the lower the score will be given/allocated. The score of 5 will be non-impact which mean no pollution is created and the score of 1 will mean high impact to environment and create loads of pollution

4.1 Transportation Waste

After studying the Lay part station process to understand the overall process using process activity chart, the schedule for brainstorming ideas for suggesting solutions had been conducted. The purpose of the meeting was to generate all possible solutions for solving transportation waste that occurred in Lay part Station in order to improve the cycle time in the process.

The alternatives are suggested as following:

1. Using Trolley that can carry all parts at once.
2. Using conveyor line to transport parts to assembly line.
3. Increase the size of Wasu boards to carry more components per round.

4.1.1 Design and develop Trolley that can carry all parts at once.

Process activity chart in Table 33 has shown the highlighted part of Transportation waste in Lay part station.

Table 33: Process Activity Chart of Lay part station focusing on transportation waste

Process Activity Chart							
No.		Sheet no.	Of	Summary			
Subject Charted:	Lay Part			Activity	Present	Propose	Saving
Activity:	Lay Part			●	5		
				➡	15		
				▬			
				D			
				▼			
Method	Present		Proposed	Distance	67.8		
Location	Factory			Time	472		
				Charted by		Date	
				Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Prepare Wasu board for the assembly board	15		●	NNVA	Process
2. Set the assembly components in the position of five Wasu boards	277		●	VA	Process
3. Pick up two Wasu boards from Lay part station	3	0.2	⇨	NNVA	Motion
4. Walk to Assembly Board	13	11	⇨	NVA	Transportation
5. Set Wasu boards on the Assembly board	19		●	NNVA	Process
6. Collect the two empty Wasu Board from Assembly board	5	0.2	⇨	NNVA	Motion
7. Walk back to Lay part Station	13	11	⇨	NVA	Transportation
8. Put down two spare Wasu boards on the Lay part station	5	0.2	⇨	NNVA	Motion
9. Pick up two Wasu boards from Lay part station	5	0.2	⇨	NNVA	Motion
10. Walk to Assembly Board	13	11	⇨	NVA	Transportation
11. Set Wasu Boards on the Assembly board	20		●	NNVA	Process
12. Collect the two empty Wasu Board from Assembly board	5	0.2	⇨	NNVA	Motion
13. Walk back to Lay part Station	13	11	⇨	NVA	Transportation
14. Put down two spare Wasu boards on the Lay part station	5	0.2	⇨	NNVA	Motion
15. Pick up one Wasu boards from Lay part station	5	0.2	⇨	NNVA	Motion

Description	Time (Sec)	Distance (m)	Symbol	Type of activity	Type of Waste
16. Walk to Assembly Board	13	11		NVA	Transportation
17. Set Wasu Board on the Assembly board	20			NNVA	Process
18. Collect the one empty Wasu Board from Assembly board	5	0.2		NNVA	Motion
19. Walk back to Lay part Station	13	11		NVA	Transportation
20. Put down one Empty Wasu boards on the Lay part station	5	0.2		NNVA	Motion
Total	472	67.8			

The team has brainstormed and recognized that the most problem that effect the cycle time of the process is when operator need to go back and forth between assembly board and lay part station. This causes not just high cycle time but also affect the fatigue of operator because the operator will have an average walk from transportation waste of 66 metres per round and with the current rate of production of 55 pieces. The operator will have to talk 55 x 66 metres = 3,630 metres per day.

Therefore, the team have decided to eliminate the transportation waste between lay part station and assembly board by applying the trolley. The Trolley will be used for transporting Wasu boards and help get the process done at one round time instead of having operator walking back and forth between lay part station and assembly board for several rounds. The trolley that could carry Wasu board will have appearance similar to the Figure 75:

Figure 75: Trolley designed for carrying Wasu boards

Table 34: Matrix score of implementing trolley in to lay part station

	Criteria					
Team Members	Productivity	Quality	Cost	Safety	Environment	Total (20)
Production department Manager	5	5	5	5	5	20.00
Production one section manager	5	5	5	4	5	19.00
Production one supervisor	5	5	5	4	5	19.00
Assistant Production Supervisor	5	5	5	4	5	19.00
10 years experience worker	4	5	5	5	5	19.00
10 years experience worker	4	5	5	5	5	19.00
10 years experience worker	4	5	5	5	5	19.00
Process engineer Manager	5	5	5	4	5	19.00
Process engineer Supervisor	5	5	5	4	5	19.00
Consultant	5	5	5	5	5	20.00
Average	4.7	5	5	4.5	5	19.20

From the Matrix score of implementing trolley machine into lay part station, the team has scored at the average of 19.20 out of 20. It means that the trolley idea could be possible for implementing and have almost non negative effect to the process. The most concern of this implement from some team members are the factor of safety and because it needs to be well analysed and follow the work study standard in order to prevent any unsafety issues that may occur.

Table 35: Pros and cons of using trolley

Pros	**Cons**
1. Low cost for implementing and creating	1. Limited for capacity extension
2. Low maintenance cost	2. Consuming working space in production line
3. Easy to use and understand	

Table 35 has illustrated Pros and Cons of using trolley for improving cycle time in Lay part station. The important benefits from using trolley is the cost because it takes low cost to build the trolley and it is easily for operators to understand how to use appropriately however on the downside is the limited capacity extension.

4.1.2 Using conveyor line to transport parts to assembly line

After brainstorming, a concept suggested that to deal with the transportation waste in lay part station. The operator should not be moving from the station, therefore the raw materials should move it self which means that there should be machine that carry components from Lay part station in to the assembly line. The example of idea could be described in Figure 76:

Figure 76: Example of Conveyor line for transporting components to the assembly line

Table 36: Matrix score of implementing Rotating conveyor line in to lay part station

	Criteria					
Team Members	Productivity	Quality	Cost	Safety	Environment	Total (20)
Production department Manager	5	5	1	4	3	15.00
Production one section manager	5	5	1	4	4	15.00
Production one supervisor	5	5	1	5	3	16.00
Assistant Production Supervisor	5	5	1	4	2	15.00
10 years experience worker	5	5	1	3	3	14.00
10 years experience worker	5	5	1	3	3	14.00
10 years experience worker	5	5	1	3	3	14.00
Process engineer Manager	5	5	2	5	3	17.00
Process engineer Supervisor	5	5	2	5	3	17.00
Consultant	5	5	1	5	3	16.00
Average	5	5	1.2	4.1	3	15.30

From the Matrix score of implementing rotating conveyor line in to lay part station, it received response score average of 15.30. The criteria that is the highest concern is in cost because in order to create conveyor line, the company needs to heavily invest in the machine and also there are limitation of space of working. The concept of this conveyor line might be helpful for expansion plan in the future however, it might not be appropriate for the company to pay high cost at this period of time, especially if there are similar methods that can provide the same results at the moment.

Table 37: Pros and cons of using conveyor line to transport parts.

Pros	Cons
1. High capacity extension	1. High cost to implement the change
2. Completely eliminate transportation waste	2. High maintenance cost
3. Ability to control the consistency of production rate output	3. Engineers still lack of technical knowledge to maximize the use of machine.

4.1.3 Increase size of the Wasu board

After internal discussion among team members, the solution of increasing Wasu board have been raised. The increasing size of Lay part Wasu board will help reduce the transportation waste by making new lay part Wasu board that can carry out more components in order to reduce numbers of walking back and forth between assembly board and lay part station.

Figure 77: Current five Wasu boards

Figure 78: Current size of Wasu board in the operator hand

Table 38: Matrix diagram of increase size of Wasu board

	Criteria					
Team Members	Productivity	Quality	Cost	Safety	Environment	Total (20)
Production department Manager	5	5	5	3	5	18.00
Production one section manager	5	5	5	4	5	19.00
Production one supervisor	5	5	5	3	5	18.00
Assistant Production Supervisor	5	5	5	5	5	20.00
10 years experience worker	5	5	5	3	5	18.00
10 years experience worker	5	5	5	3	5	18.00
10 years experience worker	5	5	5	3	5	18.00
Process engineer Manager	5	5	5	4	5	19.00
Process engineer Supervisor	5	5	5	4	5	19.00
Consultant	5	5	5	4	5	19.00
Average	5	5	5	3.6	5	18.60

The score of an average 18.60 in the Table 38 illustrated that the proposed alternative might be possible to use however the barriers of implementing this alternative are the ergonomics term standard because by increasing the Wasu board width, it might affect the work standard and it might causes injuries to worker because as seen from Figure 78 of current size of Wasu board, the operator’s hand is the average size of the operator in the assembly line. If Wasu board ought to be increasing the size, the working standard carrying equipment must be considered in more detail.

Table 39: Pros and cons Increase size Wasu boards

Pros	**Cons**
1. Low cost to implement	1. Not easy to use due to the size that are bigger and heavier weights.
2. Workers familiar with the equipment	2. Have probability of injuring workers for consistency long time use.

4.2 Motion Waste

After studying the lay Wire station and Wire Assembly station to understand the overall process and investigate on Motion waste using process activity chart. The schedule for brainstorming ideas for suggesting solutions has been conducted. The purpose of the meeting was to generate all possible solutions for solving motion waste that occur in Lay Wire station and Wire Assembly Station in order to improve the cycle time in process. Therefore, there are two alternatives proposed for improving Motion waste in the lay wire station and Wire Assembly station:

1. Introducing Tofix board
2. Install Conveyor Line

The process activity chart of Wire Assembly part station will be shown as following in order to explain which part of activity task that will be consider of evaluation for solution.

Table 40: Process activity chart of Wire Assembly station focus on Motion waste.

