PROPOSED IMPLEMENTATION OF LINE BALANCING HEURISTIC METHOD TO MINIMIZE WASTE INVENTORY IN PRODUCTION PROCESS OF SHORT-SLEEVED SHIRT CV. CJM BANDUNG

FINAL PROJECT

Proposed to Comply the Bachelor Degree

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INDUSTRIAL ENGINEERING STUDY PROGRAM

SCHOOL OF INDUSTRIAL AND SYSTEM ENGINEERING

TELKOM UNIVERSITY

2017

APPROVAL SHEET

The Final Project titled :

LINE BALANCING HEURISTIC METHOD IMPLEMENTATION TO MINIMIZE WASTE WORK IN PROCESS INVENTORY IN PRODUCTION PROCESS OF SHORT-SLEEVES SHIRT AT CV. CJM

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بسم الله الرحمن الرحيم

"In the Name of Allah, the Compassionate, the Merciful"

ABSTRACT

CV. Chikal Jaya Makmur is a make-to-order garment company that produces various clothing products such as shirts, t-shirts, jeans, sweaters, and jackets. But, the researcher only focused on production process of short-sleeves shirt. CV. CJM has a different target production each day depends on the number of employees presence. However, although the production targets are adjusted to the number of employees presence, the product realization is often did not reach the production target in several period. In the production process of shirts, researcher found inventory waste which is the buildup of work in process product in between sewing workstation that can affect the production lead time. Based on the problem of work in process that happened in several workstation of sewing process, the researcher proposed the improvement design on the production process of shirt as an effort to minimize the waste inventory to reduce the volume of work in process that accumulate in several sewing work stations.

This research phase begins from primary data collection and secondary data as a reference to map the activity mapping process to identify waste that occurs in the production process, making current state value stream mapping, identifying the cause of waste inventory by using fishbone diagram and 5 why's. After knowing the root cause of waste inventory, design of proposed improvement to reduce the cause of waste inventory need to implemented. The method to minimizing waste inventory work in process is using line balancing heuristic method: Ranked Positional Weight, Killbridge-Wester, Moodie Young Method and choose methods which produce the best result. The choosen method is Killbridge-Wester method which produce increased result of line efficiency from 42,48% in existing line to 95,2% after line balancing. And decreasing number of work in process inventory achieved was 99%.

Keywords *: Waste Inventory, Line Balancing, Ranked Positional Weight, Killbridge-Wester, Moodie Young*

ACKNOWLEDGEMENT

All praises and gratitude are always raised to Allah SWT, because his mercy, grace, and love, the author can finished the research final project titled “Line Balancing Heuristic Method Implementation to Minimize Waste Work in Process Inventory in Production Process of Short-Sleeves Shirt at CV.CJM” to accomplish the requirement for bachelor degree of Industrial Engineering Study Program School of Industrial Engineering at Telkom University. *Shalawat* and *salam* may always be lavished to Prophet Muhammad SAW, his family, his companion, and his followers as *Muslim* until the end of time.

The completion of this paper will not be accomplished without the helping hand, support, and cooperation from all partakers. Therefore, the author would like to express the gratitude and appeciation to the following parties:

1. Mr. Agus Alex Yanuar S.T., M.T, as my main supervisor who has dedicated his mind, knowledge, and huge support to provide guidance until the author finishied this final project. Author would also like to express deepest gratitude for his kindness, patience, time, and warm smile.
2. Mrs Ir. Widia Juliana, M.T. as my supervisor who always support me to finish my research paper. Thankyou for giving me a new knowledge, experience and motivation to always improve this final project.
3. For other lecturers, who have dedicated their time and knowledge in lecturing us.
4. My father,M. Syaom Barliana. Thank you for the courage and trust that I can do my best in my life, thankyou for believing in my dream more than I do, thankyou for always trying the best to make your daughter happy, and thankyou for your countless days and nights spent to send all the prayer for me. Thankyou, my favourite, and all time inspirator, Ayah.
5. My Mom, Hidayati. Thankyou for your unconditionally love, your warm hugs and smiles that always there whenever I have a hard time, the trust that I can always be the person who I’ve always wanted tobe, thankyou for always be strong. And thankyou for the days and nights prayers you have committed for my success.
6. My siblings, Adila Intifada, Nada Amira, Raya Aulia Muhammad. Thankyou for always having my back, for the support, for making me laugh when things are hard, for always loving and understanding. Thankyou.

7. For my super positive circle; Manufacturing Process Laboratory Assistants squad, IMAsc Telkom University, Society, LUNATRIX, D’Or, ESO, etc. thankyou somuch, you guys all make my uni-life cheerful and full of laughter, teach me how to be a better person each day, inspires me, and thankyou for being there for me during my ups and downs. I know you guys will be anything you wanted to be in the future.

For whose listed above, may Allah grants you with something even greater than your kindness you have given to me.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATION

LIST OF APPENDIX

LIST OF ABBREVIATIONS AND SYMBOLS

ABBREVIATION	Name	First Time Use on The Page
CV	Commanditaire Vennootschap	Title
CJM	Chikal Jaya Makmur	Title
VSM	Value Stream Mapping	5
PAM	Process Activity Mapping	5
VA	Value Added	5
NNVA	Necessary Non Value Added	5
NVA	Non Value Added	5
WIP	Work in Process	i
UCL	Upper Control Limit	27
LCL	Lower Control Limit	27

SYMBOLS	Name	First Time Use on The Page
σ	Standard Deviation	27
$\bar{\bar{x}}$	Average	27
xj	The Value of Observation	27
N	The Total of Observation	27

TERMINOLOGY

Lean Manufacturing	: A systematic approach to identify and eliminate waste or non- value-adding activities through continuous radical upgrading (radical continous improvement).
Waste	: Any activity that does not provide added value in the process of transforming inputs into outputs along the value stream.
Waste Inventory	: Materials in the form of raw materials, work in process (WIP) and finished goods with more quantities than required.
VA	: An activity or step that add value to the product
NNVA	: An activity that must exist in the production process but not provide added value to the product
NVA	: An activity that does not added value to the product.
Value Stream Mapping	: Value Stream Mapping is a Lean Six Sigma tool used to map all activities (both Value Added and Non Value Added) in the value stream. This tool allows for visual representation or resource allocation maps on current business activities (curret state) as well as how plans to add value in the future (future state).
Process Activity Mapping	: A diagram that shows the sequence of operations, inspection, transportation, delay, and storage that occur during the process or procedure.
Fishbone Diagram	: A tool used to identify the root causes presented in causal diagram format where all causes are categorized into different categories such as human, machine, material, method, measurement, and environment.
5 Why's	: A tool to find the root of a problem.

Takt Time	: The ratio of working hours available to the number of orders per day. Takt time is the average production time needed to meet consumer demand.
Kanban	: Kanban is a signal card in production process.
Line Balancing	: An activity to balancing assignment of task elements from an assembly line to a work station to minimize the number of work stations and minimize total idle time on all stations for a given level of output.

CHAPTER I INTRODUCTION

I.1 Background

The growth of micro and small manufacturing industry sector shows good number in second quarter of 2017 which is 2.5%. Especially for the garment industry entering into micro and small manufacturing industry which experienced the highest increase in second quarter of 2017 that is 8.82% (www.bps.go.id). According to increased number of growth, indicating that the competition in the relevant industry sector is increasingly competitive. In the era of competitive industrialization nowadays, every company who wants to win the hearts of consumers will pay attention to quality in order to improve customer satisfaction. An important factor for company is to take care of customers and ensure that customers have a positive experience with goods and services (Farris, Bendle, Pfeifer, and Reibstein, 2010). Customer satisfaction has the sense of a feeling satisfaction or disappointment of a person resulting from a comparison of product performance or results with expectations. If the performance is less than expectations then the customer will be disappointed and if in accordance with expectations consumers will feel satisfied. (Kotler & Keller, 2012, p.150). According to Fandy Tjiptono (2014), satisfaction comes from the Latin "Satis" which means quite good, adequate and "Facio" which means doing or making. Simply satisfaction can be interpreted as efforts to fulfill something or make something adequate. To create a production process that fulfill customer satisfaction, waste and unefficiency processes needs to be avoided so that the cost of production per unit will be low.

Waste can be defined as any operation or activity that does not added value to the production process. Based on the Toyota Production System (TPS), waste is classified into two types activities that do not provide added value but are needed in the system (Necessary Non Value Added Activity) and activities that do not provide added value and are not needed in the system or process (Non Value Added Activity) (Antony, Vinodh, & Gijo, 2016).

CV. Chikal Jaya Makmur is a garment company that produces various clothing products such as shirts, t-shirts, jeans, sweaters, and others with make to order production system. Make to order is a company that has only product design and some standard materials in the inventory system as well as manufacturing process activities have been tailored to each customer's order. In addition to receiving a variety of special orders from consumers, CV Chikal Jaya Makmur has developed its specialty by helping to produce clothing from boutique distro. One of the garments produced is for Warning Clothing boutique, which is a special brand for men's clothing, such as short-sleeved shirts. Warning Clothing has established cooperation with CV. Chikal Jaya Makmur since 2015, but for the production of new cooperation shirts starting from late 2016.

Warning clothing has regularly order a short sleeve shirt but with different pattern to CV. CJM. Here is a table that shows the number of targets and the realization of production from several periods.

Table I.1. Data of Production Target and Realization from July to November

(source: Data of CV.CJM)

Month	**Production Target**	**Production Realization**	**Percentage of Production Realization**
July	2017	1844	91%
August	5041	4484	89%
September	6546	5713	87%
October	5828	4923	84%
November	3117	2690	86%

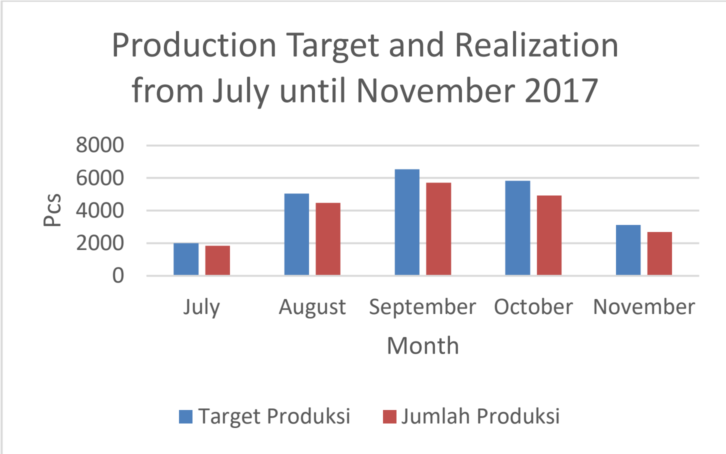


Figure I.1. Data of Production Target and Realization from July to November

(source: Data of CV.CJM)

Based on the table and chart above, there is no target realization that is reached 100%. Eventhough the company has set and determined that the target of production per day is considered from amount of operator present each day times 12 finished goods of shirt. But the operator still couldn't achieve those target and sometimes need extra time to work on it. There are some periods where the realization of production can not reach production targets. Based on the result of observation and identification conducted in production floor, researcher found that there are waste inventory in the form of accumulation work in process as one of the reason that causing the unfullfilled production target. Waste inventory is defined as materials in the form of raw materials, work in process (WIP) and finished goods with more quantities than required (Antony, Vinodh, & Gijo, 2016). Below is the table work in process on some workstation in sewing department.

Table II.2. The Amount and Duration Of Work in Process.

(source: Data of CV. CJM)

No	Workstation	The Amount of Work in process Inventory (pcs)	Waiting Time/ WIP (s)	Duration of WIP (s)	Minutes
1	Stitching Collar Leaf (Inside and Outside)	62	39	2418	40,3
2	Stitching Collar feet (Inside and Outside)	60	15	900	15
3	Stitching Collar leaf and feet	42	18	756	12,6
4	Cut the excess collar feet fabric	32	18	576	9,6
5	Stitching Front Right and Blekser	64	33	2112	35,2
6	*Kelin* Front Left	64	13	832	13,87
7	Stitching Upper and Lower Back Part	52	38	1976	32,93
8	Labelling	30	41	1230	20,5
9	Stitching Front and Back Part by Shoulder	32 (Left Front Part), 22 (Right front part), 18 (Back Part)	45	1440	24
10	Collar Stitching to the Body	Collar (13), Shirt (7)	51	357	5,95
11	*Kelin* Collar to the body	12	67	804	13,4
12	Stitching Body with Left and Right Sleeves by Shoulder	14	71	994	16,57

Table II.3. The Amount and Duration Of Work in Process.

(cont.)

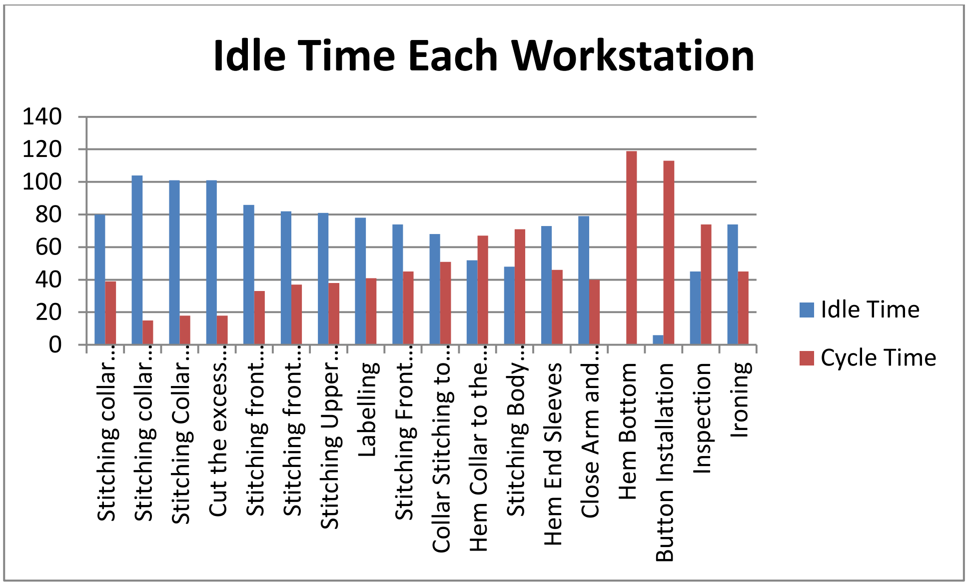
No	Workstation	The Amount of Work in process Inventory (pcs)	Waiting Time/ WIP (s)	Duration of WIP (s)	Minutes
13	*Kelin* End Sleeves	7	46	322	5,37
14	Close Arm and Side Body Part	6	40	240	4
15	*Kelin* Bottom	10	116	1160	19,3

Figure I.2. Work-in-Process of Shirt Between Each Workstation

(Source: CV.CJM)

Based on the table and figure above, there is a lot of work in process inventory waste in between each sewing workstation. This happened because there are unbalanced workload between each sewing workstation. the unequal or unbalanced workload among workstation of sewing line will lead to the increase of WIP , indicating of both the increasing of cycle time and cost (Pereira, 2013). The unbalanced workload in sewing workstation can be seen from the huge difference amount of cycle time between sewing workstation and the idle time in each workstation. The idle time in each workstation is the result of calculation of the highest amount of cycle time in sewing process minus cycle time in each sewing workstation. below is the graph that shows the differences of cycle time and idle time.

Graph of Cycle and Idle Time in Sewing Process



From the table above, it can be seen that the idle time in each workstation is high which is shows the unbalance workload between each station and will lead to work in process that wait to be processed.

Based on the problem, researcher proposed line balancing method as a tool to minimize waste inventory to reduce the volume of work in process on several sewing stations and to balance the workload between each stations. Line Balancing means balancing the production line, or any assembly line. The main objective of line balancing is to distribute the task evenly over the work station so that idle time of man of machine can be minimized (Kumar&Mahto, 2013) . These efforts begin from primary data collection and secondary data as a reference to map the activity mapping process to identify waste that occurs in the production process, making current state value stream mapping, identifying the cause of waste inventory by using fishbone diagram and 5 why's. After knowing the root cause of waste inventory, proposal stage and analysis is done which is designing the improvement proposal to minimize waste inventory. The proposal improvement is using line balancing heuristic method. In this research, researcher use 3 heuristic method which is RPW, RA, and Moodie Young method. Then from those 3 methods, will be choosen the method that obtained the most efficient result to be implemented in production process of shirt at CV. CJM.

I.2 Problem Formulation

Based on the background of problems that exist in the company, the problem formulation will be listed as follows:

1. What is the root cause of waste inventory on shirt production process in CV. Chikal Jaya Makmur?
2. How is the line balancing method that obtained the best efficiency result to be implemented in production process of shirt at CV. CJM?

I.3 Objective of Research

The purpose of the research are:

1. Identify the factors that cause the occurrence of waste inventory on production process of shirt in CV. Chikal Jaya Makmur.
2. Provide proposed improvements that can be used to minimize waste inventory on production process of shirt in CV. Chikal Jaya Makmur.

I.4 Limitation of Research

In the research that is conducted, there are several scope and limitation in order to focused on purpose of the research. The limitation of this research are as follows:

1. Stages of research conducted only a proposal improvement, and not until implemented by researchers
2. This study does not take into account the estimated costs incurred to implement the proposed design
3. The research does not done the feasibility calculation on the proposed improvement

4. The proposed improvement line balancing only applied in sewing department

I.5 Benefit of Research

This research is expected to give the benefit as follows:

1. Providing information about the waste that occurs in the shirt production process on the CV. Chikal Jaya Makmur.
2. The company aware of waste inventory that occurs on the production floor.
3. Company can make the proposed improvement as a material consideration or reference in doing continuous improvement.

I.6 Writing Systematics

Chapter I Introduction

This Chapter contains a background description of the problems that become the foundation to find the problems or waste that occur and make a design improvement of the shirt production process to minimizing waste at PT. CJM Indonesia. Also this Chapter consist of problem formulation, research objectives, problem limitations in research, research benefits, and systematic research writing.

Chapter II Literature Review

This Chapter contains relevant literature on the issues discussed and researched. Theoretical discussions include the theories of Lean Manufacturing approach and supporting theory that can be used in solving problems and resulting in the design of improvement proposals. Sources of literature or theory used are taken from reference books and research journals related to the topic of the problem and attached to the bibliography. Also in this Chapter discusses the results of previous research by describing the research objectives, methods used, similarities and differences of previous research with the author's research.

Chapter III Research Methodology

This Chapter describes detailed research steps using the Lean manufacturing approach. The research steps start from research preparation, primary and secondary data retrieval, data processing, problem solving analysis, conclusion and suggestion given to company as result of research.

Chapter IV Data Collecting and Processing

In this Chapter, there will be shown the general data of company and another supporting data. The data displayed is obtained through various processes such as interviews, Field observations, and data obtained from the company itself. Data processing is done in accordance with the methodology listed in Chapter III which then analyzed the problem for the improvement.

Chapter V Proposed Design of Improvement and Analysis

This chapter contains of analysis of the processing and proposal improvement to minimize waste inventory.

Chapter VI Conclusion and Suggestion

This Chapter contains the conclusions of the research that includes the results of data processing and proposed improvement for the company. Also this Chapter presented suggestions that can help companies to do continuous improvement also the suggestions for further research.

CHAPTER II LITERATURE REVIEW

According to the research background, researcher found the waste inventory that occur on the production process. This chapter consists of 2 part which is study of literature and previous research. The study of literature that will be explained is Lean Manufacturing Definition, Waste, SIPOC, VSM, PAM, FD, 5 Why's, Time Measurement, and Line Balancing. There are 3 previous research that written by Arini Ulfarahmah (2017), Dwi Intan Aptimura (2016), Qonitah Zahidah (2017)that written by Arini Ulfarahmah (2017), Dwi Intan Aptimura (2016), Qonitah Zahidah (2017).

II.1 Study of Literature

II.1.1. Lean Manufacturing Definition

Lean manufacturing can be defined as a combination of several tools to help eliminate non-value-added activities in products, services or processes and lean manufacturing aims to eliminate or reduce waste and improve processes. (Garcia-Alcaraz, 2014) Based on philosophy, lean is done by continuous improvement for the perfect process and service (Charron, Harrington, Voehl, & Wiggin, 2015). According to Vincent Gaspersz (Vincent Gaspersz, 2012) Lean Manufacturing can be defined as a systematic and systematic approach to identify and eliminate waste or non-value-adding activities through continuous radical upgrading (radical continous improvement) by streaming products (materials, work in processes, outputs) and information by using pull systems from internal and external customers to pursue excellence and excellence.

According to García-Alcaraz,J. & Guillermo (Charron, Harrington, Voehl, & Wiggin, 2015) there are 4 (four) purpose of lean manufacturing mention as follow:

1. Determining the value for customers.
2. Identify all activities required in the manufacture of the product from concept to product launch, from demand to delivery, and from material to finished foods.

3. Eliminate activities that do not provide value added and align the flow on each activity.
4. Analyze the results and conduct the evaluation process.

According to Vincent Gaspersz (Vincent Gaspersz, 2012) there are 5 (five) basic principle of lean manufacturing as follows:

1. Identify the value of product (goods or services) based on customer's perspective, where the customer want product (goods or services) with superior quality, with a competitive prices and on time delivery.
2. Identify the value stream process mapping (process mapping in value streams) for each product.
3. Eliminating waste that has no added value from all activities along the value stream.
4. Organize for materia, information, and products to flow smoothly and efficiently throughout the value stream process using pull system.
5. Seek continuous improvement techniques and tools (improvement tools and techniques) to achieve excellence and continuous improvement (continuous improvement

II.1.2 Waste

Waste can be defined as any activity that does not provide added value in the process of transforming inputs into outputs along the value stream (Vincent Gaspersz, 2012). APICS Dictionary (2005) defines value streams as processes for creating, producing, and delivering products (goods and or services) to the market (Gaspersz, Fontana, 2011, p.6). Based on the Toyota Production System (TPS), waste is also called young, are classified into two types, namely:

1. Type-1 MUDA is an activity that does not provide added value but is needed in the system or process. This type of waste can be minimized but can not be fully tolerated.
2. Type-2 MUDA is an activity that does not provide added value and is not required in the system or process. This type of waste should be eliminated immediately

Below is the table of 7 types of waste along with the root causes based on Swink Et al. (2011)

Table II.1.Types, Symptoms, Root Causes of Wastes

(Source: Swink et al, 2012)

Type	Symptoms	Root Causes
Processes	• Extra equipment • Reduced • Productivity • Extra material movement	• Product changes without process changes • Redundant approvals and inspection • Undefined custome requirement
Transportation	• Large storage areas • Over staffing • Damaged product • Extra paperwork/handoff • Excessive energy consumption	• Unlevel scheduling • Unfavorable facility layout • Poor organization / housekeeping • Unbalanced process
Overproduction (Processing more units than are needed)	• Extra inventory • Excessive floor space utilized • Unbalanced material flow • Complex information management • Disposal charges • Extra waste handling and treatment	• Product complexity • Misuse of automation • Overengineered equipment/capability

Table II.1.Types, Symptoms, Root Causes of Wastes

(cont.)

Type	Symptoms	Root Causes
	• Processing by product • Excess energy consumption	
Inventories (units waiting to be processed or delivered)	• Extra storage and handling • Extra rework or hidden problems • Paperwork or documents • Stagnated information flow • High disposal cost • In process packaging • Complex tracking system	• Unbalanced workload • Unreliable supplier shipments • Inadequate measurements or reward system • Incapable processes
Motions	• Reduced productivity • Large reach • Excess handling • Reduced quality • People/machines waiting	• Poor ergonomics or layout • Machine process design • Nonstandardized work method • Poor organization or housekeeping

Table II.1.Types, Symptoms, Root Causes of Wastes

(cont.)

Type	Symptoms	Root Causes
Product Defects	• Rework, repairs, &scrap • Customer returns • Loss of customer confidence • Missed shipments/deliveries • Hazardous waste generation • High disposal costs	• Lack of process control • Deficient planned maintenance • Poor product design • Customer needs not understood • Improper handling • Inadequate training

Meanwhile, according to Kaufman Consulting Group (1999) has formulated 10 types of waste in the manufacturing industry, where the 10 types of waste are grouped into 4 main categories, namely (Vincent Gaspersz, 2012):

1. People : Processing, Motion, Waiting
2. Quantity : Moving Things, Inventory, Making too much
3. Quality : Fixing Defects
4. Information : Planning, Scheduling, Execution

II.1.3 SIPOC

SIPOC is a tool that serves for process improvement that provides a summary of input and output of one or more processes in tabular form. The acronym of SIPOC is suppliers, inputs, processes, outputs and customers. (Anthony, Vinodh, & Gijo, 2016). SIPOC is an acronym of five major elements in the quality system, namely:

1. Suppliers are input providers to support the process of providing key information, materials, or other resources to the process such as human, system, or company.
2. Inputs are anything from supplier to be processed such as materials, humans, methods, and machines (4M) needed for smoothness in a process
3. Processes are collection of activities (both value added and not added value) used to manage inputs into outputs that will be delivered to customers.
4. Outputs are products (goods or services) generated from a process. In the manufacturing industry the output can be either semi-finished or finished goods.
5. Customers are persons or groups of people, or sub-processes whp receive the output. If a process consists of several sub-processes, subsequent subprocesses may be considered internal customer.

Purpose: Productivity Improvement
Owner:

Supplier	Inputs	Process	Output	Customer
ABC castings	Motor body	Motor body machining → Winding → Motor assembly → Pump assembly → Testing and inspection	Submersible pump	MN Pumps Southern Pumps
Hi-tech enamels and PVCs	Windings			
PQR bearings	Impeller			
Cast tech	Casing			
Bright plastics and polymers	Fan and blower			
XYZ switches and electricals	Starter			
	Bolts and nuts			

Figure II.1. The example of SIPOC Diagram

(Antony, Vinodh, & Gijo, 2015, p.85)

II.1.4 Value Stream Mapping (VSM)

Value Stream Mapping is a Lean Six Sigma tool used to map all activities (both Value Added and Non Value Added) in the value stream. This tool allows for visual representation or resource allocation maps on current business activities (curret state) as well as how plans to add value in the future (future state) (Charron, Harrington, Voehl, & Wiggin, 2015). Value Stream Mapping is a process mapping tool that has a way to view flow and communication in a process, or value stream. Value stream mapping has been accepted in the world of improvement because of its ability to collect, analyze, and present information in very crowded time periods (Nash, Poling, 2008). Value stream mapping is used to document current state mapping and future state mapping:

a. Current State Mapping is a basic overview from existing process where all the improvements have already measured.
b. Future State Mapping is a representation from value stream after the improvement has been done.

Below are several simbol in value stream mapping that is use in this research. The symbol shown in following table II.2.

Table II.2. The Value Stream Mapping Symbol

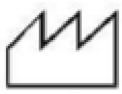
No	Name	Symbol	Definition
1	Customer/ Supplier		This symbol represents the supplier when in the upper left, the usual starting point for material flow. While the Customer is depicted when placed at the top right, the usual end point for material flow

Table II.2. The Value Stream Mapping Symbol

(cont.)

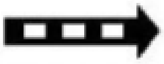
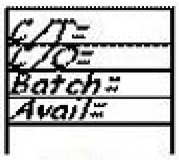
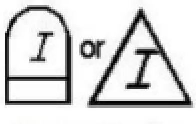
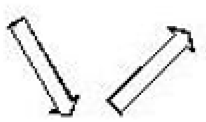
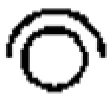
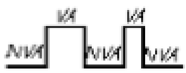
No	Name	Symbol	Definition
2	Dedicated Process		order to avoid the non-wider range of every single step process, it represents a single department with continuous process flow continuously.
3	Push Arrow		This symbol represents the material direction from one process to the other process
4	Production Control		This symbol represents the scheduling of center production or controllin departement, person or operation.
5	Data Box		This symbol is under another symbol that has significant information or data needed to analyze and observe the system. The information specially placed in the Data Box under the Factory symbol can be C / T ie the cycle time required to produce one item until the next to be produced, C / O or Changeover Time, the production turn of one product in a process for the other , the uptime is the percentage of time available on the machine to process, scrap ie the rate for batch size transfers, etc.

Table II.2. The Value Stream Mapping Symbol

(cont.)

No	Name	Symbol	Definition
5	Inventory		This symbol represents the inventory between two processes. When mapping the actual conditions in the production line, the amount of inventory can be estimated by quick calculation, and the amount is recorded below the triangle. If there is more than one accumulated inventory, use the symbol for each. This symbol also represents storage for raw materials and finished products.
6	Shipments		This symbol represents the movement of raw material material from the supplier to the factory..
14	Manual Info		Straight, thin arrows show the flow of information from memos, reports, or conversations.
26	Operator		This symbol represents the operator, indicating how many numbers of operators .
28	Timeline		This timeline shows the value added times (cycle time) and nonvalue added (waiting time). This timeline is used to calculate Lead Time and total cycle time.

(Source: http://www.strategosinc.com/vsm_symbols.htm, Accessed 20 July 2017)

II.1.5 Process Activity Mapping (PAM)

Process Activity Mapping is a diagram that shows the sequence of operations, inspection, transportation, delay, and storage that occur during the process or procedure (Sutalaksana, Ruhana, & Tjakraatmadja, 2006). The explanations of symbols in the activity mapping process are as follows (Sutalaksana, Ruhana, & Tjakraatmadja, 2006):

1. Operation is an activity where the workpiece changes the nature, both physical and chemical. Taking information or providing information on a situation is also included in the operation.
2. Inspection is an activity where the workpiece or equipment is examined both in terms of quality and quantity
3. Transportation is an activity where the workpiece, worker or equipment experience displacement of place which is not part of an operation.
4. Waiting is a process where the workpiece, worker or equipment does not experience anything other than waiting
5. Storage is the process where the workpiece is stored for a long period of time.

The general purpose of a process activity mapping can be described, as follows (Sutalaksana, Ruhana, & Tjakraatmadja, 2006):

1. Can be used to know the flow of materials or activities of people from entry into a process or procedure until the last activity.
2. This map may provide information on the timing of completion of a process or procedure.
3. Can be used to determine the amount of activities experienced by materials or people during the process or procedure takes place.
4. As a tool to make improvements to the process or method of work
5. Particularly for a map that only describes the flow experienced by a component or a person, in its entirety, this map is a tool that will facilitate the analysis process to find out places where there is inefficiency or job imperfection occurs. That way can be used to eliminate the hidden costs.

There are 5 general steps in designing Process Activity Mapping, as follows:

1. Understanding the process flow
2. Waste identification
3. Consider whether the process can be rearranged in more efficient sequence.
4. Consider a better pattern of flow, which involves a different flow layout or trasnportation arrangement route.
5. Consider whether all activity that involves in the process is necessarily needed, and what will happen if the excessive task is removed.

II.1.6 Cause- Effect Diagram (Fishbone Diagram)

Cause-Effect Diagram is a tool used to identify the root causes presented in causal diagram format where all causes are categorized into different categories such as human, machine, material, method, measurement, and environment. The cause and effect diagram is also known as the fishbone diagram (Anthony, Vinodh, & Gijo, 2016). Here is a general template of the fishbone diagram.