<table>
<tr><td colspan="8">Process Activity Chart</td></tr>
<tr><td colspan="4">No. Sheet no. Of</td><td colspan="4">Summary</td></tr>
<tr><td>Subject Charted:</td><td colspan="3">Wire Assembly</td><td>Activity</td><td>Present</td><td>Propose</td><td>Saving</td></tr>
<tr><td>Activity:</td><td colspan="3" rowspan="6">Wire Assembly</td><td>●</td><td>12</td><td></td><td></td></tr>
<tr><td></td><td>➡</td><td>4</td><td></td><td></td></tr>
<tr><td></td><td>■</td><td></td><td></td><td></td></tr>
<tr><td></td><td>D</td><td></td><td></td><td></td></tr>
<tr><td></td><td>▼</td><td></td><td></td><td></td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Method</td><td>Present</td><td></td><td>Proposed</td><td>Distance(m)</td><td>0.8</td><td></td><td></td></tr>
<tr><td>Location</td><td colspan="3" rowspan="3"></td><td>Time (sec)</td><td>468</td><td></td><td></td></tr>
<tr><td></td><td>Charted by</td><td></td><td>Date</td><td></td></tr>
<tr><td></td><td>Approved by</td><td></td><td>Date</td><td></td></tr>
</table>

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Sub-assemble the wire with components to get Pre Assemble Wire 1	91			VA	Process
2. Roll the wire in to circle shape and tight up with elastic band	21			NVA	Motion
3. Hang the wire no.1 on the bar	3	0.2		NVA	Motion
4. Sub-assemble the wire with components to get Pre Assemble Wire 2	92			VA	Process
5. Roll the wire in to circle shape and tight up with elastic band	22			NVA	Motion
6. Hang the wire no.2 on the bar	3	0.2		NVA	Motion
7. Sub-assemble the wire with components to get Pre Assemble Wire 3	94			VA	Process
8. Roll the wire in to circle shape and tight up with elastic band	21			NVA	Motion
9. Hang the wire no.3 on the bar	3	0.2		NVA	Motion
10. Sub-assemble the wire with components to get Pre Assemble Wire 4	93			VA	Process
11. Roll the wire in to circle shape and tight up with elastic band	22			NVA	Motion
12. Hang the wire no.4 on the bar	3	0.2		NVA	Motion
Total	468	0.8			

The process activity chart mapping of Lay Wire station will be shown as following in order to explain which part of activity that will be consider of evaluation for solution.

Table 41: Process activity chart of Lay wire station focus on Motion waste.

Process Activity Chart							
No.	Sheet no.		Of	Summary			
Subject Charted:	Lay Wire			Activity	Present	Propose	Saving
Activity:	Lay Wire			●	5		
				➡	8		
				▢			
				D			
				▼			
Method	Present		Proposed	Distance (m)	23		
Location	Factory			Time (sec)	504		
				Charted by		Date	
				Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to Hanging Bar of Wire Assembly Station	13	11	➡	NVA	Transportation
2. Pick up the Wire Assembly Wires	8		➡	NNVA	Motion
3. Walk to Assembly Board Station	13	11	➡	NVA	Transportation
4. Hang all the Harness on the Bar on the Assembly board	10	0.2	➡	NVA	Motion
5. Take off Wire no.1	24	0.2	➡	NVA	Motion
6. Lay wire no.1 on the assembly board	91		●	VA	Process

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
7. Take off Wire no.2	23	0.2	➡	NVA	Motion
8. Lay wire no.2 on the assembly board	92		●	VA	Process
9. Take off Wire no.3	24	0.2	➡	NVA	Motion
10. Lay wire no.3 on the assembly board	93		●	VA	Process
11. Take off Wire no.4	23	0.2	➡	NVA	Motion
12. Lay wire no.4 on the assembly board	90		●	VA	Process
Total	504	23			

4.2.1 Introducing Transferring board

Transferring board or Tofix board (common name for using in JASO standard) is the concept from Lay part's "Wasu board" where it will help operators on managing the parts and transfer parts to assembly line. Tofix board however will help transferring wires instead of parts and also help wires to not binding each other by having the slot provided for each single wire and also it will help operator to reduce cycle time of laying the wire on the board due to its ease of use. Tofix board will have appearance as below:

Figure 79: Tofix board appearance

Implementing Tofix board will significantly improve the cycle time because it will help eliminate the motion of taking off wires from rubber band because there will and it could reduce time of laying the wire on the assembly board due to the ease of use from Tofix board. From the analysis, the score results as in Table 42:

Table 42: Matrix Score diagram of using Tofix board.

	Criteria					
Team Members	Productivity	Quality	Cost	Safety	Environment	Total (20)
Production department Manager	5	5	5	5	5	20.00
Production one section manager	5	5	5	5	5	20.00
Production one supervisor	5	5	5	5	5	20.00
Assistant Production Supervisor	5	5	5	5	5	20.00
10 years experience worker	4	4	5	5	5	18.00
10 years experience worker	4	4	5	5	5	18.00
10 years experience worker	4	4	5	5	5	18.00
Process engineer Manager	5	5	5	5	5	20.00
Process engineer Supervisor	5	5	5	5	5	20.00
Consultant	5	5	5	5	5	20.00
Average	4.7	4.7	5	5	5	19.40

From the Table 42, we could see that the score represents the performance and possibility of the Tofix board alternative with the average score of 19.40. The main obstacle for this solution is the installation set up where the team need to develop equipment prior to Tofix board use such as trolley and jig fixtures for carrying Tofix board.

Table 43: Pros and cons of using Tofix board

Pros	Cons
Low cost of implementing	Limited capacity extension
Reduce the wires binding	
Easy to use and similar to Wasu board	
Low maintenance cost	

From Table 43, we could see the pros and cons of implementing transferring board. The main benefits are the low cost and easy to use whereas the downside is the limited capacity for extending production output.

4.2.2 Install Conveyor Line

Conveyor line have been introduced by most of the team members. The concept of conveyor line is to let the operator working in just their position and let the assembly board move by itself. Conveyor line can help fixing the time of the whole process from beginning of assembly until the end of the assembly. By using conveyor line, operator will have better motion on their specific task because they will have limited time for getting the task done the board will go pass their station and they would not be able to reach it.

Figure 80: Example of Conveyor line Assembly

After discussion with in the meeting, the score can be described as a result in Table 44 below:

Table 44: Matrix Score diagram of using conveyor line.

	Criteria					
Team Members	Productivity	Quality	Cost	Safety	Environment	Total (20)
Production department Manager	5	5	1	4	2	15.00
Production one section manager	5	5	1	4	2	15.00
Production one supervisor	5	5	1	4	3	15.00
Assistant Production Supervisor	5	5	1	4	3	15.00
10 years experience worker	5	5	1	3	3	14.00
10 years experience worker	5	5	1	3	3	14.00
10 years experience worker	5	5	1	3	3	14.00
Process engineer Manager	5	5	1	5	2	16.00
Process engineer Supervisor	5	5	1	5	2	16.00
Consultant	5	5	1	5	3	16.00
Average	5	5	1	4	2.6	15.00

From the Table 44, we could see that the score represents 15.00 out of 20. The reason the score is quite low comparing to another alternative is because the cost that will need to invest on implementing it, but it could be a good use for a long term investment for the company. The company might reevaluate using Conveyor line once the company have good financial support and more orders

.

Table 45: Pros and cons of using Conveyor line

Pros	Cons
Improve entire process and reducing motion waste	High cost of implementation
Easily fix the production rate time with at takt time	High cost of maintenance
	Not significantly reduce the binding of wires issues

4.3 Conclusion for selecting alternatives

4.3.1. Selecting solution for transportation waste

Table 46: Comparing total score of each alternative for improving transportation waste

	Criteria		
Team Members	Using Trolley for carring parts	Rotating Conveyor line	Increase size of Wasu board
Production department Manager	20.00	15	18
Production one section manager	19.00	15	19
Production one supervisor	19.00	16	18
Assistant Production Supervisor	19.00	15	20
10 years experience worker	19.00	14	18
10 years experience worker	19.00	14	18
10 years experience worker	19.00	14	18
Process engineer Manager	19.00	17	19
Process engineer Supervisor	19.00	17	19
Consultant	20.00	16	19
Average	19.20	15.3	18.6

Table 47: Comparing each criteria's average score of each alternatives for improving motion waste

Criteria \ Alternative	Trolley	Rotating Conveyor line	Increase size of Wasu board
Productivity	4.7	5	5
Quality	5	5	5
Cost	5	1.2	5
Safety	4.5	4.1	3.6
Environment	5	3	5
Average Total	4.84	3.66	4.72

According from Table 34, 36 and 38, we could summarize the results by comparing the score of each alternatives for transportation waste improvement as in Table 46 and Table 47. The result shown the average score of each criteria and alternatives. The highest score goes to implementing Trolley with the average of 19.20 and the upcoming of 18.60 from Increase size of Wasu board alternative and lastly score 15.30 from conveyor line. The results shown that trolley is the best alternative in this situation for improving cycle time and improve the transportation waste. Unfortunately, comparing the score of increase size of Wasu board alternative, the score are not far from each other however the team has pointed out that in term of safety issues, it is important for operator to be able to work in long period of time. If the size of Wasu board has increased it might affect the fatigue of workers and might causes the injuries. In the perspective of using conveyor line, it is a good alternative for long term investment however at this certain point of time. The company is not willing to invest in it. Therefore Trolley is the best alternative that has chosen for improving transportation waste in the Wiring harness assembly process.

4.3.2. Selecting solution for improving motion waste

Table 48: Comparing total score of each alternative for improving motion waste

Team Members	Criteria	
	Using Transferring board (Tofix board)	Install conveyor line
Production department Manager	20	15
Production one section manager	20	15
Production one supervisor	20	15
Assistant Production Supervisor	20	15
10 years experience worker	18	14
10 years experience worker	18	14
10 years experience worker	18	14
Process engineer Manager	20	16
Process engineer Supervisor	20	16
Consultant	20	16
Average	19.4	15

Table 49: Comparing each criteria's average score of each alternatives for improving motion waste

Criteria \ Alternative	Tofix board	Install Conveyor line
Productivity	4.7	5
Quality	4.7	5
Cost	5	1
Safety	5	4
Environment	5	2.6
TOTAL	4.88	3.52

According from Table 42 and 44, we could summarize the results by comparing the score of each alternatives for motion waste improvement as in Table 48 and Table 49. The company have decided to choose transferring board because the board can help in both stations on motion waste instantly and also it could be easily implemented and familiar with operators because it has been developed from Wasu board that are currently using in Lay part station which give workers familiar of working environment. In conclusion, conveyor line could be wise to invest in the future for the company however the most important thing for the company now is to instantly improve the cycle time in order to meet with the increasing of demand from customers.