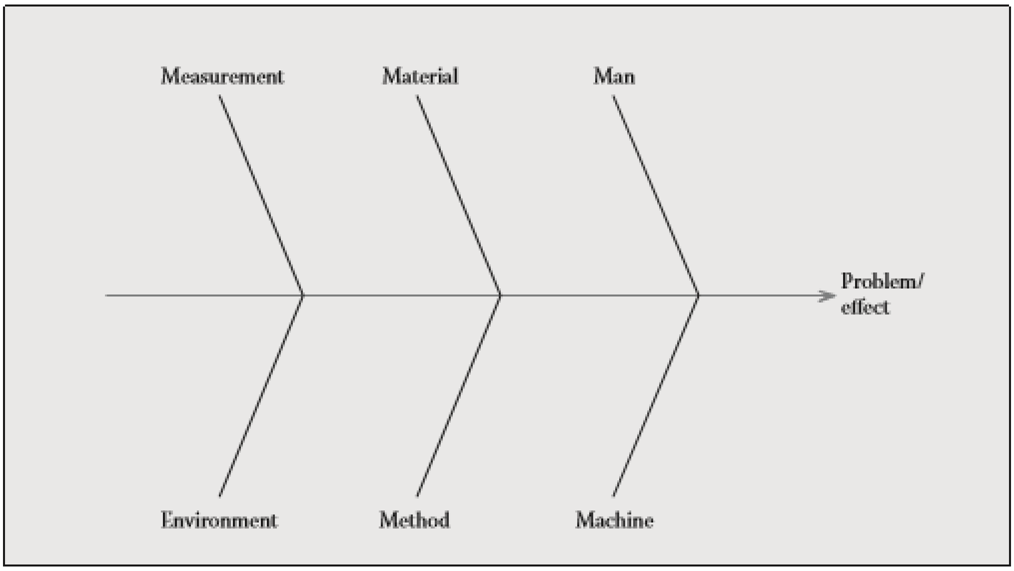


Figure II.2. Fishbone Diagram

(Source: Anthony, Vinodh, & Gijo, 2016, p. 100)

The Fishbone diagram has a function to identify key characteristics and key process parameters that influence output, as a tool to help achieve a general understanding of a problem, and to reduce subjective decision making events (Anthony, Vinodh & Gijo, 2016, p 98)

II.1.7 5 Whys

Root cause or 5 Whys is a simple tool to find the root of a problem. Sakichi Toyoda, the father of the Japanese industrial revolution, developed this problem solving tool in the 1930s, but later it became popular in the 1970s. 5 Whys Analysis is most effective when it comes from interviewee who has direct experience in the production process. The 5 Whys work is when a problem occurs, the researcher begins to prepare the question no less than 5 times to be able to know the nature and source of the problem (Anthony, Vinodh, & Gijo, 2016).

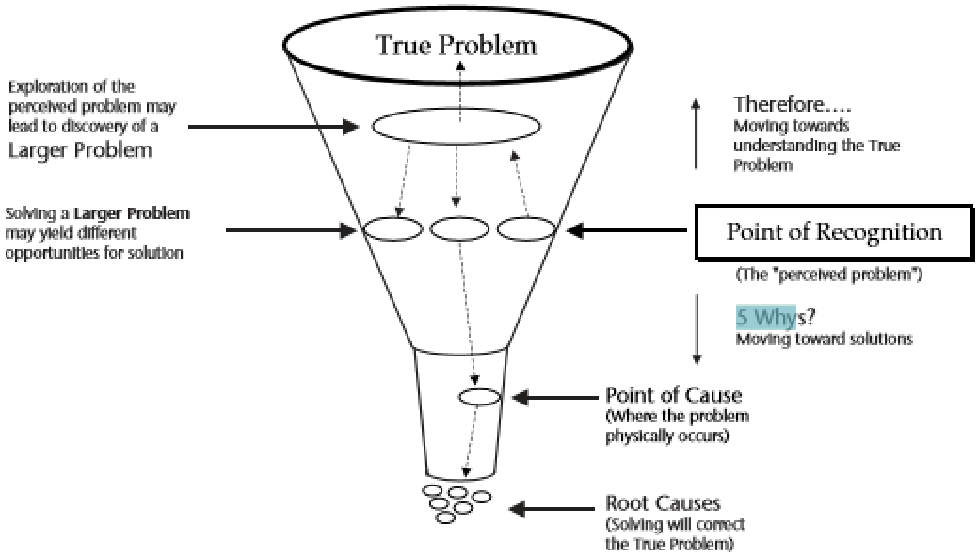


Figure II.3. 5 Why's Explanation

(Source: Liker & Meier, 2006, p. 331)

When the problem is encountered, then do inverted proof of repeated questions with the phrase "Why". This question is repeated until the root cause of the problem arises. In practice, the Whys 5 strategy is very simple and can help to locate the root of the problem. A much more complex and complex problem may not be effective using the Whys 5 strategy, but the first step of the Whys 5 Strategy is enough to help the problem solved. The Whys 5 strategy uses direct measurement, and is not a long-term solution, but it is a precaution to avoid similar problems. The questions in 5 Whys should be answered with actual conditions occurring instead of events that may occur. Floating and non-factual answers will only make the Whys 5 strategy so confusing. Keep asking "why" until the answer can represent the root cause and can no longer search for further answers, and that's the solution. But if the answer is still unsure, then consider using other problem solving strategies such as Root Cause Analysis. (*http://ikhtisar.com/mencari-akar-masalah-secepatnya-dengan-strategi-5-whys/*)

II.1.8 Time Measurement

Time measurement is work of observing and recording working times in each element or cycle by using tools such as stopwatch, sheets of observation, pen or pencil, and observation board. (Sutalaksana,Anggawisastra & Tjakraatmadja, 2006)

II.1.7.1 Uniformity Test

Uniformity of data within a system are things that can go unnoticed. Therefore, we need a tool that can detect or control it. The control limits are established from the data is uniform or not a determinant variable data. A group of data is expressed uniformly when the data is between the two control limits. Defined control limits are Upper Control Limit (UCL) and the Lower Control Limit (LCL). When the data is outside these limits, then the data is declared not uniform. Here are the stages of conducting uniformity test. (Sutalaksana, Anggawisastra & Tjakraatmadja 2006 , p. 151)

1. Calculating the Average:

$$\bar{\bar{x}} = \frac{\sum Xi}{k} \quad \text{II.1}$$

Explanation:

Xi = Average number of i subgroup

K = The amount of subgroup formed

2. Calculating the actual standard deviation of a settlement:

$$\sigma = \sqrt{\frac{\sum(Xj - \bar{x})^2}{N-1}} \qquad \text{II.2}$$

Explanation:

N = The amount of preliminary observation that has been done

Xj= An observed time during preliminary measurements

3. Calculating standard deviation from the amount of average distribution value, with formula as follows :

$$\sigma\bar{x} = \frac{\sigma}{\sqrt{n}} \qquad \text{II.3}$$

Explanation:

n = Amount of subgroups

4. Determining the upper control limit (UCL) and lower control limit (LCL)

   BKA = $\bar{\bar{x}} + 3\,\sigma\bar{x}$ ……………………………………………………II.4

   BKB = $\bar{\bar{x}} - 3\,\sigma\bar{x}$ ……………………………………………………II.5

The limits of this control is the limit to determine the subgroup uniformity. If all average subgroup is within the UCL and LCL, then all existing value can be used to count the number of measurements required.

II.1.7.2 Data Sufficiency Test

If the average subgroup already is under control then data will have to go through adequacy test. Adequacy test of the data is done by doing a comparison between the value of N' and the value of N (Sutalaksana, Anggawisastra & Tjakraatmadja 2006, p.152). Where the value of N is the number of measurement data that has done as many as 30 data. Here are the stages in performing the test the adequacy of the data:

1. Calculating the total time required from all subgroup using formula:

   $\sum x = x1 + x2 + x3 + \cdots + xn$…………………………………II.6

2. Calculating the square of total data from subgroup using formula:

   $(\sum x)^2 = (x1 + x2 + x3 + \cdots + xn \ldots)^2$……………………….………II.7

3. Calculate the square of each data then summed using formula:

   $\sum x2 = x12 + x22 + x32 + \cdots + xn$………………………………II.8

4. Calculating the N' value as a comparison using formula:

   $N' = (k\ s/\sqrt{N}\ (\sum x2) - (\sum x)2\ \sum x)^2$………………………………II.9

This formula is used for a confidence level of 95% and 5% level of accuracy. The level of accuracy indicates the maximum deviation of the measurement results of actual settlement proceeds, usually expressed as a percent. While confidence levels indicate the level of confidence that the result obtained are fullfilled the requirement of accuracy . If the number of measurements required was still greater than the number of measurements that have been performed (N '> N), the measurement is not adequate levels of data so that additional measurements need to be done. This additional measurement performed until the required number of measurements has exceeded that has been done (N '<N).

II.1.7.3 The Calculation of Cycle Time

If the measurements have been completed, that all of the data obtained has the desired uniformity, and the number that have met the desired precision and confidence, then proceed with the calculation to get the average cycle time. The steps of getting an average cycle time of the data collected are as follows (Sutalaksana, Anggawisastra & Tjakraatmadja 2006 , p.155). Calculating the cycle time, ie the time of completion of the production unit from the start of raw materials to the finished product:

$$Ws = \frac{\sum Xi}{N}$$ ………………………………………………………...………II.10

Explanation:

Xi = The average value of i-th subgroup

K = The number of subgroup formed

II.1.7.4 The Calculation of Takt Time

Takt Time is the ratio of working hours available to the number of orders per day. Takt time is the average production time needed to meet consumer demand. A cycle time of production must be less than the takt time to maintain the flow in the manufacturing process (Anthony, vinodh, & Gijo, 2016). Here is a formula to calculate takt time*:*

Takt time $= \frac{Working\ Hours\ Available}{The\ Amount\ of\ Demand}$……………………………………………….....II. 11

II.1.9 Line Balancing

II.1.9.1 Line Balancing Explanation

According to Gaspersz (2004), line balancing is an activity to balancing assignment of task elements from an assembly line to a work station to minimize the number of work stations and minimize total idle time on all stations for a given level of output. In line balancing, the time requirements per unit of product specified for each task and sequential relationship should be considered. According to Purnomo (2004), line balancing is a group of people or machines that perform sequential tasks in assembling a product that is assigned to each resource equally in every production path, resulting in high work efficiency at each work station. Line balancing is an assignment of a number of jobs into interrelated work stations in a single track or production line. The work station time should not exceeding the cycle time and work station. The function of Line balancing is to create a balanced path. The principal purpose of track balancing is to minimize idle time on the path determined by the slowest operation (Baroto, 2002).

II.1.9.2 Line Balancing Heuristic Method

The heuristic method is based on a mathematical and common sense approach. The heuristic boundaries state the trial and error approaches and this technique gives mathematically unoptimal results but is quite easy to use. This method is a practical, easy to understand, and easy to apply method (Sawyer, 1970). Here are some explanations of methods and steps for completing the method.

a. Metode Helgeson dan Birnie (Ranked Positional Weight)

It is a method developed by W.B Helgeson and D.P Birnie. This method is suitable for precedence diagrams starting from one operation and then branched into two or more operations which then end in more than one operation (Baroto, 2006). Here are the steps for completing the track balancing method (Elsayed & Boucher, 1994). Below is the step of doing line balancing RPW method.

1. Arranging precedence diagram
2. Determine the position of rank (positional weight) for each work element (ranking position of an interconnected operation from the longest running time from the beginning of operation to the end of the network).
3. Create a sequence of working elements from the top ranked position by ranking position in step number two.
4. The process of distributing the work elements based on work element with highest ranking to lowest ranking
5. If at the work station there is a residual time after the placement of an operation, place operations in the next sequence at the work station, as long as the

operation does not violate the precedence relationship, the time of the work station is not allowed beyond the cycle time

b. Metode Hillbridge-Wester (Region Approach)

This method was developed by Bedworth to overcome the lack of ranked positional weight method. There is no specific diagram suitable for the applied region approach method (Baroto, 2006). Here are the steps for completing the track balancing method (Elsayed & Boucher, 1994).

1. Divide the region or area from left to right. If its possible, distribute the work element in the right.
2. Determine the ranking for each work element in each region based on the time maximum to the minimum time.
3. Based on the provision stating that the region or the left region is first and the operating rank in the region at step b do the loading of work elements into the work station provided that it does not violate the precedence diagram and cycle time does not exceed the actual cycle time.

c. Metode Moodie Young

The moodie young method is suitable to use in precedence diagrams that start from 1 or many separate and branched to two or more operation and end in one operation . The steps of solving the moodie young method consist of 2 phases. Here are the steps for completing the track balancing method (Elsayed & Boucher, 1994).

1. The first phase of the work element is assigned to the work station in sequence on the assembly line with the largest candidate rule. The largest-candidate rule consists of assigning possible

elements (no precedences restrictions) in descending order. In other words, if two elements allow for assignment on a single station, elements that have a larger time are assigned first. After each element is assigned, possible elements are considered in decreasing time sequences in subsequent assignments. Using the matrix P (to indicate the predecessor working element) and the matrix F (indicating the working elements that follow) as the assignment procedure.

2. The second phase is done by distributing idle time equally on all stations through the mechanism of sale and transfer of elements between stations (obey the precedence limits)

II.1.9.3 The Terms in Line Balancing

Below is the term and parameter that can be use to calculate the line performance (Baroto, 2002)

a. Precedence diagram, is a network, with work elements represented by circles or nodes and precedence relationships represented by directed line segments connecting the nodes.
b. Work stasiun (WS) is the place on the track where the track process is performed. After determining the cycle time, the minimum number of workstations to be formed can be calculated using the following formula:

$$(K)_{min} = \frac{\sum_{j=1}^{n} t_j}{CT} \quad \text{……………………………………………II. 12}$$

c. Idle time (I) or delay time is the difference between cycle time (CT) and station time (ST)..Idle time occurs if the processing time on the work station is smaller than the cycle time.
d. Line efficiency is the ratio between the time spent and the time available. A good production trajectory has a high track efficiency

rating that indicates that all work stations have a time that is close to a predetermined cycle time. So it can be said that the higher the efficiency of the track, the better the trajectory. Here is the formula of line efficiency calculation:

$$LE = \frac{\sum_{m=1}^{K}(ST)_m}{(K)(CT)} \times 100\% \quad \text{……………………………………….II.13}$$

e. Balance delay time is the amount of idle time on production assembly lines caused by the uneven division of work among operators or stations. It is related to the extent and way the total task is subdivided. In this paper the problem of balance delay is treated empirically and analytically. A good production line has 0 balance delay, it means that the production line has no idle time in all work station.:

$$SI = \sqrt{\sum_{m=1}^{K} ((ST)_{max} - (ST)_m)^2} \quad \text{…………………………………………….II. 14}$$

f. Smoothest index is an index that has a relative smoothness of the balancing of a particular production path. A good production path has a smoothes index value close to zero. In other words the smaller the smoothest index value the better. Here is the smoothest index formula:

$$SI = \sqrt{\sum_{m=1}^{K} ((ST)_{max} - (ST)_m)^2} \quad \text{……………………………………..II. 1}$$

Keterangan:

ST_{max} = Maximum time in workstation

ST_m = Station time from m to k

K = Number of workstation formed

CT = Cycle time (the highest time in workstation)

T_j = work element (j=1,2,3,4,…..,n)

K_{min} = The amount of worksatation

II.2 Previous Research

As a research reference, the authors compare the 3 pieces of research done earlier using the tools and methods of lean manufacturing and can be implemented to minimize waste inventory that occurs on the production floor. These three studies entitled "Proposed Improvement Production Process Shirt to Minimize Waste Inventory at PT. Indonesia with Lean Manufacturing Approach "written by Dwi Intan Aprimuna," Proposed Improvement of Sandal Production Process to Reduce Waste Inventory with Lean Manufacturing Approach in CV. ASJ "By Arini Ulfarahmah," Proposed Design of Kanban Method to Minimize Waste Inventory on Production Process of AHM Blue Bottle Oil Bottle in Injection Molding and Finishing Area on CV. WK Using Lean Manufacturing Approach "By Qonitah Zahidah.

II.2.1 Proposed Improvement Of Production Process Of Shirt To Minimize Waste Inventory At PT. Indonesia With Lean Manufacturing Approach (Final Task By Dwi Intan Aprimuna, 2016)

PT. Progressio Indonesia (Pronesia) is a company engaged in the field of convection. Products that can be produced are t-shirts, jackets, polo shirts, shirts, pants, and others. In shirt making process at PT. Indonesia, found a problem in the accumulation or inventory that occurs in each work station sewing process and the buildup in the warehouse caused by the allowance that is mapped by PT. Pronesia is 1%. After the identification of waste, there are three waste with the highest percentage, one of which is waste inventory of 16%. In an effort to minimize waste inventory, lean manufacturing method is used. Research phase begins with primary data collection, then performed data processing. The initial stage of data processing is by mapping the value stream mapping. The next step is to identify the waste and proceed to identify the dominant cause of waste inventory by using fishbone diagram. Stage of problem solving for each root cause of waste inventory in the form of line balancing, pull system production with kanban, and job rotation. Based on the use of lean manufacturing tools, it is proposed that the proposed improvements in the form of grouping of several activities, controlling the amount of production to fit the needs, and doing job rotation so that the operational ability of the operator can be balanced.

II.2.2 Proposed Improvement of Sandal Production Process to Reduce Waste Inventory with Lean Manufacturing Approach in CV. ASJ (Final Project By Arini Ulfarahmah, 2017)

CV. ASJ is a subcontractor company that receives orders from various companies to produce sandals, especially men's sandals. CV. ASJ has a daily target of producing 500 pairs of sandals per day. However, production targets are often not achieved ie production floor can only produce 400 pairs of sandals. In the process of producing sandals found workup process of goods in process (WIP) on several work stations. The buildup is indicated as waste (waste) inventory that makes the lead time of production to be long so that daily production targets are not achieved. Based on the problem of waste inventory that occurs, then the design of proposed improvements to reduce the cause of waste inventory in the production process of sandals with lean manufacturing method approach. Identification of root cause of waste inventory problem is done by depiction of fishbone diagram. Furthermore, the design of proposed improvements to reduce the cause of waste inventory by applying pull system using kanban on assembly preparation department, upper department and insole department and line balancing on the process of making upper and assembly sandal process.

II.2.3 Proposed Design of Kanban Method to Minimize Waste Inventory on Production Process of AHM Blue Bottle Oil Bottle in Injection Molding and Finishing Area on CV. WK Using Lean Manufacturing Approach

CV. WK was established in 2000. The company is engaged in the production of Plastic Injection and also Mold Maker, which aims to provide production services, especially in the field of plastic. Plastic Product Types studied in this study focus on the blue AHM oil bottle cap. Based on company data, there are several delays in delivery of AHM oil cap product in January to October 2016. Based on the problem of the delay of delivery, then by using lean manufacturing approach done mapping of current stream value stream mapping (VSM) to know the manufacture of product from start order until the product is sent to the customer, then mapping the activity process mapping (PAM) current state by describing the production process activities that will be grouped into the category of value added, non value added, and non value added activities in each workstation, so that the result of the identification of waste inventory of 99.15%. Therefore, it is necessary to draft proposed improvements to minimize waste inventory in the area of injection molding and finishing with lean manufacturing approach.

The next step, identify the root cause of waste inventory with fishbone diagram and 5 why's. And for the stage of problem solving on every root cause of waste inventory can by implementing kanban system.

Based on the implementation of kanban system, it is obtained the production control card and the proposed product design to support the running kanban system in the form of post kanban design, where the defect component, and the aids in WIP transportation on injection molding and finishing area.

CHAPTER III RESEARCH METHODOLOGY

The research methodology is the research steps that provide a clear idea of the methods and how the researchers solve problems to achieve the research objectives. This chapter explains the conceptual model and research steps used in detail in solving the problem in order to meet the objectives of the study.

III.1 Conceptual Model

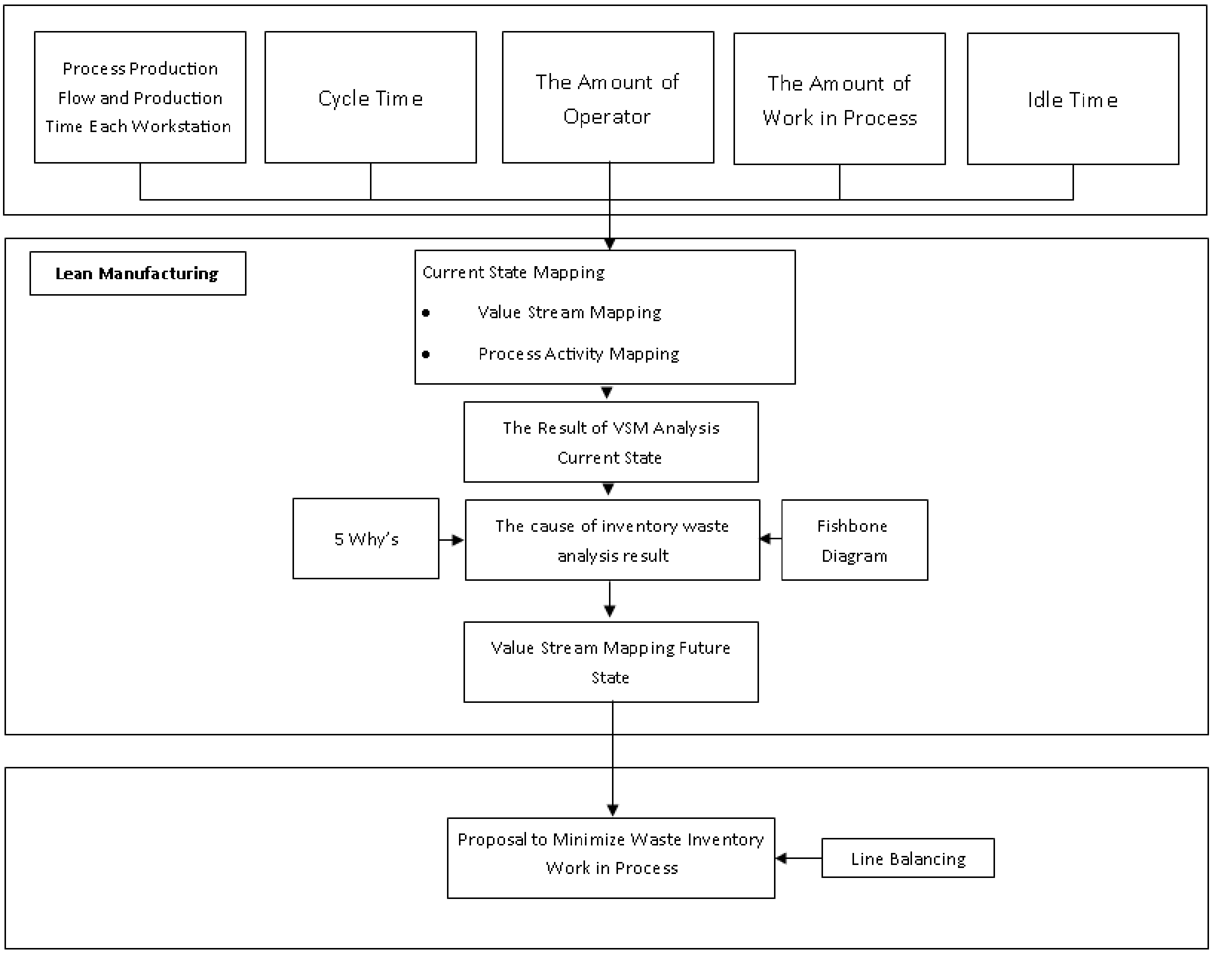


Figure 3. Conceptual Model

Figure III.1 is a conceptual model used in research. In the conceptual model, the required input data is cycle time, production process sequence along with production process time at each work station, number of operators involved, number of work in processs, and time to store work in processs. The input data will be used to determine the overall condition of the shirt production process of CV. CJM which will then be poured on current state value stream mapping and also activity mapping process that serves for the determination of category of value added activity (VA) which means activities that add value to the product, activities necessary non value added (NNVA) which means an activity must exist in the production process but not provide added value to the product, and the last is non-value added activities (NVA) is an activity that does not provide added value to the product. After classifying by category of VA, NNVA, and NVA, it can be seen the percentage of each waste in the production process of the company. Then identify the root cause of waste inventory by using fishbone diagram tool and 5 why's. After knowing the root cause of waste inventory, the proposed design to minimize waste inventory by using kanban method, job rotation, line balancing, and takt time.

III.2 Problem Solving Systematic

Systematic problem solving is a tool used to describe the steps and flow of thought regularly and systematically to be taken to solve the problems that occur. The problem solving framework in this research consists of 3 stages: data collection and data processing, proposal analysis stage, and conclusion and suggestion stage. Below is an image of the problem-solving framework.

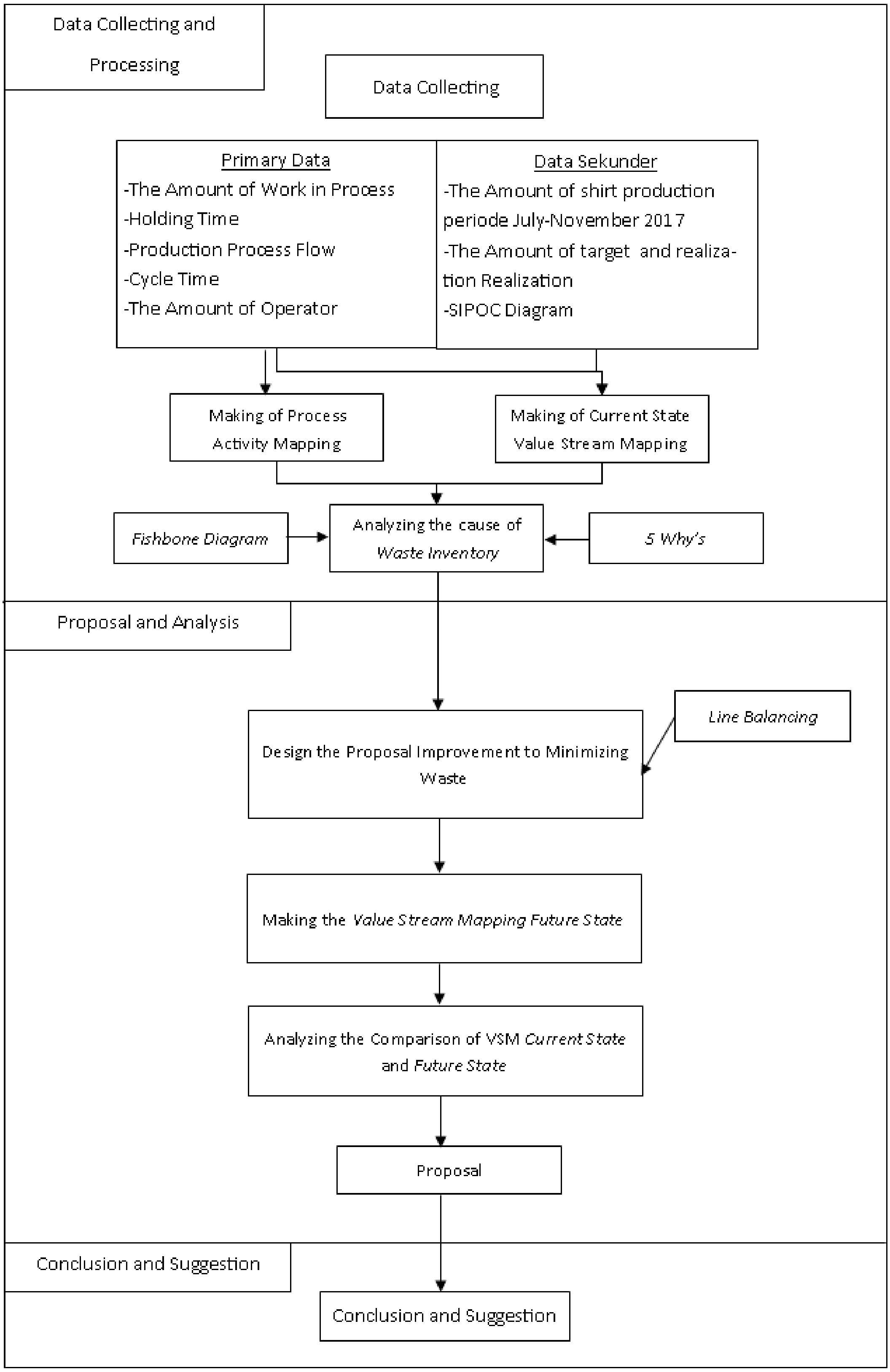


Figure III.1. Data Collecting and Processing

III.2.1 Data Collecting and Processing

1. **Primary and Secondary Data Collecting**

   At this stage data collection is needed to solve existing problems within the company. The data is then processed to produce a proposed improvement plan. The required data consist of:

   1. Primary Data

      Primary data is needed to find out the problems that occur on the company's production floor. In this study, the primary data obtained from observation directly on the production floor. Here is a table of data and how the measurements are displayed in the table:

Table III.1. Primary Data

Data	Source
The Amount of Work in Process	The amount of work in process is done by observing each workstation. Then calculate the amount of work in process work in process to get the average duration of waiting time each WIP.
The Duration of Work in Process Storage	Duration time of work in process is measured by direct observation of the amount of component buildup and calculation of the average time that occurs from entering WIP

Table III.1. Primary Data

(cont.)

Data	Source
	from the previous work station until WIP is processed again.
Process Production Flow	The flow of production process is taken by observation directly on the production floor and observing to every sequence of production process.
Cycle Time	Cycle time is done by calculating the process time in each station
The Amount of Operator	The amount of Operators is obtained from interviewing the company's production head

2. Secondary Data

Secondary data is data obtained from company documents

Table II.2 Secondary Data

Data	Source
The amount of Shirt Production Periode July-August	Taken from the document of PT. CJM
The amount of production target and product realization	Taken from the document of PT. CJM
SIPOC Diagram	Taken from the document of PT. CJM

2. VSM and PAM Mapping

After getting the required data, next step is to mapping Value Stream Mapping (VSM) and Process Activity Mapping (PAM). Value Stream Mapping mapping steps are as follows (Accessed from http://leanmanufacturingtools.org/551/creating-a-value-stream-map/ , 17 September 2017)

1. Determine the process or area you want to map.
2. Determine the process steps from the supplier start to the customer or vice versa. There are many ways that can be done to identify those processes.
3. Gather basic information about the current state map by using a series of questions such as daily production capability, daily production demand, how customers order products.
4. Collecting data related to the performance of each process. The data that need to be collected are inventory data, cycle time, number of

operators, working time, available working time, palette size.

5. Begin Documenting the process flow, starting with mapping the main stream, mapping out how the product moves from one process to the next, mapping the inventory, mapping the number of operators on each work station, measuring the cycle time of each work station, measuring non value added time, measure change over time.
6. Counting lead time production and value added time

Next is the mapping process activity mapping needed to see the picture of the shirt production process in order to identify the waste that occurs in the production process. The stages required in making PAM are as follows:

3. Understand the process flow
4. Identify waste
5. Consider whether the process can be rearranged in a more efficient order
6. Consider a better flow pattern, involving different flow layouts or transportation arrangement routes
7. Consider whether everything that is being done at each stage is really necessary and what will happen if the excessive task has been removed

By mapping a PAM, it can help identify the waste that occurs in the production process and then menyentasekan each category of waste to be able to know the highest percentage of waste to then be minimized.

3. **Analyzing the root cause of waste inventory**

Analyze the root cause of waste inventory that occurs on the production floor by using a fishbone diagram. In addition to using the tool 5 why to get the cause of problems on the production floor in detail.

III. 2.2 Proposed and Analysis Stage

After performing the data collection and processing phase, the next step is to perform the proposal and analysis stage according to the problems that occur on the production floor based on the root of the problem obtained from the use of fishbone diagram and 5 Why's. After knowing the root of the problem then the next is to mapping the future state on value stream mapping (VSM) and the proposed improvement using lean manufacturing tools.

III.2.3 Conclusion and Suggestion

This stage is the final stage of the study which contains the conclusions and suggestions of the research that has been done. This stage contains the results of the research objectives that have been set, and also researchers provide suggestions for the company and consideration materials for further researchers.

CHAPTER IV DATA COLLECTION AND PROCESSING

This chapter will be discussed about data that support the research based on methodology explained in chapter 3. Researcher collect the data from various method such as observation, interview, and secondary data.

IV.1 Data Collection

IV.1.1 Research Object

Based on the previous chapter, this research was conducted at a company called CV Chikal Jaya Makmur which is engaged in garment industry. CV CJM produces various types of clothing such as shirts, pants, sweaters, jackets, and T-shirts. However, this research only focus on the process of short-sleeves shirt. Below is the production process flow from shirt making which will be explained with SIPOC diagram.