CHAPTER 5: IMPLEMENTATION FOR IMPROVEMENTS AND CONTROL PLAN

In chapter 4, alternatives have been proposed and evaluated among the research team for improving transportation waste and motion waste. The alternatives for each waste had been chosen which are implementing Trolley for Lay part station and Tofix board for both Wire Assembly station and lay wire station. In this chapter 5, the research will implement the alternatives in the factory of Case Study Company. Therefore implementation plan for the action must be conducted and follow by the team as in the Table 48 shown.

Table 50: Implementation plan

Steps	Description	Responsible	Start Time	End Time
1	Install the alternatives in production line	Process Engineer	23-03-15	03-04-15
2	Training operators for new equipment and methods	Production Manager	03-04-15	04-04-15
3	Review work instruction of the process with operators.	Supervisor /	06-04-15	06-04-15
4	Trial run the production	Production Manager / Supervisor / Operators	06-04-15	17-04-15
5	Analyse the results from trial run production	Production Manager / Author / Supervisor / Process Engineer	20-04-15	24-04-15
6	Create work instruction for new production line	Production Manager / Process Engineer	24-04-15	30-04-15
7	Start Running production with new solution	Production Manager / Supervisor / Operators	10-05-15	30-06-15
8	Evaluate the results	Production Manager / Author	01-07-15	10-07-15

5.1 Implementing solutions

5.1.1 Implementing Trolley for transporting Wasu board from Lay part Station to Assembly line.

Before discussion the ergonomic design of the trolley, considering the significance of ergonomics design is crucial. As it was not anticipated by the researcher that such a design change would be required, it is only to just to describe the relative importance of ergonomics design before engaging in the process of implementation. According to (Grossmith 1998) “The role ergonomics plays in improving productivity and quality has been well documented although generally not well recognized. In most cases, ergonomics interventions have been reactive, i.e. initiated only after an injury has occurred and after losses have been sustained to both the organization and the worker(s)”. What they were referring to is that with a proper ergonomic design, it not only affects the performance of the workers in the production line, but it ultimately also improves the overall profitability of the company. For instance, with a better designed trolley the outcomes are wide, such as faster production time, more production quantity and etc (Sánchez 2014). (Sánchez 2014) further demonstrated that in industrial engineering, re-design a simple work-station can result in improved productivity. It is all about the suitability and comfort of the operators in the long-run. Ergonomics are also crucial in the overall performance of the worker and therir long-term health risks. Carpel tunnel syndrome and others are examples of how workers can be in risk by repeated performance of the same task (Eatough EM 2012).However, it is well understood that poor ergonomic conditions does not result in some serious injuries, but it can greatly affect productivity in two levels. Firstly, it can affect the productivity based on inefficiency of the design, and secondly, based on the stress on the human body due to the poor ergonomic design (Luttmann 2010); (Cavanagh 2012). It is precisely for these reasons that the researcher of this paper have decided that ergonomic implementation is also crucial in improving the time in which the wiring harnesses are made, which further elaborates the objectives and goals of the implementation process.

This implementation involves the creating of trolley cart for carrying Wasu board in order to improve the transportation waste between Lay part station and the Assembly line.

Figure 81: Meeting for implementing Trolley

The Figure 81, shows the meeting had been held for brainstorming ideas on creating the trolley for lay part station. The process engineer team is the leader for developing the prototype of Trolley. The prototype will have an appearance as in Figure 82:

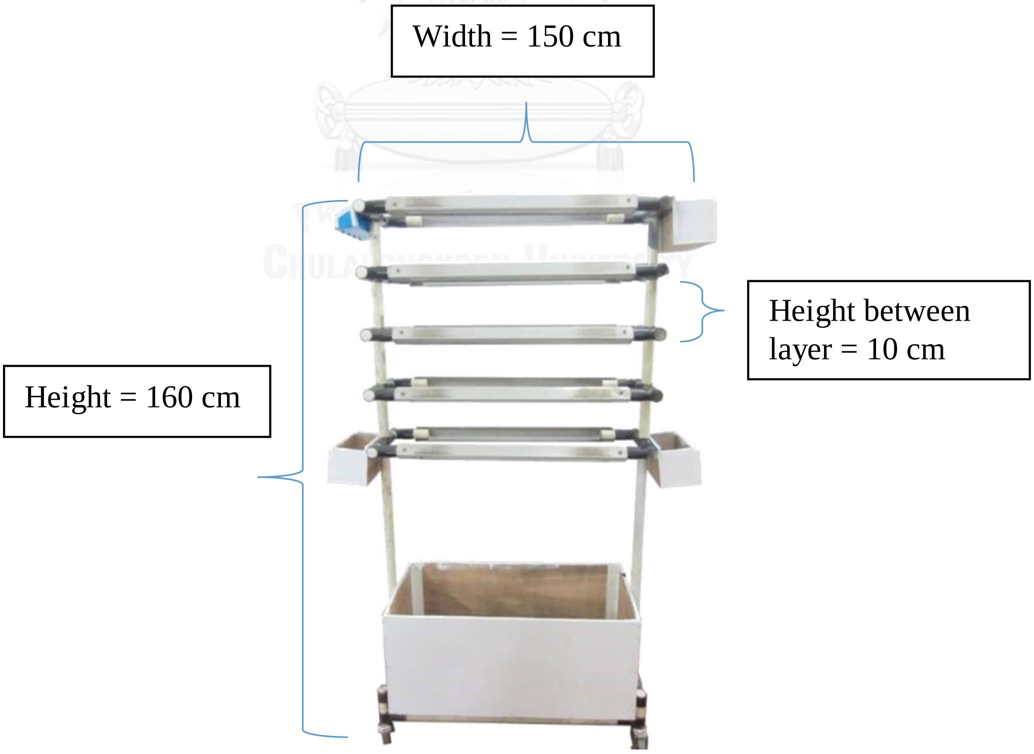

Figure 82: Lay Part Trolley design

Figure 83: Side view of Trolley

The main components are made from PVC pipe and woods. The main concept for creating Trolley will be based from “Common Posture measurement” from Work study ergonomics. The dimensions of trolley will be described as below:

Height

According from the measurement, the height where operator should be able to reach Wasu board from trolley is around 151 cm to 165 cm. Therefore our process engineer have decided to use the height of 160 cm.

Width

In term of width size of trolley, process engineer decided to use 120 cm because maximum length of Wasu board is 100 cm which there are 20 cm in spare for protecting Wasu board to get damaged.

Deep

The deep side has been fixed with the limited idle space as in Figure 85. The space has idle area for 120 cm however it must be concern with operator walking in parallel. Therefore the deep dimension for Lay part trolley to go in assembly line will be 40 cm and operator need to push the trolley in on side way because it use space lower than pushing trolley with front view inside that have width of 150 cm.

The average of workers height for women in the company are around 157 cm. The trolley are designed based on the Ergonomic guideline BIFMA (2002) (Scott Openshaw 2006). According to the Measurement table presented below:

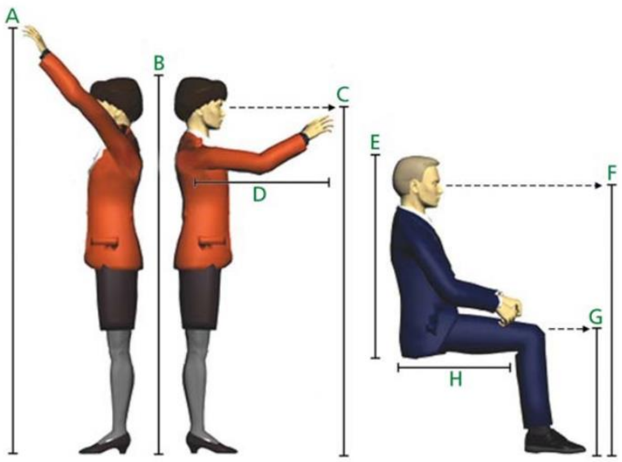

Figure 84: Common office environment Posture measurements.

Table 51: Anthropometric measurements (including allowances for clothing) of small and large males and females, from BIFMA Ergonomics Guidelines, 2002. All measurements are in inches.

Measurement	Letter	Female	Male
Standing Overhead Reach	A	74.9” – 86.8”	81.2” – 93.7”
Standing Height	B	60.2” – 68.4”	64.8” – 73.5”
Standing Eye hieght	C	56.9” – 65.0”	61.4 “ – 69.8”
Standing Forward Reach	D	30.8 “ – 36.1”	33.8” – 39.5”
Sitting Height	E	31.3 “ – 35.8”	33.6” – 38.3”

Sitting Eye height	F	42.6 “ – 48.8”	46.3” – 52.6”
Sitting knee height	G	19.8” – 23.2”	21.4” – 25.0”
Seat Depth	H	16.9” – 20.4”	17.7” – 21.1”

On the other hand, trolleys have to fit with the production plant layout by utilizing the idle-space (120 cm) as shown below in Figure 85. The space is sufficient for the trolley to be use inside the production line.

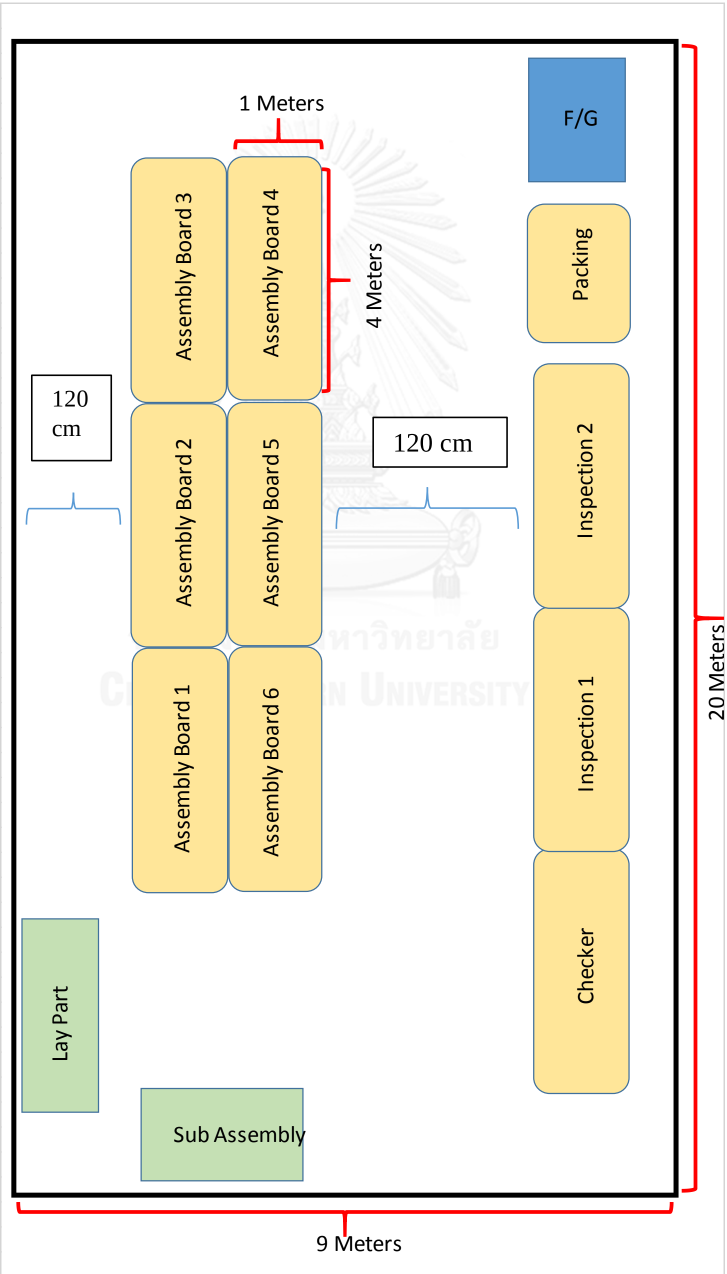

Figure 85: Idle Space of Walking route in Assembly line

After trolley has been created and implemented, the team has conducted a trial–run with the prototype of trolley for ten days in order to confirm the appropriate usage and its functionality. The trolley in the assembly line can be seen in Figure 86 and Figure 87

Figure 86: Lay part's Trolley in Assembly line

Figure 87: Lay part's Trolley with Five Wasu boards

After testing using trolley for ten days, the team has agreed that there are no errors or defects during usage and it is ready to be used for long term production. Therefore, the new process activity chart can be described as in Table 52, comparing with before implementation process activity chart.

Table 52: New process activity chart of Lay part station

Process Activity Chart

Lay Part before Implementation

No.	Sheet no. Of		Summary			
Subject Charted:	Lay Part		Activity	Present	Propose	Saving
Activity:	Lay Part before Implementation		●			
			➡			
			■			
			D			
			▼			
Method	Present	Proposed	Distance	67.8		
Location	Factory		Time	472		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of	Type of Waste
1. Prepare Wasu board for the assembly board	15		●	NNVA	Process
2. Set the assembly components in the position of five Wasu boards	277		●	VA	Process
3. Pick up two Wasu boards from Lay part station	3	0.2	➡	NNVA	Motion
4. Walk to Assembly Board	13	11	➡	NVA	Transportation
5. Set Wasu boards on the Assembly board	19		●	NNVA	Process
6. Collect the two empty Wasu Board from Assembly board	5	0.2	➡	NNVA	Motion
7. Walk back to Lay part Station	13	11	➡	NVA	Transportation
8. Put down two spare Wasu boards on the Lay part station	5	0.2	➡	NNVA	Motion
9. Pick up two Wasu boards from Lay part station	5	0.2	➡	NNVA	Motion
10. Walk to Assembly Board	13	11	➡	NVA	Transportation
11. Set Wasu Boards on the Assembly board	20		●	NNVA	Process
12. Collect the two empty Wasu Board from Assembly board	5	0.2	➡	NNVA	Motion
13. Walk back to Lay part Station	13	11	➡	NVA	Transportation
14. Put down two spare Wasu boards on the Lay part station	5	0.2	➡	NNVA	Motion
15. Pick up one Wasu boards from Lay part station	5	0.2	➡	NNVA	Motion
16. Walk to Assembly Board	13	11	➡	NVA	Transportation
17. Set Wasu Board on the Assembly board	20		●	NNVA	Process
18. Collect the one empty Wasu Board from Assembly board	5	0.2	➡	NNVA	Motion
19. Walk back to Lay part Station	13	11	➡	NVA	Transportation
20. Put down one Empty Wasu boards on the Lay part station	5	0.2	➡	NNVA	Motion
Total	472	67.8			

Lay Part After Implementation

No.	Sheet no. Of		Summary			
Subject Charted:	Lay Part		Activity	Present	Propose	Saving
Activity:	Lay Part After Implementation		●			
			➡			
			■			
			D			
			▼			
Method	Present	Proposed	Distance	22.6		
Location	Factory		Time	371		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (M)	Symbol	Type of Activity	Type of Waste
1. Prepare Wasu board for the assemble	15		●	NNVA	Process
2. Lay assembly components in the position of five Wasu boards	276		●	VA	Process
3. Set Wasu board on Trolley machine	12	0.2	➡	NNVA	Process
4. Move Tray machine to Assembly Board	14	11	➡	NNVA	Transportation
5. Put the Wasu boards on the Assembly baord	28	0.2	➡	NNVA	Motion
6. Pick up empty Wasu boards to Trolley	12	0.2	➡	NNVA	Motion
7. Move Trolley back to Lay Part station	14	11	➡	NNVA	Transportation
TOTAL	371	22.6			

According to the Table 52, the process steps has been reduced from 20 steps to 7 steps. The results of total time usage has been significantly reduce to 371 seconds from previous 472 seconds. The different is 101 seconds however the transportation waste has been reduced 50 seconds. The other 60 seconds that has been indirectly improved came from the effect of using trolley which had reduced motion in the process of picking up and unloading Wasu boards several times. The conclusion of the results can be shown in Table 55.

Table 53: Comparing results before and after implementation trolley for lay part station.

	Before Implementation	After Implementation	Improvement	Reduced time %
Total Lay part Cycle Time	472 seconds	371 seconds	101 seconds	21.4%
Transportation Waste time	78 seconds	28 seconds	50 seconds	64.1%

5.1.2 Implement Transferring Board in Wire Assembly station

This implementation will involve the use of Transferring board (Tofix board) throughout the process for carrying out wires. The design of Tofix board has been develop from Lay part station's Wasu board. The design and appearance will look similar to Wasu board however, the difference parts are at the slots for holding the wires instead of holding the components. In order to implement Tofix board in to Wire Assembly Station, there are 3 main tools that need to be install in production line. The equipment are below:

1. Tofix board for holding wires
2. Sliding Gutter for holding Tofix board at the Wire Assembly station
3. Trolley for transporting Tofix board to the assembly line

Figure 88: Meeting for design and create Tofix board and equipment

1. Tofix board

The Tofix board concept has been developed from Wasu board of Lay part station where the application is to hole the components on the board for ease of moving the components. Process engineer team has use the model of Lay part Wasu board as the main prototype for designing Tofix board.

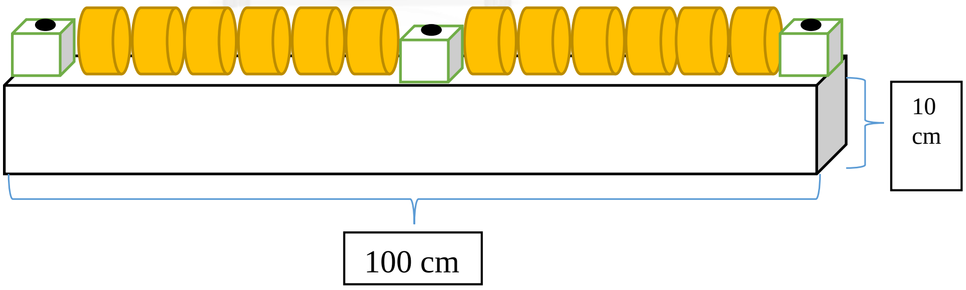

Figure 89: Sketch Design of Tofix board

According to the Figure 89, design of Tofix board, we based the length of 100 cm from the usage of wires that placed in. There will be 32 slots of Yellow slots in order to hold up to 30 wires per Tofix board. The width of 10 cm has been based from Wasu board because at this 10 cm, the hand of female workers in the company can be able to hold easily.

2. Sliding Gutter for the Wire Assembly Station

Sliding Gutter for Wire Assembly station will be installed for holding Tofix board during operator work in process. The installation design has been based on the standard of the female worker working standard “standing forward reach” category which can be described in Figure 90.