IV.1.2 SIPOC

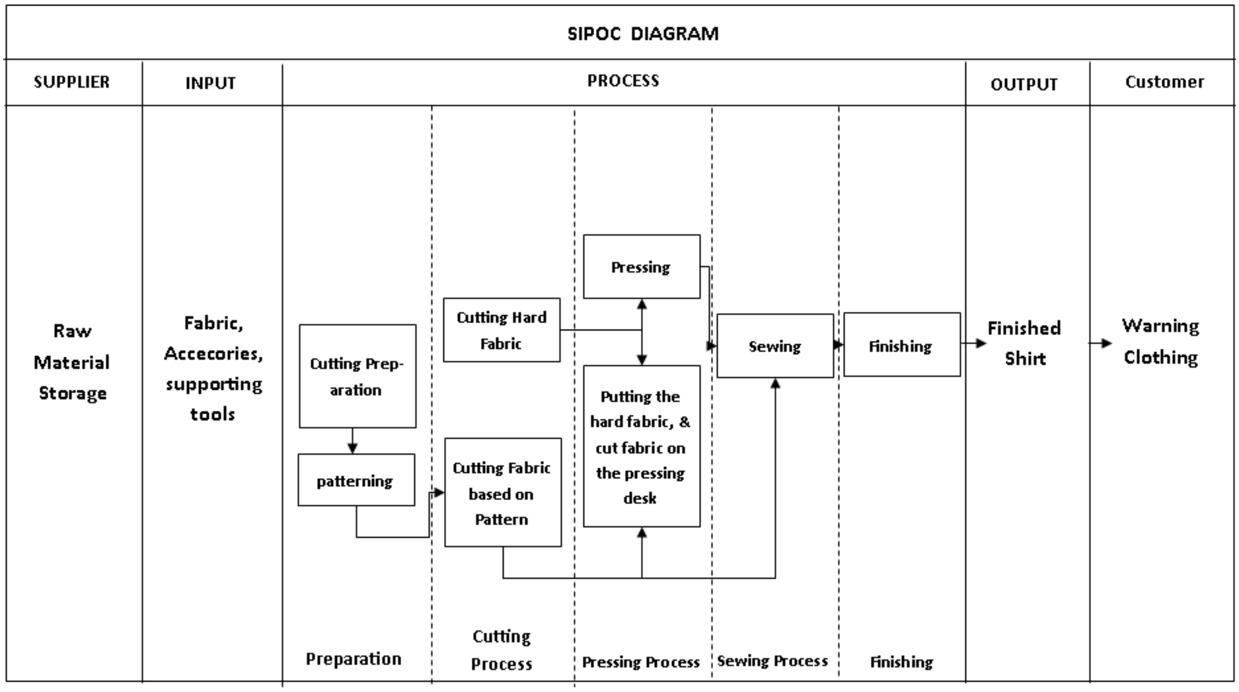


Figure IV.I SIPOC Diagram of CV. CJM

Below is the explanation of SIPOC diagram:

a. Supplier : Supplier of short-sleeves production process is raw material storage
b. Input : The input is fabric, accecories embroidery and buttons, as well as as supporting tools such as sewing machine, pressing machine, and button installation machine.
c. Process : Production process of short-sleeves shirt in CV. CJM is divided into 5 major parts as follows.
   1. Preparation

The first preparation process is the preparation of raw materials which is preparing the materials needed for the process of Cutting . The type of fabric used is among others USA drill. Cotton, and flannel. After that the process of marking cloth that is the cloth roll is placed on the fabric spreading tool. Then the cloth is spread over the available table, many piles of fabric strands adjusted to the amount of P.O ordered on the fabric. The spread of fabric is done on a table with a length of 5 meters and a width of 2 meters. Below is an image of the process of fabric overlays

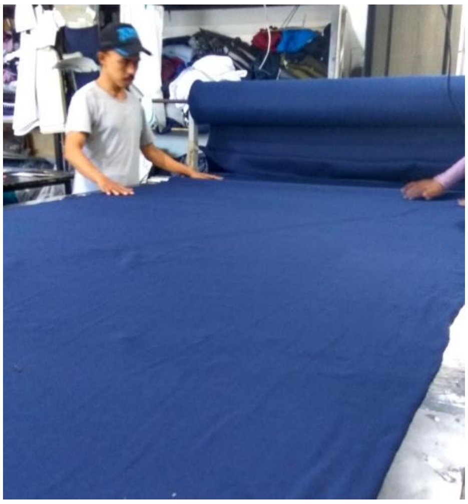


Figure IV.II. Preparation Process

After the fabric is overlaid and stacked according to P.O data, the marking process can be performed. The process of marking is done by placing the existing pattern on the top of the pile of fabric. The marking process is done using the shape of the collar foot, collar, blekser, right and left front, back, shoulders, right and left sides, which have various sizes, S, M, L, XL. Here are some pictures of example the pattern.

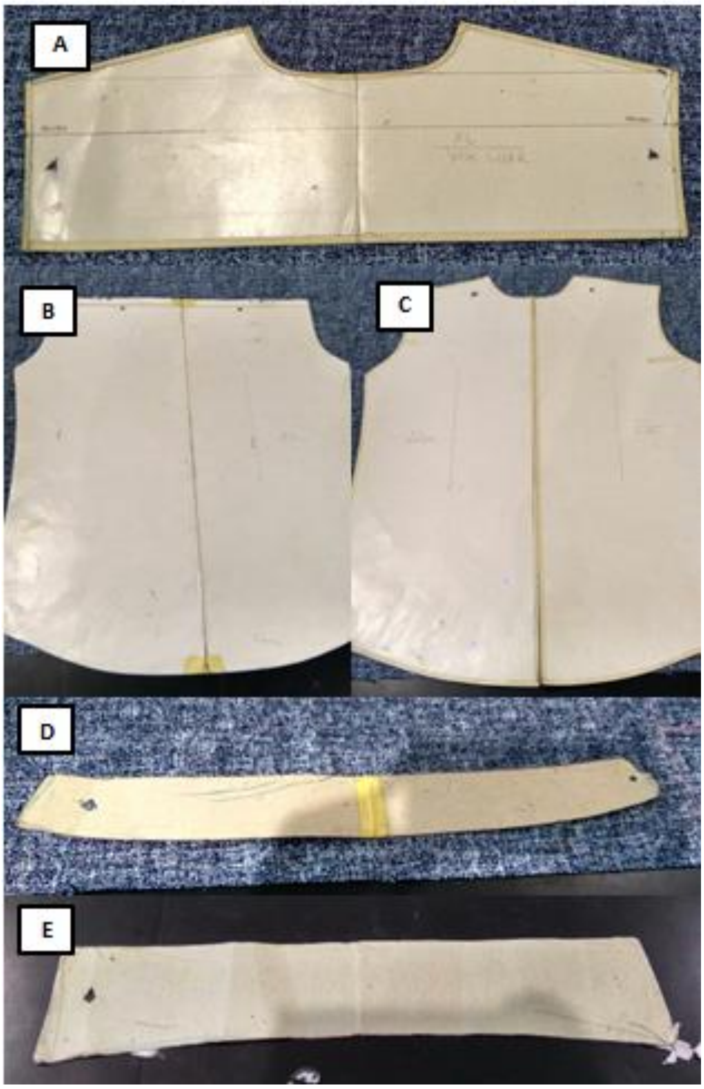


Figure IV.3. Shirt Pattern

2. Cutting Process
    a) Process of Fabric Cutting

After the marking process is done, then the next process is Cutting process which is cutting the fabric according to the pattern left on top of the pile of fabric. The output of the Cutting process will then be the input of the pressing process (leaf collar, collar feet, *blekser*) and sewing. The machine used in this process is 2 pieces of cutting machine. Here is a picture of the cutting machine.

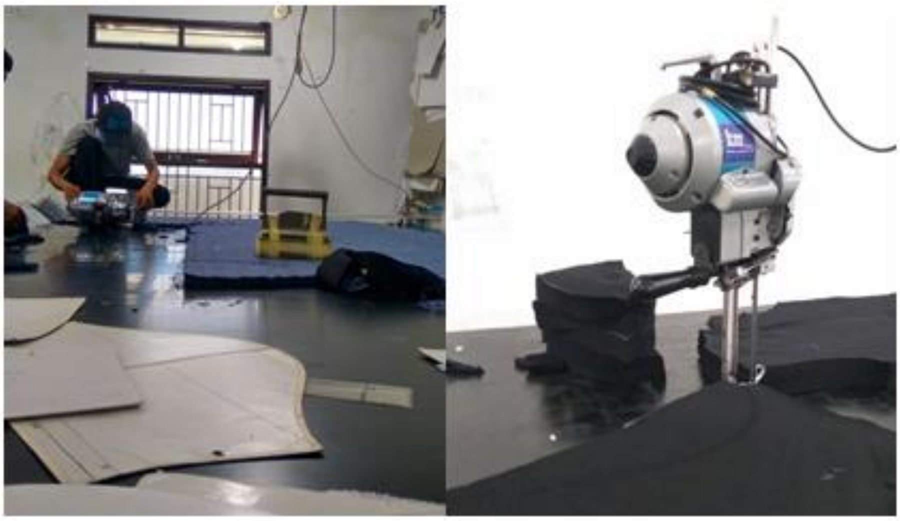


Figure IV.4. Cutting Machine

b) Process of Hard Fabric Cutting

The process of cutting hard fabric is done by 1 operator. The process of cutting hard fabric is assisted using a wooden pokayoke with both nails placed far apart in accordance with the size of hard fabric to be paired with blekser, leaf collar, and collar feet. First take a roll of hard cloth then put it on pokayoke by taking the hard fabric around of pokayoke for 60 times

.

Figure IV.5. Hard fabric

Then cut in both ends of the hard part of the fabric. Hard fabric that has been cut then tied into one as many as 60 pieces.

3. Pressing Process

Input of the pressing process is hard fabric and result Cutting collar leaf, collar feet and blekser. Pressing is the process of bringing together hard fabrics with each collar leaf, collar feet and *blekser*. First 3 collar leaf/collar feet/*blekser* are placed on the table, then a hard cloth is placed above the cloth. Then they pushed together into the pressing machine. After the pressing process is complete, the output will then be grouped by size (S, M, L, XL) according to the existing P.O number. The following is a Hashima branded pressing machine issued in 2004 and is still in good shape.

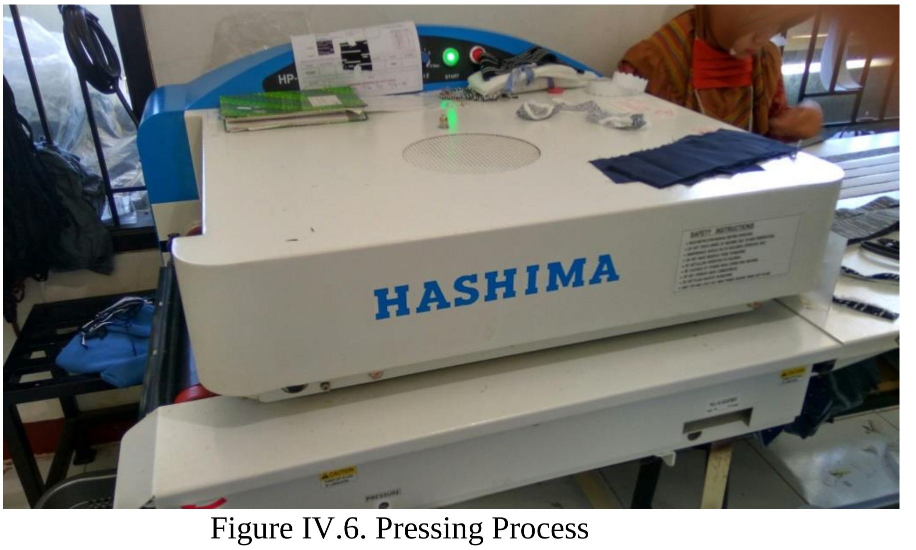


Figure IV.6. Pressing Process

4. Sewing Process

After the inspection process is done, the fabrics will be distributed in the sewing area. the sewing process consists of 15 processes each of which is performed by 1 operator. The process of sewing consists of several processes as follow: Stitching collar leaf inside and outside, stitching collar feet inside and outside, stitching collar leaf and feet, cut the excess colar feet fabric, stitching fron and left blekser, stitching upper and lower back part, labelling, stitching front and back part by shoulder, collar stitching to the body, hem collar to the body, sitching body with left and right sleeves by shoulder, hem circular sleeves, stitching side part of the body, and the last is hem bottom of shirt. below is an example of sewing operation activities at 3 sewing workstation such as stitching inner and outer collar, stitching inside and outside collar, and stitching of collar leaf and feet.

Figure IV.7. Example of Sewing Process

Sewing process requires several tools such as sewing machines, scissors, lime, yarn, and sewing lamps. The output of the sewing process will then be the input for the finishing process.

5. Finishing Process

Is the last process of the shirt making process. In this area consists of several processes namely button installation, ironing, label installation, packaging, and final inspection. The process of button installation is done by 3 operators. The buttoning process is started by the first operator which is done the marking process for button location, then the buttons are mounted on the marks by using the button attaching machine, after which the suturing of the buttonhole and holes in it by using the button holing machine.

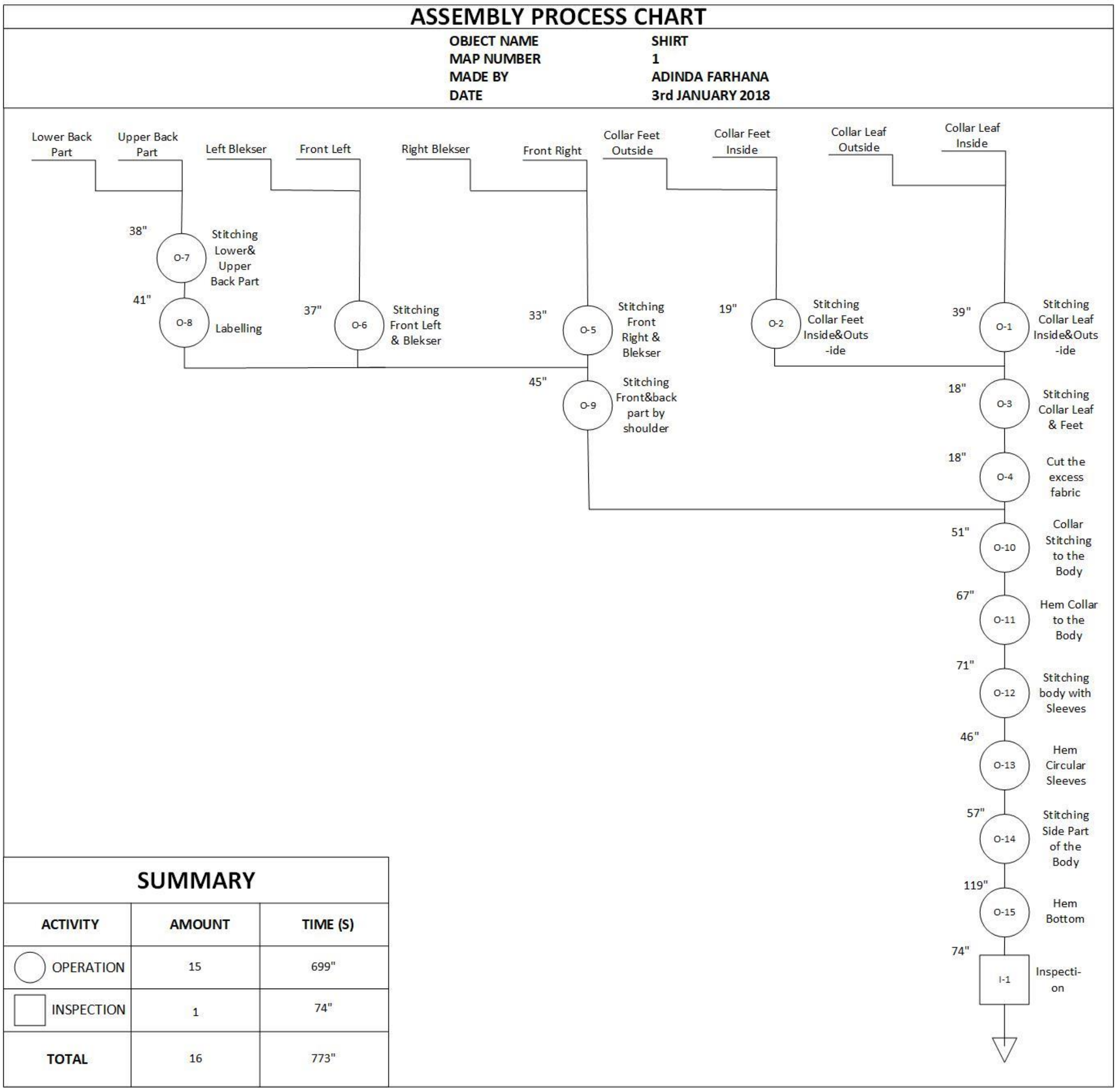
Figure IV.8. Mesin Button Installation

After the buttoning process is complete, next is the ironing process which is done by one operator using iron steam. After that the installation of tag label, then packaging, and final inspection which is done by 3 operators.

d. Output : The output of this production process is short-sleeves shirt.
e. Customer : The costumer of this product is Warning Clothing.

IV.1.3 Assembly Process Chart

Below is the assembly process chart of process short-sleeves shirt makin in CV. CJM.



SUMMARY		
ACTIVITY	AMOUNT	TIME (S)
OPERATION	15	699"
INSPECTION	1	74"
TOTAL	16	773"

Figure IV.9. Assembly Process Chart

IV.2 Data Processing

IV.2.1 Process Time Testing

Data collection on the process of production short-sleeved shirt CV.CJM done as much as 30 times by using time stucy. The results of data retrieval is used to test normality, uniformity, and data adequacy.

IV.2.1.1 Data Normalization

The data normality test is used to prove that the observed time data has presented the actual population time. Testing the normality of this data using Kolmogorov-smirnov test in statistical product software and service solution (SPSS). Table below shows an example of normalized data test using SPSS software.

One-Sample Kolmogorov-Smirnov Test

		hard_fabric_cutting	pressing_process	alligning_the_fabric
N		30	30	30
Normal Parameters[a,b]	Mean	37,9000	21,5333	17,1667
	Std. Deviation	,84486	1,00801	1,23409
Most Extreme Differences	Absolute	,257	,202	,213
	Positive	,257	,202	,187
	Negative	-,204	-,178	-,213
Kolmogorov-Smirnov Z		1,406	1,104	1,166
Asymp. Sig. (2-tailed)		,038	,174	,132

a. Test distribution is Normal.

b. Calculated from data.

Figure IV.104. Data Normality Test

The hypothesis of Kolmogorov-Smirnov test is shown as follow:

H0 : Data is normally distributed (asymp.sig. (2-tailed) > α)

H1 : Data is not normally distributed (asymp.sig. (2-tailded <α)

Based on table IV.2 can be known Asymp value. Sig (2-tailed) for hard fabric cutting is 0,038, for pressing process 0,174 and for aligning the fabric is 0,132 which is all the value is> 0.05 or receive H0, so the data is normally distributed which states no significant difference of the hypothesis and samples of time data taken and can be present with the time of the population. The detailed test of normality of data can be seen in the attachment.

IV.2.1.2 Data Uniformity

Uniformity of data within a system are things that can go unnoticed. Therefore, we need a tool that can detect or control it. The control limits are established from the data is uniform or not a determinant variable data. A group of data is expressed uniformly when the data is between the two control limits. Defined control limits are Upper Control Limit (UCL) and the Lower Control Limit (LCL). When the data is outside these limits, then the data is declared not uniform. Here are the stages of conducting uniformity test. (Sutalaksana, Anggawisastra & Tjakraatmadja 2006 , p. 151).

1) Determine the number of subgroups by using the formula
   Total Subgroup = 1+(3.3 x Log N)

   N = Total sample

   From the formula of determining the number of subgroups with a value of N given 30, then obtained results of 5.8 or equivalent to 6. Based on the results of these calculations the number of subgroups is 6. Table IV.2 shows subgroup division on activity Pattern Positioning in Fabric Sheet.

Table IV.1 Data Uniformity Test

Subgroup	Xi	Time (s)	$\bar{x}$ (s)
I	1	73	74
	2	75	
	3	75	

Table IV.1 Data Uniformity Test

(cont.)

Subgroup	Xi	Time (s)	$\bar{x}\ (s)$
	4	75	
	5	72	
II	6	72	72,8
	7	73	
	8	74	
	9	73	
	10	72	
III	11	73	74,4
	12	75	
	13	75	
	14	75	
	15	74	
IV	16	72	74
	17	75	
	18	74	
	19	74	
	20	75	

Table IV.1 Data Uniformity Test

(cont.)

Subgroup	**Xi**	**Time (s)**	$\bar{x}$ **(s)**
V	21	74	73,6
	22	74	
	23	74	
	24	73	
	25	73	
VI	26	75	73,6
	27	73	
	28	72	
	29	73	
	30	75	

2) Calculate the average of each subgroup by using the formula :

$$\bar{\bar{x}} = \frac{\sum xi}{k}$$

Where :

x_i = harga rata – rata dari subgroup ke-i

k = harga banyaknya subgroup yang terbentuk

Sehingga :

$$\bar{\bar{x}} = \frac{74+72.8+74.4+74+73.6+73.6}{6}$$

$\bar{\bar{x}}$ = 74 s

3) Calculate the standard deviation by the formula :

$$\sigma = \frac{\sqrt{\sum(xj - \bar{\bar{x}})^2}}{N-1}$$

Where :

N = number of observations made

x_j = the completion time observed during the preliminary measurement

So that

$$\sigma = \frac{\sqrt{(73-74)^2+(75-74)^2+\ldots+(75-74)^2}}{30-1}$$

$$\sigma = 0.55 \text{ s}$$

4) Calculate the standard deviation of the subgroup averages. As for the calculation is to use the formula as follows.

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

Where :

n = the size of the group

So that :

$$\sigma_{\bar{x}} = \frac{0.55}{\sqrt{5}}$$

$$\sigma_{\bar{x}} = 0.24 \text{ s}$$

5) Calculating Upper Control Limit (UCL) and Lower Control Limit (LCL) As for the calculation is to use the formula as follows.

UCL = $\bar{\bar{x}} + 3\sigma_{\bar{x}}$

= 74 + 3(0.24)

= 74.5 s

LCL = $\bar{\bar{x}} - 3\sigma_{\bar{x}}$

= 74 – 3(0.24)

= 73 s

Based on the calculation of UCL and LCL obtained upper control limit of 74.5 s and lower control limit of 73 s. UCL and LCL is the limit of data control is uniform or not.

Table IV.2. The Result of Data Uniformity

Activity	Uniformity Test					
	$\bar{\bar{x}}$	**σ**	**σx**	**BKA**	**BKB**	**Result**
Pattern Positioning in Fabric Sheet	74	0,55	0,24	74,5	73,0	UNIFORM

Based on the table IV.3 it can be concluded that the activity of Pattern Positioning in Fabric Sheet belongs to the uniform category, since the mean of all subgroups are within the upper control limits and lower control limits. The complete uniformity test data can be seen in the appendix.

IV.2.1.3 Data Sufficiency Test

Adequacy test of the data is done by doing a comparison between the value of N' and the value of N (Sutalaksana, Anggawisastra & Tjakraatmadja 2006, p.152). Where the value of N is the number of measurement data that has done as many as 30 data. Here are the stages in performing the test the adequacy of the data:

$$N' = \left(\frac{k/s\sqrt{N\,(\Sigma x)^2 - (\Sigma x^2)}}{\Sigma x}\right)^2$$

where :

N’: The number of observation that supposed to be done

N’: The number of observation that has been done

s : The level of Accuracy

k : Level of Confidence

x : Observation Time

The value of k is determined by condition :

- Level of confidence ≤ 68% value of k = 1

- Level of confidence 68% < 1 – α ≤ 95%, value of k = 2
- Level of confidence 95% < 1 – α ≤ 99%, value of k = 3

Data is sufficient if N’>N then it takes longer time measurement as much N’-N and then retest. This study used a confidence level of 95% and a precision level of 5%. Here is one of N's calculations on the front right and back of fabric sewing activities.

Table IV.3. The Result Sufficiency Test Data

Activities	Sufficiency Data			N'	Result
	∑(X²)	∑(X)	(∑X)²		
Sewing the front right and back of the fabric	5625	409	167281	14,051	SUFFICIENT

Based on the calculation example of the activity of the front right and back of the fabric,

$$N' = \left(\frac{k/s\sqrt{N\ (\Sigma x)^2 - (\Sigma x^2)}}{\Sigma x}\right)^2$$

$$N' = \left(\frac{2/0.05\sqrt{30\ (167281)^2 - (5625^2)}}{409}\right)^2$$

N' = 14.051 data

Based on calculation of data sufficiency test, it is found that N> N 'so that it can be concluded that the front right and back of the fabric sewing activity has enough data (N = 30) to perform standard time calculation. Complete sufficiency test data can be seen in the attachment.

IV.2.2 Value Stream Mapping Current State

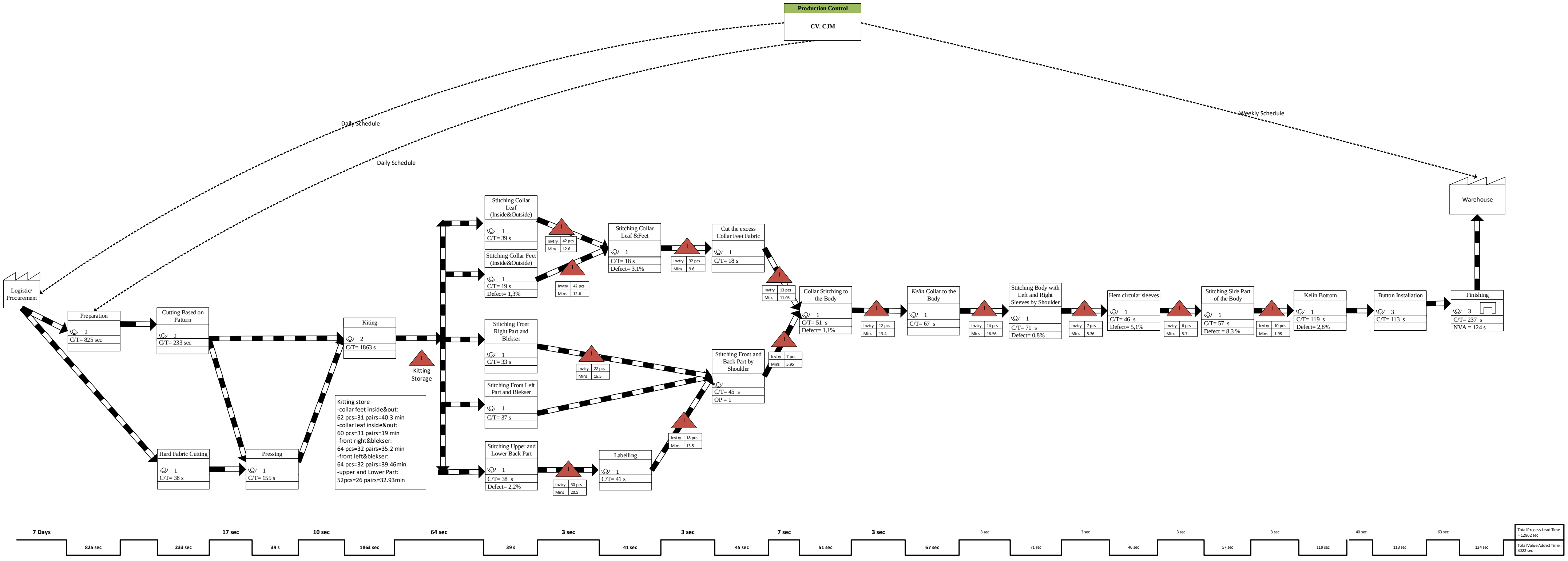


Figure IV.11. Value Stream Mapping Current State

IV.2.3 Waste Inventory Identification

After making the value stream mapping, it was found activities that are classified as VA, NVA, and NNVA. In the value stream mapping we can see that there is the buildup - work in process on each work station sewing section. Work in process on sewing process occur because of the unbalanced workload on each workstation with different cycles time. Following is a picture of work in process inventory

Figure IV.12. WIP between Sewing Workstation

IV.2.4 Cause Effect Diagram (Fishbone Diagram)

The following is a fishbone diagram for work in process inventory problems on the tailoring workstation that will be displayed in the image below.

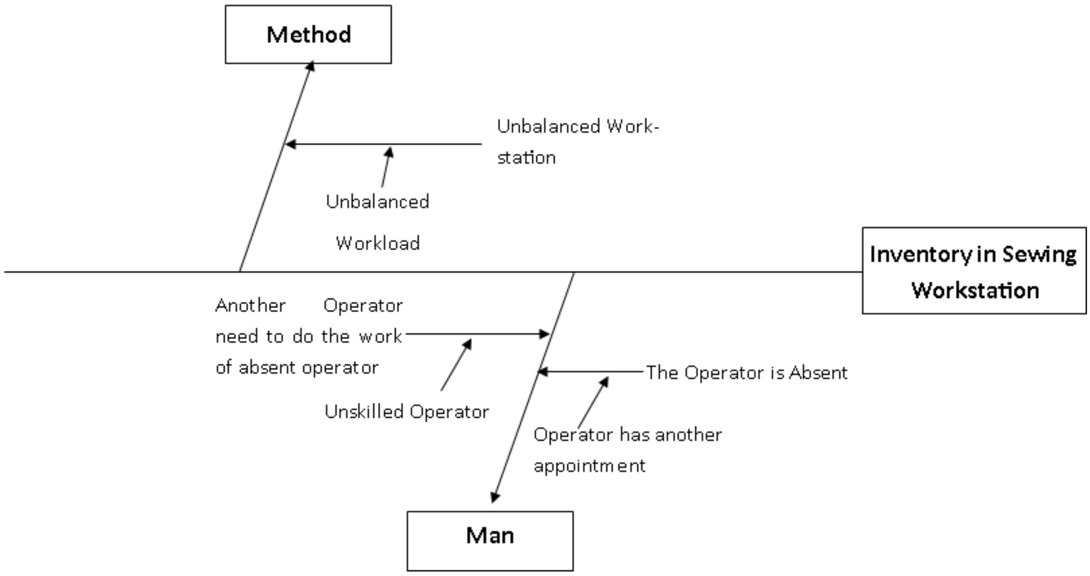


Figure IV.13. Fishbone Diagram

The picture above shows the fishbone diagram that causes the inventory work in process on the sewing workstation . Fishbone results show that inventory on ws sewing caused by 2 factor which is method , and operator.

After done the observation on production process of shirt and found several categories that cause the work in process inventory in sewing workstation, researcher then conduct the validation of fishbone diragram is represent the true state of production process condition. The validation is by conducted re-observation and interview with supervisor. Below is the table of checklist and the result of interview will be shown on the appendix.

Date: 25 September 2017	Observant: Adinda Farhana	information	
No	Waste Inventory Cause	Yes	No
1	The inbalance workload between each WS	v	
2	There are WIP between each sewing WS	v	
3	There are operator who replace another jobdesk	v	

IV.2.5 5 Why's Analyis

Figure 5. 5 Why's Analysis

Sub Cause	Why (1)	Why (2)	Why (3)	Why (4)
There is work in process inventory in between sewing workstation	Work in process waiting to be processed	The operator is still working in previous WIP	Operator of predecessor process is done faster than operator of following process	There is an unbalance workload between workstation

Table above is an analysis table of 5 why to help finding the root cause of waste inventory. The subcause is an inventory process between sewing workstation. After done the 5 why analysis, researcher found the root cause of waste inventory work in process is there is an unbalance workload between each workstation.

After knowingthe root cause of waste inventory work in process on ws sewing, next will do the proposal improvement for the problem. Below is the proposal of improvement table.

Table IV.4. Table of Proposal

No	Root cause	Proposal Improvement	Reason
1	The unbalanced of workload in sewing workstation	*Line Balancing*	Equity of workload and cycle time each workstation to to minimize the existence of work in process between sewing workstation. .