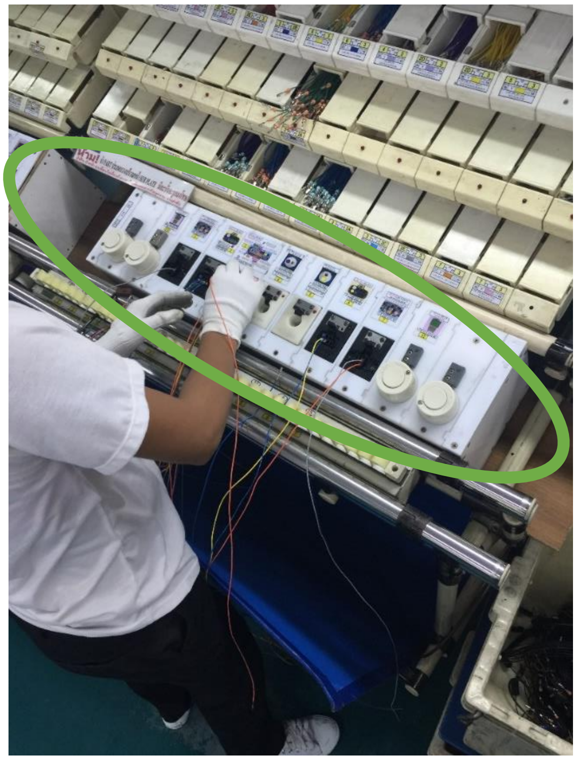

Figure 90: Installed Sliding Gutter at Wire Assembly Station

3. Trolley for transporting Tofix Board.

Tofix board has been designed and created similar to lay part trolley however there are slight modification in order to be able to carry wires instead of components. Since the trolley of Tofix board cannot carry Tofix board in different level layer similar to lay part’s trolley because the wires might get tied up or damaged. Therefore, the best way to arrange them is to put them into the same level of layer. The Figure 91, 92, 93 and 94 show Tofix board’s trolley.

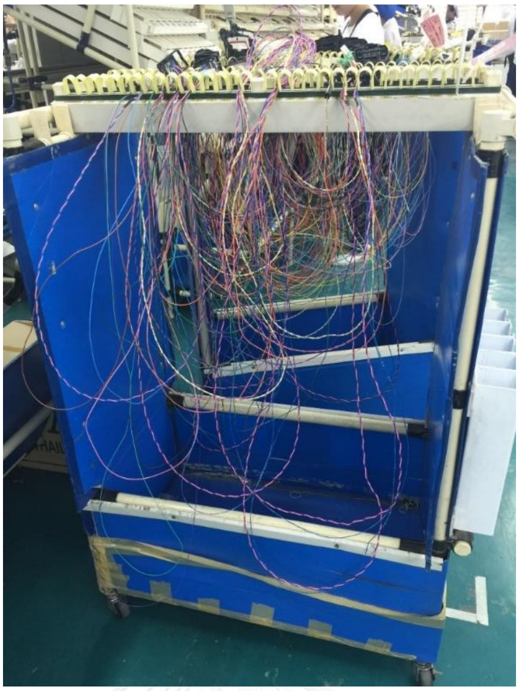

Figure 91: Back side of the Trolley

Figure 92: Side view of the Trolley

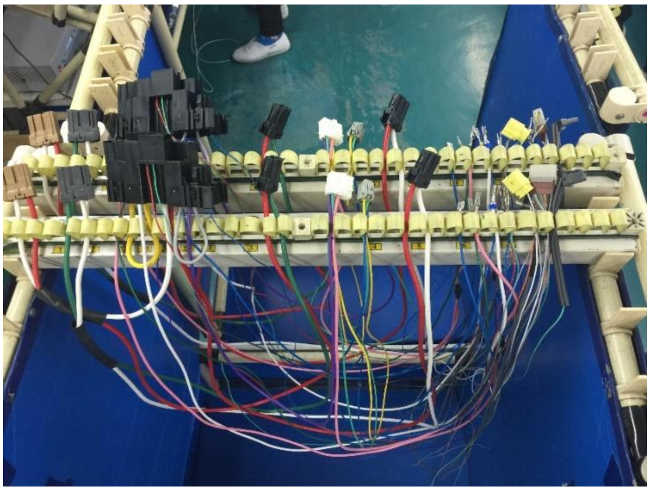

Figure 93: Top View of the Trolley

Figure 94: Holder for empty Tofix board

After testing using the trolley for ten days, the team has agreed that there are no errors or defects during usage and it is ready to be used for long term production. Therefore, the new process activity chart can be described as in Table 54 comparing with before implementation process activity chart.

Table 54: New process activity chart of Wire Assembly station

Process Activity Chart

No.	Sheet no. Of		Summary			
Subject Charted:	Wire Assembly		Activity	Present	Propose	Saving
Activity:	Wire Assembly before Implementation		●	4		
			⇨	8		
			▬			
			D			
			▼			
Method	Present	Proposed	Distance	0.8		
Location	Factory		Time	468		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Sub-assemble the wire with components to get Pre Assemble Wire 1	91		●	VA	Process
2. Roll the wire in to circle shape and tight up with elastic band	21		⇨	NVA	Motion
3. Hang the wire no.1 on the bar	3	0.2	⇨	NVA	Motion
4. Sub-assemble the wire with components to get Pre Assemble Wire 2	92		●	VA	Process
5. Roll the wire in to circle shape and tight up with elastic band	22		⇨	NVA	Motion
6. Hang the wire no.2 on the bar	3	0.2	⇨	NVA	Motion
7. Sub-assemble the wire with components to get Pre Assemble Wire 3	94		●	VA	Process
8. Roll the wire in to circle shape and tight up with elastic band	21		⇨	NVA	Motion
9. Hang the wire no.3 on the bar	3	0.2	⇨	NVA	Motion
10. Sub-assemble the wire with components to get Pre Assemble Wire 4	93		●	VA	Process
11. Roll the wire in to circle shape and tight up with elastic band	22		⇨	NVA	Motion
12. Hang the wire no.4 on the bar	3	0.2	⇨	NVA	Motion
Total	468	0.8			

No.	Sheet no. Of		Summary			
Subject Charted:	Wire Assembly		Activity	Present	Propose	Saving
Activity:	Wire Assembly after Implementation		●	4		
			⇨	2		
			▬			
			D			
			▼			
Method	Present	Proposed	Distance	0.3		
Location	Factory		Time	355		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1.Set four tofic boards on the Wire Assembly Station	15		⇨	NNVA	Motion
2. Sub-assemble the wire with components to get Pre Assemble Wire 1	83		●	VA	Process
3. Sub-assemble the wire with components to get Pre Assemble Wire 2	83		●	VA	Process
4. Sub-assemble the wire with components to get Pre Assemble Wire 3	82		●	VA	Process
5. Sub-assemble the wire with components to get Pre Assemble Wire 4	82		●	VA	Process
6. Put tofic board on the Tofix trolley	10	0.3	⇨	NNVA	Motion
Total	355	0.3			

In Table 54 shown above, the process steps has been reduced from 12 steps to 6 steps. The results of total time usage has been significantly reduce to 355 seconds from previously of 468 seconds. The cycle time improvement is 113 seconds however the motion waste has been reduced 73 seconds. The other 40 seconds that has been indirectly improved came from the effect of using Tofix board that help operators on assemble wires easier and more effectively. The conclusion of the results are shown in Table 55.

Table 55: Comparing results before and after implementation Tofix board for Wire Assembly station.

	Before Implementation	After Implementation	Improvement	Reduced Time %
Total Cycle Time	468 seconds	355 seconds	113 seconds	24.1%
Motion waste	98 seconds	25 seconds	73 seconds	74.5%

5.1.3 Implement Tofix Board in Lay Wire station

This implementation will continue using Tofix board to support on improving motion waste. In this Lay wire station, in order for Tofix board to be used in appropriate way, there need to be fixtures installed to the assembly board for holding the Tofix board during operator laying the wires.

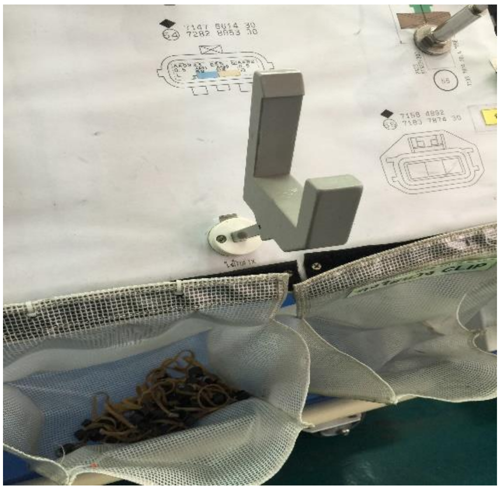

Figure 95: Fixtures installed on the Assembly board

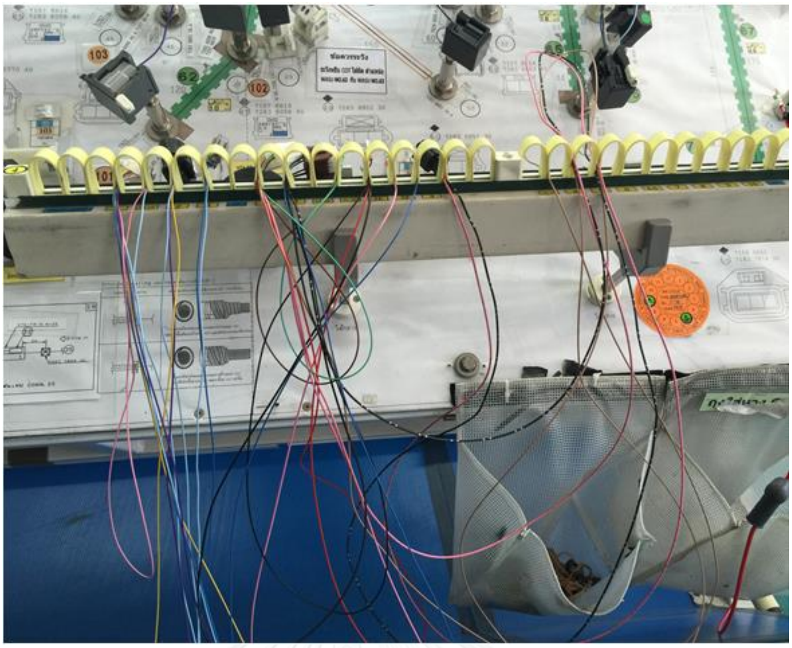

Figure 96: Fixtures holding the Tofix board on the assembly board

Figure 97: Operator is using Tofix board to lay wire

After testing it by using Tofix board for ten days, the team has agreed that there are no error or defects during usage and it is ready to be used for long term production. Therefore, the new process activity chart of Lay wire station can be described as shown in Table 56.