IV.2.6 Value Stream Mapping Future State

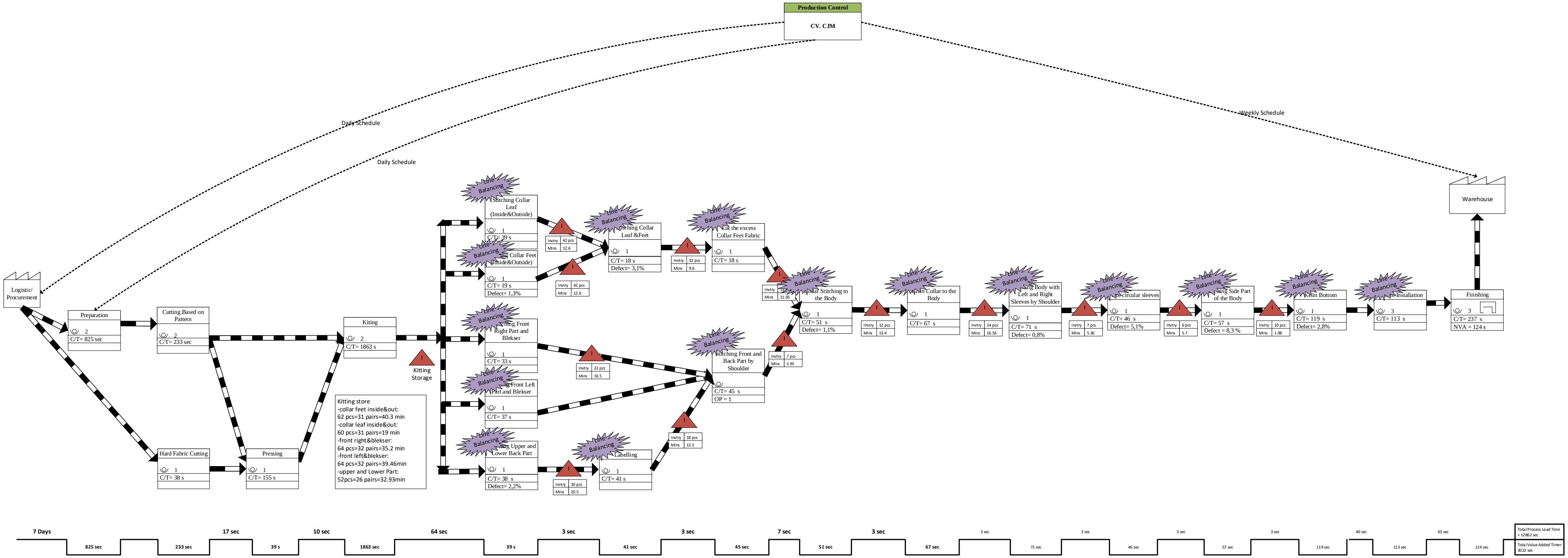


Figure IV.14 Value Stream Mapping Future State

IV.2.7 Takt Time Calculation

Takt Time is the ratio of working hours available to the number of orders per day. Takt time is the average production time needed to meet consumer demand. A cycle time of production must be less than the takt time to maintain the flow in the manufacturing process (Anthony, vinodh, & Gijo, 2016). Here is a formula to calculate takt time:

$$Takt\ time = \frac{Working\ Hours\ Available}{The\ Amount\ of\ Demand}$$

The takt time calculation is done by using the number of demand per day and the number of effective work hours of the company. The amount of work per day is Monday to Friday is shown in the table below.

Table IV.5. Workhour Operator

	Time		**Duration**		
	Start	Until	Hour	Minutes	Second
Work	08.00	12.00	4	240	14400
Break Time	12.00	13.00	1	60	3600
Work	13.00	17.00	4	240	14400
	Total		9	540	32400
	Effective Time		8	480	28800

Based on the above table, the effective working hours of the operator per day is 8 hours or 28,800 seconds. The average number of corporate demand per day from July to November is 120 per day. then takt time calculation for production process shirt CV. CJM is as the following .

$$Takt\ time = \frac{28.800\ detik}{120\ pcs/hari} = 240\ detik$$

The results of takt time calculation of shirt production process is 240 seconds . It is have meaning that company need to done 1 product in 240 seconds to meet customer's demand.

IV.2.8 The Proposal of Line Balancing in Sewing Workstation

This research will use 3 heuristic line balancing methods that is Helgeson-Birnie (Positional Weight), Killbridge-Wester (Region Approach) method, and Moodie Young method. The results of these three methods will be compared and the results obtained from the methods that produce the highest efficiency. Line balancing will only be done on the workstations of the sewing department. Before starting the calculation of line balancing with the three methods, we will calculate the balance delay, line efficiency, and smoothest index of the existing process. Here is a table of workstation sequences together time cycle each workstation

Table IV.6. Process Sequences

	TASK	**PREDECESSOR**	**TIME (s)**
SCL	Stitching collar leaf (inside and outside)	-	39
SCF	Stitching collar feet (inside and outside)	-	15
S	Stitching Collar leaf and feet	SCL,SCF	18
CUT	Cut the excess colar feet fabric	S	18
SRB	Stitching front right and blekser	-	33
SLB	Stitching front Left and blekser	-	37
SUL	Stitching Upper and Lower Back Part	-	38
L	Labelling	SUL	41
SFB	Stitching Front and Back Part by Shoulder	SRB,SLB,L	45
SCOL	Collar Stitching to the Body	SFB,CUT	51
HCOL	Hem Collar to the Body	SCOL	67
SSLE	Stitching Body with Left and Right Sleeves by Shoulder	HCOL	71
HSLE	Hem End Sleeves	SSLE	46
SIDE	Close Arm and Side Body Part	HSLE	40
HBO	Hem Bottom	SIDE	119
BI	Button Installation	HBO	113
INS	Inspection	BI	74
IR	Ironing	INS	45

Based on the table above , each workstation has different cycle time. It can be seen that most of cycle time in sewing workstation is far above the cycle time, this will cause the work in process inventory between workstation sewing , because some activity do in a short time while activity others do in quite a long time. So that it need an improvement with combining some element work or break work element to avoid exceeds value takt time. Below is the comparison chart between takt time and cycle time each workstation before line balancing implementation.

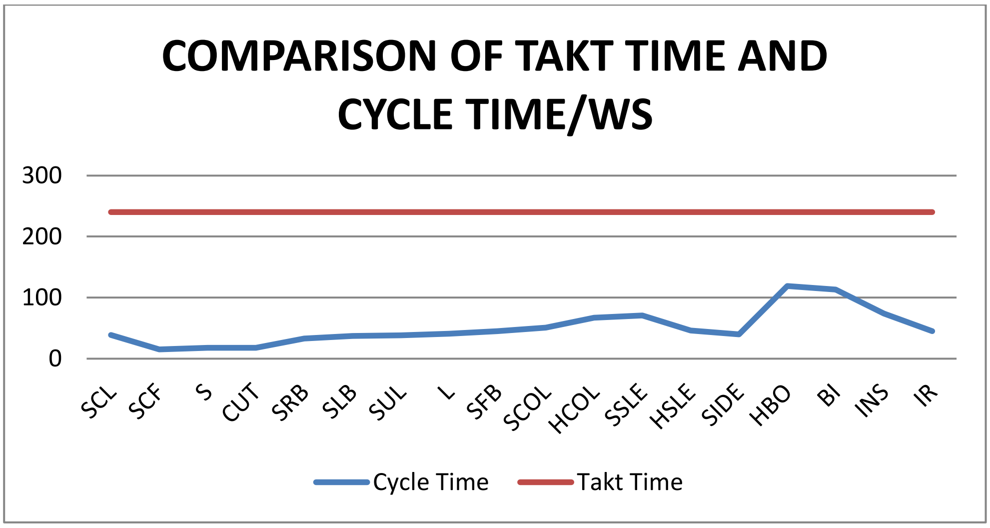


Figure IV.15. Takt Time and Cycle Time Comparison of Current State

Based on the comparison chart between takt time and cycle time of each workstation, the entire workstation cycle time is far below takt time, this can cause the work in process inventory on each workstation. After comparing the cycle time with takt time, the calculation of Line Efficiency, Balance Delay, and Smoothest Index will be done for actual condition before line balancing impelementation.

Based on the workstation table data that shown above, the cycle time on the shirt production process is 240 which is obtained from the calculation of available operator time divided by the average demand per day. And the total cycle time of all ws is 910 with total number of workstations is 18 workstations. With these three formulas, it will be calculated Line Efficiency, Balance Delay, and Smoothest Index.

a. Line Efficiency

Line efficiency is the ratio between the time spent and available time. A good production line have high amount of line efficiency and indicate that all workstation have a time that is almost similar to the determined cycle time. So it can be concluded that the higher line efficiency, it produce the better production line (Baroto,2002). The calculation of line efficiency is calculated with the formula below.

$$LE = \frac{\sum_{i=1}^{K} ST_i}{(K)(CT)} \times 100$$

$$LE = \left(\frac{910}{18x240}\right) x100\% = 42{,}48\%$$

The result of line efficiency calculation is 42,48%

b. Balance Delay

Balance delay is a measure of the inefficiency of the track resulting from the actual idle time caused by poor allocation between work stations. A good production path has a value of balance delay of zero, which means no idle time on all workstations. The smaller the value of balance delay, the better (Baroto, 2002). The calculation of balance delay can use the formula below.

$$BD = \frac{(K \times CT) - \sum_{i=1}^{n} ti}{(K \times CT)} \times 100\%$$

$$BD = \left(\frac{18x240 - 1352}{18x240}\right) x100\% = 57{,}5\%$$

The result of balance delay calculation is 57,5%

c. Smoothest Index

Smoothest index is an index that has a relative smoothness of the balancing of a particular production path. A good production path has a smoothes index value close to zero. In other words the smaller the smoothest index value the better. Here is the formula for calculating the smoothest index.

$$SI = \sqrt{\sum_{i=1}^{n} (STi\max - STi)^2}$$

SI= 314,0032

The result of smoothest index calculation is 839,4.

d. The calculation of the minimum workstation that must be formed

Below is the calculation of minimum workstation that must be formed.

$$(K)_{min} = \frac{\sum_{j=1}^{n} t_j}{CT}$$

$$(K)min = \frac{910}{240} = 3{,}791 \sim 4$$

The result of minimum workstation that must be formed is 4 workstation.

Then will be calculated line efficiency and idle time in each workstation. Below is the table of efficiency and idle time each workstation.

Table IV.7. Efficiency of Each Sewing Workstation

Code	**TASK**	**PREDECESSOR**	**Idle Time**	**efficiency**
SCL	Stitching collar leaf (inside and outside)	-	80	77%
SCF	Stitching collar feet (inside and outside)	-	104	100%
S	Stitching Collar leaf and feet	SCL,SCF	101	97%
CUT	Cut the excess colar feet fabric	S	101	97%
SRB	Stitching front right and blekser	-	86	83%
SLB	Stitching front Left and blekser	-	82	79%
SUL	Stitching Upper and Lower Back Part	-	81	78%
L	Labelling	SUL	78	75%
SFB	Stitching Front and Back Part by Shoulder	SRB,SLB,L	74	71%
SCOL	Collar Stitching to the Body	SFB,CUT	68	65%
HCOL	Hem Collar to the Body	SCOL	52	50%
SSLE	Stitching Body with Left and Right Sleeves by Shoulder	HCOL	48	46%

Table IV.7. Efficiency of Each Sewing Workstation

(cont.)

Code	TASK	PREDECESSOR	Idle Time	efficiency
HSLE	Hem End Sleeves	SSLE	73	70%
SIDE	Close Arm and Side Body Part	HSLE	79	76%
HBO	Hem Bottom	SIDE	0	0%
BI	Button Installation	HBO	6	6%
INS	Inspection	BI	45	43%
IR	Ironing	INS	74	71%

Based on the table above , it can be seen that idle time numbers still high and efficiency each workstation still located far below 100%. After calculating Line Efficiency, Balance Delay, and Smoothest Index, then line balancing is done using RPW, RA, and Moodie Young method.

1. Helgeson-Birnie (Ranked Positional Weight)

The first step of line balancing is making precedence diagram. Before making precedence diagram, first will created the table of workstation sequence along with time cycle. The table will be displayed below.

Table IV.8 Process Sequences for Precedence

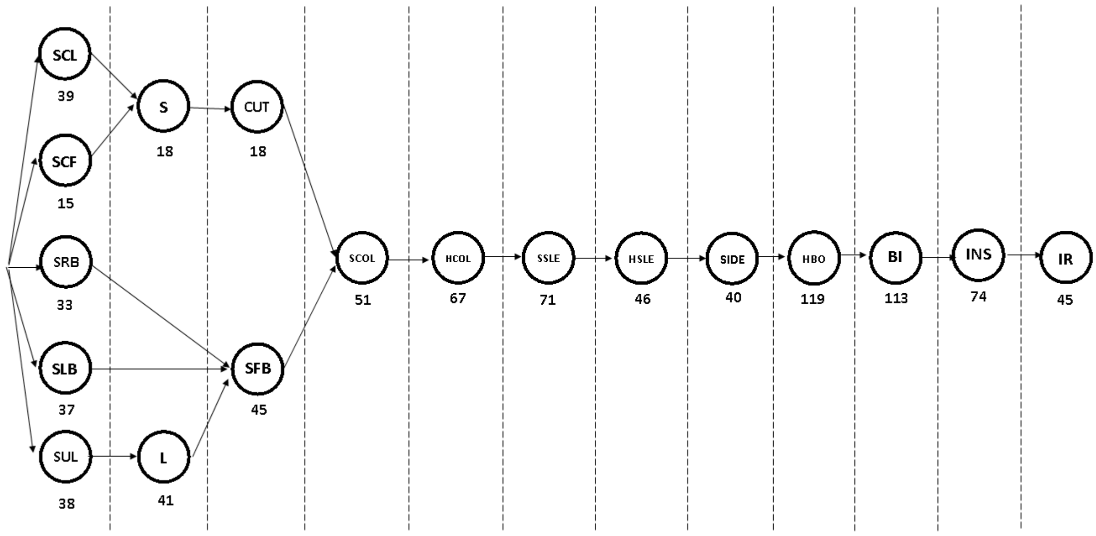
	TASK	PREDECESSOR	TIME (s)
SCL	Stitching collar leaf (inside and outside)	-	39
SCF	Stitching collar feet (inside and outside)	-	15
S	Stitching Collar leaf and feet	SCL,SCF	18
CUT	Cut the excess colar feet fabric	S	18
SRB	Stitching front right and blekser	-	33
SLB	Stitching front Left and blekser	-	37
SUL	Stitching Upper and Lower Back Part	-	38
L	Labelling	SUL	41
SFB	Stitching Front and Back Part by Shoulder	SRB,SLB,L	45
SCOL	Collar Stitching to the Body	SFB,CUT	51

Table IV.8 Process Sequences for PrecedencE

(cont.)

	TASK	PREDECESSOR	TIME (s)
HCOL	Hem Collar to the Body	SCOL	67
SSLE	Stitching Body with Left and Right Sleeves by Shoulder	HCOL	71

After knowing the sequence of the shirt production process that is shown on table above, the next step is making precedence diagram. Precedence diagram is used for make it easier to control and planning activities . Precedence diagram is displayed on picture below this.



. *Figure IV.16. Precedence Diagram*

After making the precedence diagram, next is determining the positional weight for each workstation. The calculation of the positional weight will be shown by the table below.

Table IV.9. Total RPW Each Sewing WS

Work Station	The total of RPW	Time (S)
SCL	701,0	39
SCF	677,0	15
S	662,0	18

Table IV.9. Total RPW Each Sewing Ws

(cont.)

Work Station	The total of RPW	Time (S)
CUT	644,0	18
SRB	704	33
SLB	708	37
SUL	750	38
L	712	41
SFB	671	45
SCOL	626	51
HCOL	575	67
SSLE	508	71
HSLE	437	46
SIDE	391	40
HBO	351	119
BI	232	113
INS	119	74
IR	45	45

After each weight is already determinded, the next step is to sort workstation based on the highest weight to least weight. Below is the sorting result.

Table IV.10. RPW Sorting

Work Station	The total of RPW	Time (S)
SUL	750	38
L	712,0	41
SLB	708,0	37
SRB	704,0	33
SCL	701	39
SCF	677	15
SFB	671,0	45
S	662	18
CUT	644	18

Table IV.10. RPW Sorting

(cont)

Work Station	**The total of RPW**	**Time (S)**
SCOL	626	51
HCOL	575	67
SSLE	508	71
HSLE	437	46
SIDE	391	40
HBO	351	119
BI	232	113
INS	119	74
IR	45	45

After sorting process, the next step is the process of distributing workstation to new workstation starting from the workstation that has highest amount of workstation. The thing that need to be considered in this distributing process is that the station time should not be exceeding the cycle time which is 240 seconds. Below is the table after the workstation has already distributed to a new workstation.