Table 56: New process activity chart of Lay wire station

Process Activity Chart

No.	Sheet no. Of		Summary			
Wireject Charte	Lay Wire		Activity	Present	Propose	Saving
Activity:	Lay wire before Implementation		●	4		
			➡	8		
			■			
			D			
			▼			
Method	Present	Proposed	Distance	23		
Location	Factory		Time	504		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to Hanging Bar of Wire Assembly Station	13	11	➡	NVA	Transportation
2. Pick up the Wire-Assembly Wires	8		➡	NNVA	Motion
3. Walk to Assembly Board Station	13	11	➡	NVA	Transportation
4. Hang all the Harness on the Bar on the Assembly board	10	0.2	➡	NVA	Motion
5. Take off Wire no.1	24	0.2	➡	NVA	Motion
6. Lay wire no.1 on the assembly board	91		●	VA	Process
7. Take off Wire no.2	23	0.2	➡	NVA	Motion
8. Lay wire no.2 on the assembly board	92		●	VA	Process
9. Take off Wire no.3	24	0.2	➡	NVA	Motion
10. Lay wire no.3 on the assembly board	93		●	VA	Process
11. Take off Wire no.4	23	0.2	➡	NVA	Motion
12. Lay wire no.4 on the assembly board	90		●	VA	Process
Total	504	23			

No.	Sheet no. Of		Summary			
Wireject Charte	Lay Wire		Activity	Present	Propose	Saving
Activity:	Lay wire after Implementation		●	4		
			➡	4		
			■			
			D			
			▼			
Method	Present	Proposed	Distance	33.3		
Location	Factory		Time	405		
			Charted by		Date	
			Approved by		Date	

Description	Time (sec)	Distance (m)	Symbol	Type of Activity	Type of Waste
1. Walk to Wire Assembly Station	13	11	➡	NNVA	Transportation
2. Move the Tofix's trolley from Wire Assembly station to Lay wire Station	13	11	➡	NNVA	Transportation
3. Unload Tofix board from Trolley to Assembly board	20	0.3	➡	NNVA	Motion
4. Lay wire no.1 on the assembly board	87		●	VA	Process
5. Lay wire no.2 on the assembly board	86		●	VA	Process
6. Lay wire no.3 on the assembly board	86		●	VA	Process
7. Lay wire no.4 on the assembly board	87		●	VA	Process
8. Move the Trolley back to Wire Assembly station	13	11	➡	NNVA	Transportation
Total	405	33.3			

According to the Table 56 shown above, the process steps has been reduced from 12 steps to 8 steps. The results of total time usage has been significantly reduce from average of 504 seconds to an average of 405 seconds. The cycle time improvement is 99 seconds and the motion waste has been reduced to 40 seconds from 112 seconds. The other 27 seconds that has been indirectly improved came from the effect of using Tofix board that help operators on lay wires easier and more effectively. The conclusion of the results are shown in Table 59.

Table 57: Comparing results before and after implementation Transferring board for Lay wire station.

	Before Implementation	After Implementation	Improvement	Reduced time %
Total Cycle Time	504 seconds	405 seconds	99 seconds	19.6 %
Motion Waste	112 seconds	20 seconds	92 seconds	82.1 %

5.2 Results after implementation

After implementation of solutions that improved transportation waste and motion waste in the production process. The results have been collected and analyzed by the author and team members in order to evaluate the solutions and long term plan on implementing with the future production line. The results can be shown in three Figures which are Figures 98, 99 and 100. The Figures will demonstrated the new cycle time and the outputs from 2 months experiment.

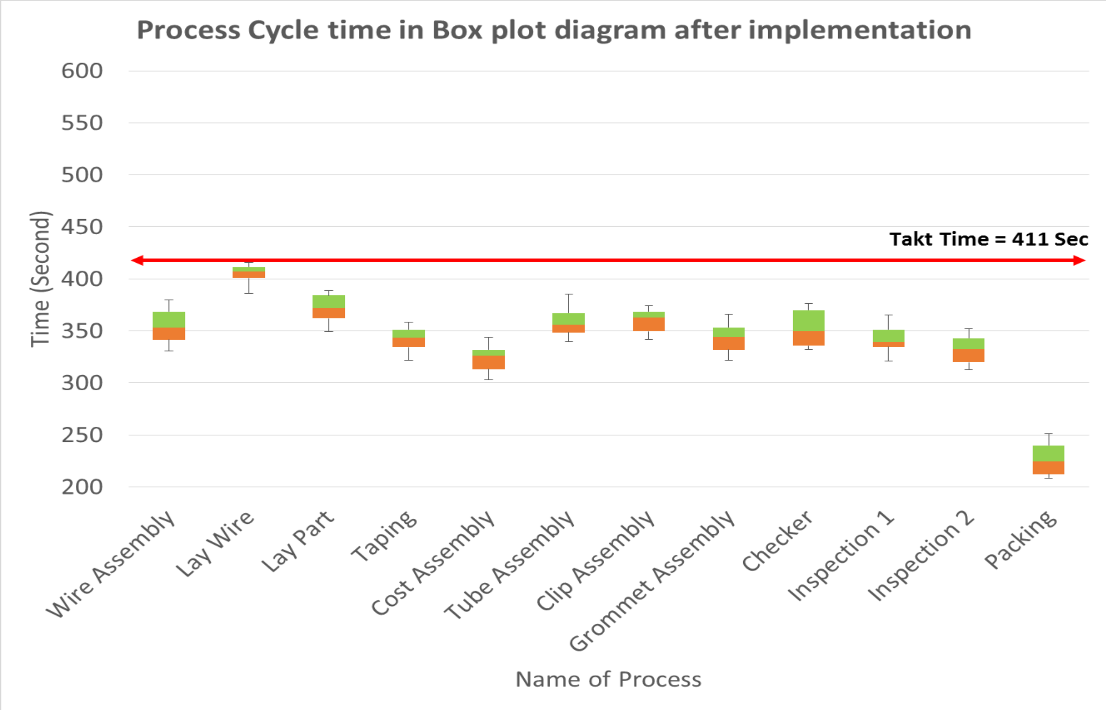

Figure 98: Process cycle time in Box plot diagram after implementation

In Figure 98, the new cycle time has been created where all of the cycle time in the process has not exceed the takt time of 411 seconds. The highest cycle time in the process is Lay wire with an average of 405 seconds. Therefore by accomplished

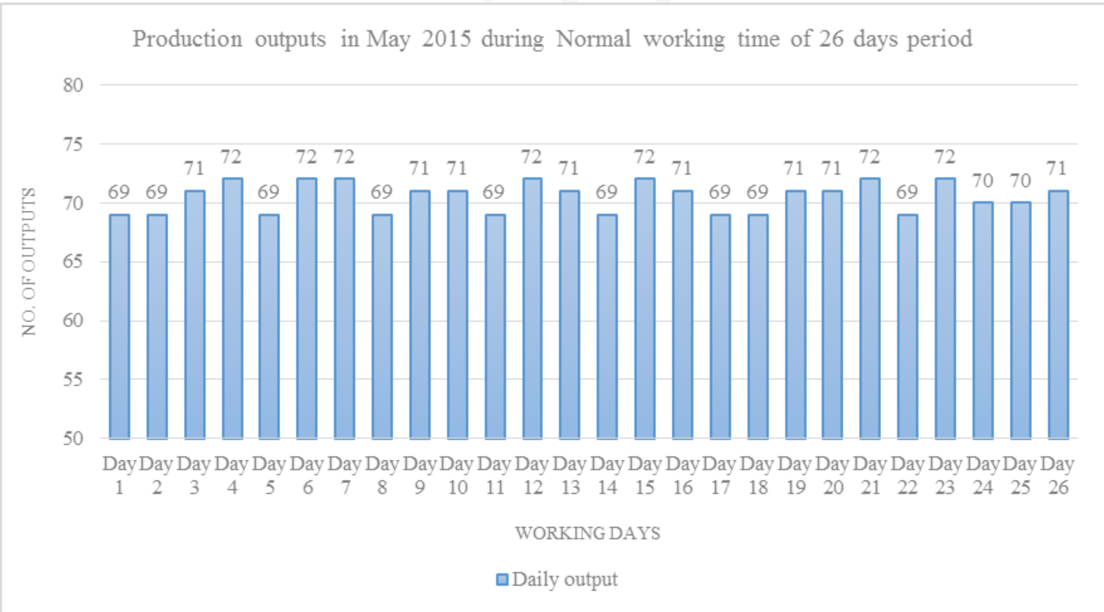

Figure 99: Production outputs in May 2015 during 26 days of working.

In the Figure 99, the graph demonstrated the outputs in May 2015 where the number of inputs (working hours, number of workers, resources and etc.) in the production process are remain the same except the methodology and equipment added to the process from the two new solutions implemented earlier. The total output is 1,833 pieces during 26 working days in May 2015 (excluded Sunday). The outputs has increased from average of 55 pieces to average of 70 with the lowest output of 69 pieces and the highest output of 72 pieces.

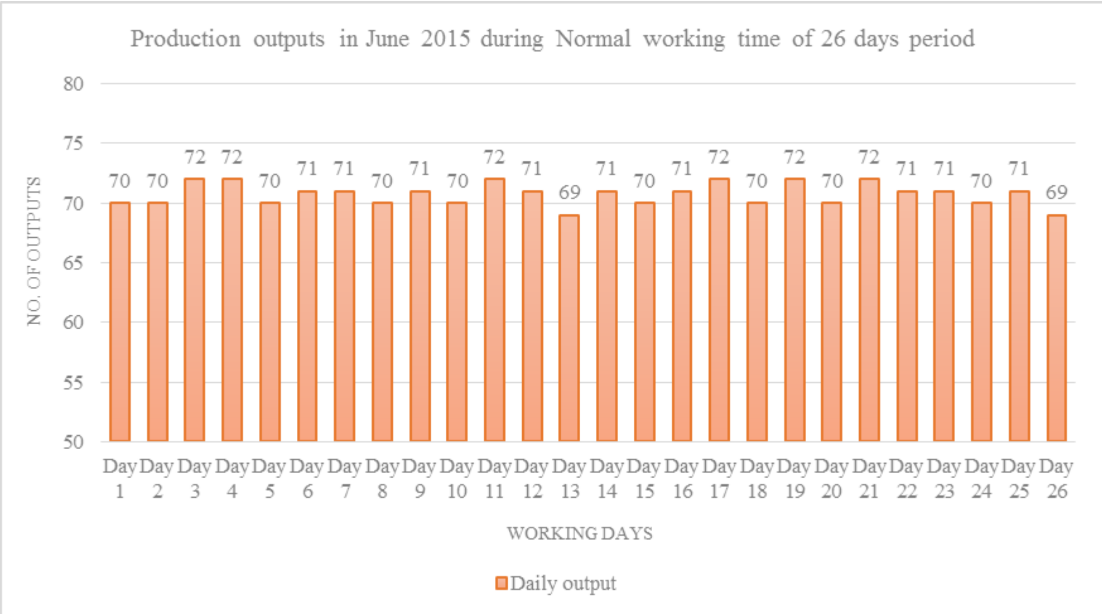

Figure 100: Production outputs in June 2015 during 26 days of working.

In the Figure 100, the graph demonstrated the outputs in June 2015 where the number of inputs (working hours, number of workers, resources and etc.) in the production process are all the same except the methodology and equipment added to the process from the two new solutions. The total output is 1839 pieces during 26 working days in June 2015. The daily output has still remained the same as in May 2015 with the average of 70 pieces whereas the lowest output per day was 69 pieces and the highest output per day was 72 pieces. Therefore the summary of total outputs for two months can be shown in Table 58.

Table 58: Total outputs of May and June 2015 production

Criteria \ Months	May 2015	June 2015	Average between May and June 2015
Total output	1833 pieces	1839 pieces	1836 pieces
Production hrs.	208 hours	208 hours	208 hour
Avg. output/hrs.	8.81 pieces/ hour	8.84 pieces / hour	8.83 pieces / hour
Daily output	70.5 pieces / day	70.73 pieces/ day	70.62 pieces / day

The total monthly output in May and June are 1,833 pieces and 1,839 pieces respectively. The production hours in total was two hundred and eight hours, which is the average normal working time of the company. The results in Table 58 has shown the average total output between May and June 2015 are 1,836 pieces with the average daily output of 70.62 pieces. In Figure 101 will demonstrated the changing shift of an average daily output from May 2014 to June 2015. The major shift is in May 2015 and June 2015 where the new solutions has been implemented.

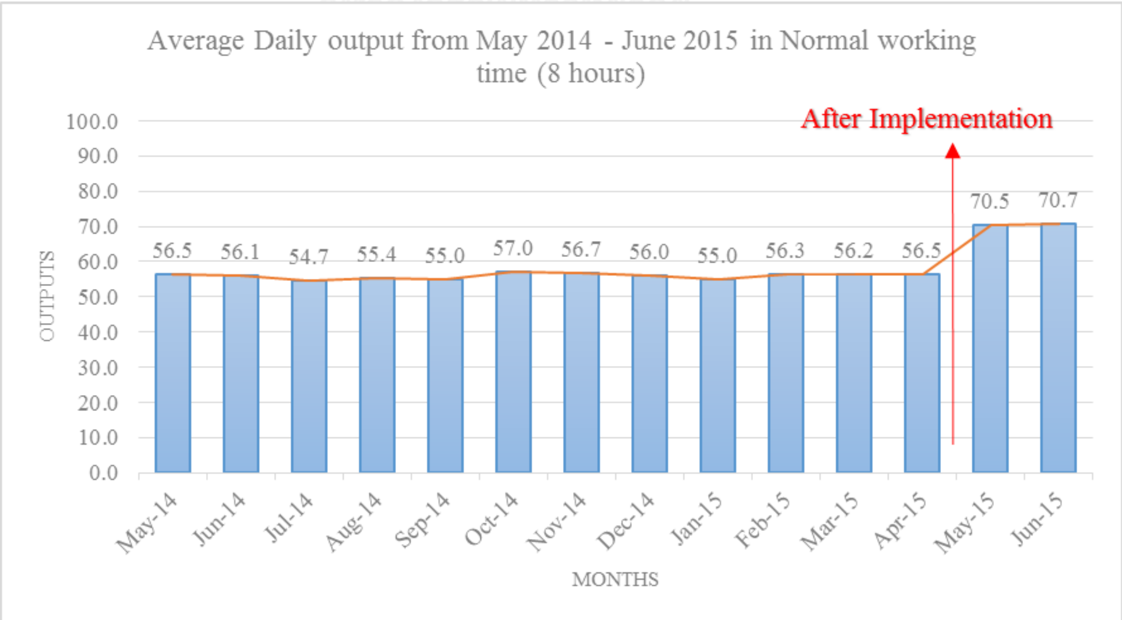

Figure 101: Average daily output from May 2014 – June 2015

5.3 Control Plan

After all implementation has been implemented and results have been analysed. The next phase is to consider on creating control plan for the implementation. The "work instruction" will be used for controlling the new method in order to make workers work more effectively and safely.

5.3.1. Lay Part work instruction

Work Instruction	Approved by	Checked by	Prepared by	Document No.
Name	Lay part station	Maker	Responsibility	Session
		Passenger Car	Supervisor	Assembly
Objective	To ensure workers understand and work appropriately	Reference	Engineering Specify	
Steps	Description	Remark		
1. Lay Part on Wasu board	Lay down the part on to the Wasu board by matching the colors and numbers. In each slot must contain only one part.			
2. Put wasu board on to the Trolley	Put wasu board on to the trolley by placing at the number indicate on the trolley			
3. Lay Wasu board on the assembly board	Put Wasu board on the correct position of Assembly board by matching the right number position			
Remark : If there are abnormality occurrence in the work station, worker must follow these steps				
What are the abnormality	Must do:	Suggestion during work		
1. Equipment doesn't work	1. Stop working	1. Must Lay parts down on the correct position on the Wasu board		
2. Parts quality fail to meet standard	2. Separate the bad parts	2. Do not move trolley too fast.		
	3. Record the problem and inform process engineer			

Figure 102: Work Instruction – Lay part

Figure 102 above shows the work instruction of Lay part that has been created from development team. Work instruction of Lay part will be used for controlling the new work process in Lay part station. The concerned part in this station is the use of trolley because it is the new equipment that have not been used before in the production line. Therefore workers will need to use the trolley in the appropriate way by following the instruction.

5.3.2. Wire Assembly work Instruction

Work Instruction	**Approved by**	**Checked by**	**Prepared by**	**Document No.**
Name	**Wire Assembly Station**	**Maker**	**Responsibility**	**Session**
		Passenger Car	Supervisor	Assembly
Objective	To ensure workers understand and work appropriately	**Reference**	Engineering Specify	
Steps	**Description**	**Remark**		
1. Setting up Tofix boards	Put four Tofix boards from the Trolley on to the gutter in wire assembly station.			
2. Assemble Wires with components	Assembling wires with the components and place it in its position on the Tofix board. The position will have the label for each wires to be in.			
3. Put Tofix board on the trolley	After fully assemble wires on four tofix boards, put the tofix boards on the trolley in its position according to the label.			
Remark : If there are abnormality occurrence in the work station, worker must follow these steps				
What are the abnormality	**Must do:**	**Suggestion during work**		
1. Equipment doesn't work	1. Stop working	1. Must put wires in its position according to the label on the tofix boards		
2. Parts quality fail to meet standard	2. Separate the bad parts	2. Do not move trolley too fast.		
	3. Record the problem and inform process engineer	3. Gently put wires on tofix boards		

Figure 103: Work Instruction – Wire Assembly

Figure 103 above shows the work instruction of Wire Assembly that has been created from the development team. There are 3 main steps in the work instruction from setting up Tofix board until putting Tofix board on the trolley. Work instruction of wire assembly will be used for controlling the new work process in work assembly station. The concerned part in this station is the use of Tofix board because it is the new equipment that have not been used before in the production line. Therefore workers will need to use the Tofix board in the appropriate way by following the instruction.

5.3.3. Lay Wire work instruction

Work Instruction	**Approved by**	**Checked by**	**Prepared by**	**Document No.**
Name	**Lay Wire Station**	**Maker**	**Responsibility**	**Session**
		Passenger Car	Supervisor	Assembly
Objective	To ensure workers understand and work appropriately	**Reference**	Engineering Specify	
Steps	**Description**	**Remark**		
1. Moving Tofix board Trolley to the Lay Wire station	Carefully move the trolley from Wire assembly station to the Lay Wire station			
2 Unloading Tofix board	Unload tofix board from the trolley and put it on the fixtures on the assembly board			
3. Laying the wires on the assembly board	Put the wires from Tofix board and assemble it on the assembly board according to the label on the assembly board.			
4. Moving Tofix Board Trolley back	Carefully move the trolley from Lay wire station station to the Wire assembly station			
Remark : If there are abnormality occurrence in the work station, worker must follow these steps				
What are the abnormality	**Must do:**	**Suggestion during work**		
1. Equipment doesn't work	1. Stop working	1. Lay wires according to the label attached on the assembly board		
2. Parts quality fail to meet standard	2. Separate the bad parts	2. Do not move trolley too fast.		
	3. Record the problem and inform process engineer	3. Gently take out wires from the tofix board.		

Figure 104: Work Instruction – Lay Wire

Figure 104 above shows the work instruction of Lay wire that has been created from development team. There are 4 main steps in the work instruction from moving Tofix board to the assembly line and move it back. Work instruction of lay wire will be used for controlling the new work process in Lay wire station. The concerned parts in this station are the use of Tofix board and trolley because there are the new equipment that have not been used before in the production line. Therefore workers will need to use the Tofix board in the appropriate way by following the instruction.

CHAPTER 6: CONCLUSION, SUGGESTION AND DISCUSSION

This chapter summaries the research study and concludes about the results of the production process after implementation. Recommendation will be discussed further for providing the case study company to consider on future plan in order to maintain and increase its effective and efficiency.

6.1 Conclusion

Labour costs of Thailand that are increasing every year combined with the result of labour law that ease the stress on labour by giving them more benefits. The case study company has faced significant problems due to this and are direly in need to adapt the company with external factors in order to survive and maintain profits throughout the market. In this research study, the researcher have been involved in the adaptation of the company and apply the knowledge from Universities to consider improving the situation of the case study company within the production process area.

The analysed information had demonstrated that the company has wastes and waste processes in the production process which can be eliminated or improved by the use of various alternatives as suggested by the author and the team. The purpose of this research study was to propose an improvement plan to improve the cycle time of the production process in order to gain more outputs by changing method of working on some activities. There were two main alternatives that were implemented and the results after implementation was positive and has achieved the goal of the project proposal. Based on the result after the implementation, the cycle time has been improved, as shown in Table 59, 60, 61.

Table 59: Total improvement of cycle time in Lay part station

	Before Implementation	After Implementation	Improvement	Improve %
Total Lay part Cycle Time	472 seconds	371 seconds	101 seconds	21.40%
Transportation Waste time	78 seconds	28 seconds	50 seconds	64.10%

In Table 59, total improvement of cycle time in Lay part station demonstrates an improvement of Lay part station cycle time and transportation waste time. Lay part station has a reduced cycle time from 472 seconds to 371 seconds where it is 101 seconds improvement or an average of 21%. On the other hand, transportation waste, the company has reduced the waste occurred from 78 seconds to 28 seconds which is a 50 second reduction or an average of 64% improvement.

Table 60: Total improvement of cycle time in Wire Assembly station

	Before Implementation	After Implementation	Improvement	Improve %
Total Wire Assembly Cycle Time	468 seconds	355 seconds	113 seconds	24.15%
Motion waste	98 seconds	25 seconds	73 seconds	74.47%

In Table 60, total improvement of cycle time in Wire Assembly station has shown the results of improvement of Wire Assembly cycle time and motion waste time. Wire Assembly station has reduced cycle time from 468 seconds to 355 seconds where it is 113 seconds improvement or average of 24%. On the other hand, motion waste in Wire Assembly station, the company has reduced the waste occurred from 98 seconds to 25 seconds which is a 73 seconds reduction or an average of 74% improvement.

Table 61: Total improvement of cycle time in Lay Wire station

	Before Implementation	After Implementation	Improvement	Improve %
Total Lay wire Cycle Time	504 seconds	405 seconds	99 seconds	19.64%
Motion Waste	112 seconds	20 seconds	92 seconds	82.1%

As shown in Table 61, the total improvement of cycle time in lay wire station demonstrates a significant level of improvement in the lay wire cycle time and motion waste time. Lay wire station has reduce cycle time from 504 seconds to 405 seconds which demonstrates a 99 seconds improvement or an improvement with an average of 19%. On the other hand, motion waste in Wire Assembly station, the company has reduced the waste occurred from 112 seconds to 20 seconds which is a reduction by 92 seconds or an average of 82.1% improvement. In terms of outputs, the new solutions has increased the average of outputs of 208 production hours from 1,454 units to 1836 units per month (based on the Appendix 1, comparing only the months that contains production hours of 208 hours in normal working time period).

In conclusion, the author has summarized tools, method and results gained from the research and study in Table 62.

Table 62: Summarize tools, method and results gained

Chapter	**Phase**	**Process**	**Tools and Method**	**Results gained**	**Appropriate**
3	Problem Objective	Study and Selecting Problem	Process Flowchart	Understand the process of creating Wiring harness	Appropriate
	Problem Measurement	Analyse situation before improvement	Process activity chart	Factors for measurement: 1. Cycle time of each activity 2. Wastes occurred in the process	Appropriate

Chapter	**Phase**	**Process**	**Tools and Method**	**Results gained**	**Appropriate**
3	Analyzing Root cause	Evaluating the root cause of the problem	Cause and effect diagram	There are 6 factors that has been pointed out to be the root cause of high cycle time in the current process 1. Factors composed of Man, Method, Machine, Environment, Materials and Management. 2. "Method" factor which contains waste are the root cause of the problem according from the process activity chart	Appropriate
	Analyzing Root cause	Evaluating the root cause of the problem	7 Waste management	Be able to identify the wastes in production process which in this case study company has Transportation waste and Motion waste that considered the root cause of high cycle time.	Appropriate
4	Selecting Solution for tackling problem	Analyse best alternatives	Brainstorming	Five alternatives have been suggested on improving motion waste and transportation waste which are: Productivity, Quality, Safety, Cost and Environment.	Appropriate
			Matrix Diagram	The solutions have been chosen from 2 out of 5 to be implemented which are: 1. Trolley for Lay part station 2. Transferring board for Wire Assembly station and Lay wire station	Appropriate

Chapter	Phase	Process	Tools and Method	Results gained	Appropriate
5	Solving problem	Improve Method and implementing solution	Work study	Work study Ergonomics help in designing: 1. Trolley for Lay part station 2. Tofix board for using in Lay wire and Wire assembly station 3. Tofix board trolley for moving Tofix board in production line.	Appropriate
			Process activity chart	The results from implementation are: 1. Reduce cycle time in Lay part station 101 seconds or 21.4% 2. Reduce cycle time in Wire Assembly station 113 seconds or 24.1% 3. Reduce cycle time in lay wire station 99 seconds or 19.6% 4. Reduce overall processing time of wiring harness producing from 504 seconds to 405 seconds.	Appropriate
			Graph	The results show the significant shift from before implementation and after implementation	Appropriate
	Control	Control the process	Work instruction	Give workers better understanding on how to handle new method and new equipment added.	Appropriate

6.2 Discussion

The new equipment has been created and installed in the production Line. These implemented alternatives have not just improved the cycle time of the process of manufacturing wiring harness but it has also been able to maintain the number of labors at the same amount without any plan for increasing new labors in the future. This helps the company from avoiding repercussion that take place due the labour shortages in the future since Thai labour is now looking to find job in ASEAN countries, according to the ASEAN Economic Community (AEC). Moreover these equipment and methods are not getting labors to have less payment from over time session, but were moved to other projects that need overtime or other jobs that give labour the same amount of income. This helps in maintaining both a happy workforce and an efficient organizational process in the production-line. Furthermore, the company has gained more flexibility in terms of allocation resources and production capacity.

There are also many theories that have been applied and implemented in this research. The main ones are composed of Work study, Seven Wastes and FMEA that has helped the research significantly in many ways. The following is the demonstration of how these theoretical references have aided the study:

<u>Work study</u>

1. Providing process activity mapping chart that is used for identifying specific tasks in the production process which allows the researcher to easily understand the process in the production line and evaluate the problems as well.

2. Help providing time on each task that can be later on used for calculating the non-value added time that should be eliminated in order to reach the takt time target.

3. Give an ease for using seven waste management because it provides the type of activity and wastes of the tasks.

Seven waste management

1. Help identify the wastes occur in the production process which helps in the successful identification of the root problems that exist in the process and to tackle it effectively.

2. Give the ball park of the process on type of wastes that currently occurring and might occur in the future which the company could use for analysing and prevent the expected not preferable outcome.

6.3 Suggestions

1. The company should set up daily checking team for observing issues related to the new equipment in order to make sure the new equipment is running stable.

2. The company should motivate bottom-up activity to allow employees in the production line to be creative and be able to suggest Kaizen or continuous improvement projects in the future. Worker's input are very vital in understanding several of the root problems in the organization.

3. The company should commit more on day-to-day activity management control in order to monitor the results after improvement and apply Standard-Do-check-action technique.

4. The company should extend these improvements to other production line for improving productivity in different area of the company, in order to increase the level of standard of the company.

5. The company should occasionally review the problems inside the production line and set up the meeting for brainstorming the ideas that provide alternative solutions and therefore a continuous improvement strategy.

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APPENDIX

1. Production output during March 2014 – April 2015 with normal working time and overtime session.

Month	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	Total Average
Normal Time (8 hours)															
Total Output	1443	1234	1469	1458	1423	1440	1430	1482	1475	1120	1321	1239	1462	1243	1374
Production Hours	208	176	208	208	208	208	208	208	208	160	192	176	208	176	197
Average Output/Hr	6.94	7.01	7.06	7.01	6.84	6.92	6.88	7.13	7.09	7.00	6.88	7.04	7.03	7.06	7.0
Daily out put	55.5	56.1	56.5	56.1	54.7	55.4	55.0	57.0	56.7	56.0	55.0	56.3	56.2	56.5	55.9
Overtime (2.5 Hours)															
Total Output	210	221	276	225	280	225	284	297	276	342	223	211	279	221	258
Production Hours	30	30	40	35	40	35	40	43	40	50	30	30	40	30	37
Average output/Hr	7.00	7.37	6.90	6.43	7.00	6.43	7.10	6.99	6.90	6.84	7.43	7.03	6.98	7.37	7.0
Daily output	17.50	18.42	17.25	16.07	17.50	16.07	17.75	17.47	17.25	17.10	18.58	17.58	17.44	18.42	17.38
Total Normal time and Over time (10.5 hours)															
Total Output	1653	1455	1745	1683	1703	1665	1714	1779	1751	1462	1544	1450	1741	1464	1629
Production Hours	238	206	248	243	248	243	248	251	248	210	222	206	248	206	233
Average output/Hr	6.97	7.19	6.98	6.72	6.92	6.68	6.99	7.06	7.00	6.92	7.16	7.04	7.00	7.21	7.0
Daily output	73.00	74.51	73.75	72.15	72.23	71.46	72.75	74.47	73.98	73.10	73.63	73.90	73.67	74.92	73.4

VITA

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