Table IV.11. RPW Station Distribution

Station	Work Station	Time(S)	Station Time
1	SUL	38	203
	L	41	
	SLB	37	
	SRB	33	
	SCL	39	
	SCF	15	
2	SFB	45	199
	S	18	
	CUT	18	
	SCOL	51	
	HCOL	67	

Table IV.11. RPW Station Distribution

(cont.)

Station	Work Station	Time(S)	Station Time
3	SSLE	71	157
	HSLE	46	
	SIDE	40	
4	HBO	119	232
	BI	113	
5	INS	74	119
	IR	45	

Above is the table after the workstation has already distributed to a new workstation. The workstation that is formed after done line balancing using RPW method is 5 workstations. After that, a new precedende diagram after line balancing is made. The new precedence diagram will be show below.

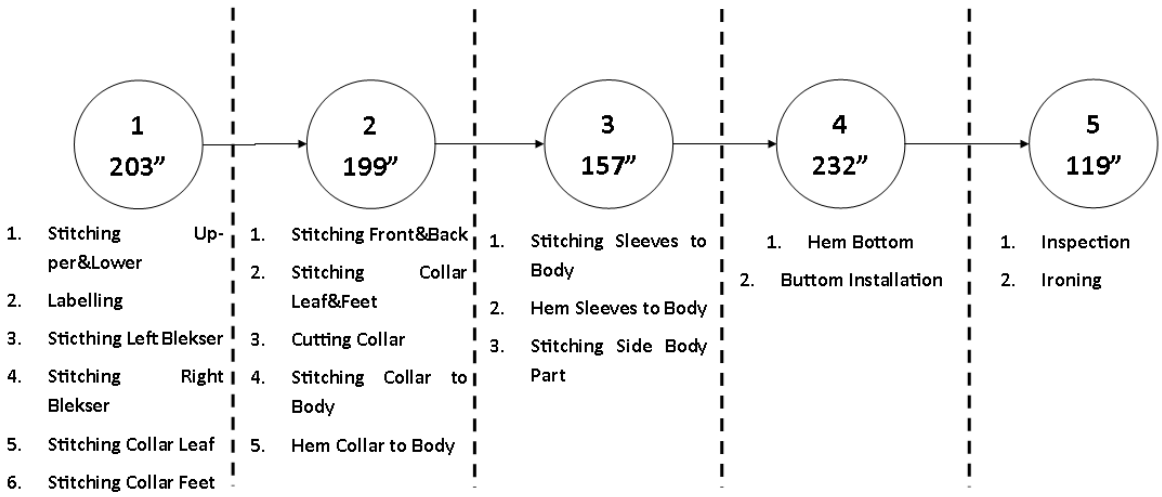


Figure IV.17. Precedence DIagram After RPW

After done line balancing using RPW method, the new workstation formed is 5 workstation. The explanation of each station will be explained below.

1. Worstation 1 consist of 6 WS combined as 1 station, the WS is stitching upper and lower part, labelling, stitching left blekser, stitching right blekser, stitching collar

leaf, stitching collar feet with total cycle time is 203 seconds. Those station will be done by 1 operator only.

2. Worstation 2 consist of 5 WS combined as 1 station, the WS is stitching fornt and back part, stitching collar leaf and feet, stitching collar to the body, hem collar to the body with total cycle time is 199 seconds. Those station will be done by 1 operator only.
3. Worstation 3 consist of 3 WS combined as 1 station, the WS is stitching sleeves to the body, hem, stitching side body part with the total cycle time is 157 seconds. Those station will be done by 1 operator only.
4. Worstation 4 consist of 2 WS combined as 1 station, the WS is hem bottom part of shirt, and button installation with total cycle time is 232 second. Those station will be done by 1 operator for hem bottom and 3 operator for button installation because the process is done by 3 different machine.
5. Worksation 5 consist of 2 WS combined as 1 station, the WS is Inspection and Ironing with the total cycle time is 119 seconds. Those station will be done by 1 operator for ironing and 2 operator for inspection.

After that next step is to calculatin new workstation efficiency and idle time. The calculation of workstation efficiency and idle time will be show below.

Table IV. 12 RPW Station Efficiency and Idle Time Calculation

Station	Work Station	Station Time	Workstation Efficiency (%)	Idle Time
1	SUL	203	88%	29
	L			
	SLB			
	SRB			
	SCL			
	SCF			
2	SFB	199	86%	33
	S			
	CUT			
	SCOL			
	HCOL			
3	SSLE	157	68%	75
	HSLE			
	SIDE			
4	HBO	232	100%	0
	BI			
5	INS	119	51%	113
	IR			

Based on the table above, it can be seen that there is an dereasing number of idle time eventhough not too significant and the amount of workstation efficiency is increasing but there are workstation that the value of efficiency still above 100%. After that, the calculation of line efficiency, balance delay, and smoothest index after line balancing need to be done. Below is the calculation of line efficiency, balance delay, and smoothest index.

a. Line Efficiency

$$LE = \frac{\sum_{i=1}^{K} ST_i}{(K)(CT)} \times 100$$

$$LE = \left(\frac{910}{5x240}\right) x100\% = 78{,}4\%$$

b. Balance Delay

$$BD = \frac{(K \times CT) - \sum_{i=1}^{n} ti}{(K \times CT)} \times 100\%$$

$$BD = \left(\frac{5x240 - 910}{5x240}\right) x100\% = 21{,}6\%$$

c. Smoothest Index

$$SI = \sqrt{\sum_{i=1}^{n} (STi\max - STi)^2}$$

SI= 142,5623

The calculation shows that after line balancing is done, the value of line efficiency is increasing from 42,48% to 78,4%, when the value of balance delay and smoothest index is decreasing to 21,6% and 142,5623.

2. Killbridge-Wester (Region Approach)

In this method, the thing to do is divide the region from left to right. After that count the number of predecessor operations from the workstation. The result of calculating the predecessor amount on each workstation is shown in the table below.

Table IV.13. Killbridge-Wester Predecessor Amount

Work Station	The total Predecessor	Time (s)
SCL	0	39
SCF	0	15
S	2	18
CUT	3	18
SRB	0	33
SLB	0	37
SUL	0	38
L	2	41
SFB	4	45
SCOL	9	51
HCOL	10	67
SSLEE	11	71
HSLEE	12	46
SSIDE	13	40

Table IV.13. Killbridge-Wester Predecessor Amount

(cont.)

Work Station	The total Predecessor	Time (s)
HBOM	14	119
BI	15	113
INS	16	74
IR	17	45

After the calculation of the number of predecessor, next is sorting workstation based on the lowest number of predecessor. The sorting results are shown by the table below.

Table IV.14. Sorting Based the Amount of Predecessor

Work Element	The total Predecessor	Time (s)
SCL	0	39
SCF	0	15
SRB	0	33
SLB	0	37
SUL	0	38
S	2	18
L	2	41
CUT	3	18
SFB	4	45
SCOL	9	51
HCOL	10	67
SSLEE	11	71
HSLEE	12	46
SSIDE	13	40
HBOM	14	119
BI	15	113
INS	16	74
IR	17	45

After the sorting, next is the allocation of each workstation on a new work station with the provision does not violate the precedence diagram and station time does not exceed the actual cycle time of 240. Allocation of work stations is shown in the table below.

Table IV.15 Killbridge-Wester Station Distribution

Station	Work Element	Time	Station Time
1	SCL	39	239
	SCF	15	
	SRB	33	
	SLB	37	
	SUL	38	
	S	18	
	L	41	
	CUT	18	
2	SFB	45	234
	SCOL	51	
	HCOL	67	
	SSLEE	71	
3	HSLEE	46	205
	SSIDE	40	
	HBOM	119	
4	BI	113	232
	INS	74	
	IR	45	

The table above shows the result of workstation grouping on new work station. Obtained work station results after line balancing using Killbridge-Wester method is 4 workstations. Then a new precedence diagram is created after the line balancing shown in the figure below.

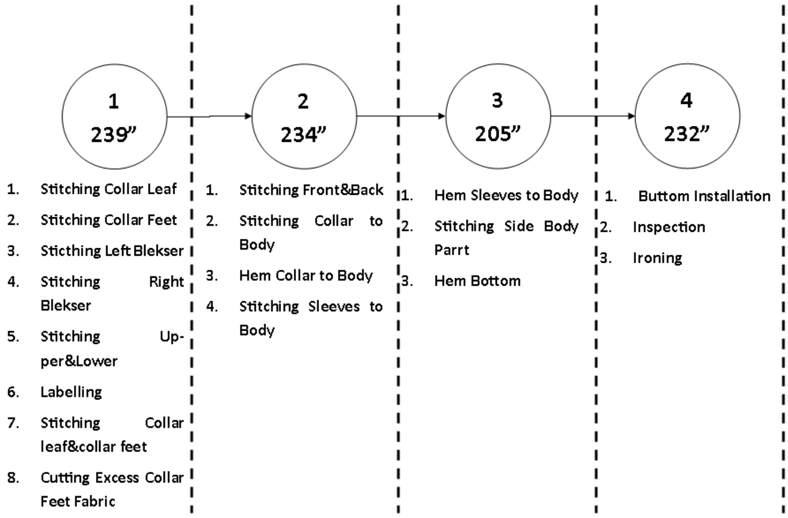


Figure IV.18 Precedence DIagram After Killbridge-Wester

After done line balancing using Killbridge-Wester method, the new workstation formed is 4 workstation. The explanation of each station will be explained below.

1. Worstation 1 consist of 8 WS combined as 1 station, the WS is stitching collar leaf, stitching collar feet, stitching upper and lower part, labelling, stitching left blekser, stitching right blekser, stitching collar leaf and feet, cut the excess collar feet fabric with total cycle time is 239 seconds. This station will be done by 1 operator only.
2. Worstation 2 consist of 4 WS combined as 1 station, the WS is stitching front and back, stitching collar to body, hem collar to body, stitching sleeves to the body with total cycle time is 234 seconds. This station will be done by 1 operator only.
3. Workstation 3 consist of 3 WS combined as 1 station, the WS is hem sleeves to body, stitching side body part, and hem botton with the total cycle time is 205 seconds. This station will be done by 1 operator.
4. Worstation 2 consist of 4 WS combined as 1 station, the WS is button installation, ironing, and inspection with the total of cycle time is 232 seconds. This station will be done by 3 operator of button installation, 1 operator for ironing, and 2 operator for inspection.

After the line balancing is done, the next step is to do the calculation of work station efficiency after the grouping. The efficiency of the work station after grouping is shown in the table below.

Table IV.16 Killbridge-Wester Station Efficiency and Cycle Time Calculation

<table>
<tr><th>Station</th><th>Work Element</th><th>Station Time</th><th>Workstation Efficiency (%)</th><th>Idle Time</th></tr>
<tr><td rowspan="8">1</td><td>SCL</td><td rowspan="8">239</td><td rowspan="8">100%</td><td rowspan="8">0</td></tr>
<tr><td>SCF</td></tr>
<tr><td>SRB</td></tr>
<tr><td>SLB</td></tr>
<tr><td>SUL</td></tr>
<tr><td>S</td></tr>
<tr><td>L</td></tr>
<tr><td>CUT</td></tr>
<tr><td rowspan="4">2</td><td>SFB</td><td rowspan="4">234</td><td rowspan="4">97,9%</td><td rowspan="4">5</td></tr>
<tr><td>SCOL</td></tr>
<tr><td>HCOL</td></tr>
<tr><td>SSLEE</td></tr>
<tr><td rowspan="3">3</td><td>HSLEE</td><td rowspan="3">205</td><td rowspan="3">85,8%</td><td rowspan="3">34</td></tr>
<tr><td>SSIDE</td></tr>
<tr><td>HBOM</td></tr>
<tr><td rowspan="3">4</td><td>BI</td><td rowspan="3">232</td><td rowspan="3">97,1%</td><td rowspan="3">7</td></tr>
<tr><td>INS</td></tr>
<tr><td>IR</td></tr>
</table>

Furthermore, the calculation of line efficiency, balance delay, and smoothest index after line balancing by using Killbridge-Wester method.

a. Line Efficiency

$$LE = \frac{\sum_{i=1}^{K} ST_i}{(K)(CT)} \times 100$$

$$LE = \left(\frac{910}{4x240}\right) x100\% = 95,2\%$$

b. Balance Delay

$$BD = \frac{(K \times CT) - \sum_{i=1}^{n} ti}{(K \times CT)} \times 100\%$$

$$BD = \left(\frac{4x240 - 910}{4x240}\right) x100\% = 4{,}8\%$$

c. Smoothest Index

$$SI = \sqrt{\sum_{i=1}^{n} (STi\ \max - STi)^2}$$

SI= 35,071

After line balancing by using Killbridge-Wester, it is seen that the value of line efficiency rose significantly from the previous value that is 95.2%. While the balance delay and smoothest index value decreased to 4.8% and 35.071

3. Moodie-Young.

This method consist of 2 phases which is the first phase work element is placed on successive work station in assembly line by using rule of candidate of largest candidate while second phase is distributing the idle time evenly. The largest-candidate rule consists of placing the elements that exist for the purpose of decreasing the time. The first phase for this method is to create 2 pieces of Matrix F (follower) and Matrix P (Predecessor). Table matrix F and P are shown in the table below.

a. Matriks P

Table IV.17. P Matrices

Work Station	**P MATRICES**			**TIME (S)**
SCL	0	0	0	39
SCF	0	0	0	15
S	SCL	SCF	0	18
CUT	S	0	0	18,0
SRB	0	0	0	33
SLB	0	0	0	37
SUL	0	0	0	38
L	SUL	0	0	41
SFB	SRB	SLB	L	45
SCOL	CUT	SFB	0	51
HCOL	SCOL	0	0	67
SSLE	HCOL	0	0	71
HSLE	SSLE	0	L	46
SIDE	HSLE	0	0	40
HBO	SIDE	0	0	119
BI	HBO	0	0	113
INS	BI	0	0	74
IR	INS	0	0	45

b. Matriks F

Table IV.18 F Matrices

Work Station	F MATRICES					TIME (S)
SCL	S	0	0	0	0	39
SCF	S	0	0	0	0	15
S	CUT	0	0	0	0	18
CUT	SCOL	0	0	0	0	18,0
SRB	SFB	0	0	0	0	33
SLB	SFB	0	0	0	0	37
SUL	L	0	0	0	0	38
L	SFB	0	0	0	0	41
SFB	SCOL	0	0	0	0	45
SCOL	HCOL	0	0	0	0	51
HCOL	SSLE	0	0	0	0	67
SSLE	HSLE	0	0	0	0	71
HSLE	SIDE	0	0	0	0	46
SIDE	HBO	0	0	0	0	40
HBO	BI	0	0	0	0	119
BI	INS	0	0	0	0	113
INS	IR	0	0	0	0	74
IR	0	0	0	0	0	45

After creating the matrix table F and P, next is distributing workstation to a new work station by following the rules of the of moodie young method, keeping in mind the allocation of each station time should not exceed the cycle time of 240. Below is a table result of the allocation of stations work using the moodie young method.

Table IV.19. Moodie-Young Station Distribution

Station	Work Station	Time (S)	Station Time (S)
1	SCL	39	221
	SUL	38	
	SLB	37	
	SRB	33,0	
	SCF	15	
	S	18	
	L	41	
2	SFB	45	181
	CUT	18	
	SCOL	51	
	HCOL	67	
3	SSLE	71	157
	HSLE	46	
	SIDE	40	
4	HBO	119	232
	BI	113	
5	INS	74	119
	IR	45	

The table above shows the result of distributing workstation on new work station. Workstation results obtained after line balancing using Moodie-Young method is 5 workstations. Next go into the second phase which is distributing idle time to each workstation evebly. The steps in completing the second phase are as follows:

1. Identify the largest station time and the least station time
   ST_{max}= 232 is in 4th workstation
   ST_{min}= 119 is in 5th workstation
2. Moving the workstation that can be moved

This step is the transfer of one of the work elements that can be moved from the station which has the maximum station time to the minimum station time, in other words move the work element on work station 4 to the work station 5 but must pay attention to the relation between the matrix F and P. In this case , working elements of the Button Installation that meet the criteria to be moved. However, after the moving the workstation, the result of balance delay, line efficiency, and smoothest index still produce the same value. It will still be used for distributing workstations in the first phase. Next is to create the new precedence diagram after line balancing using moodie young method.

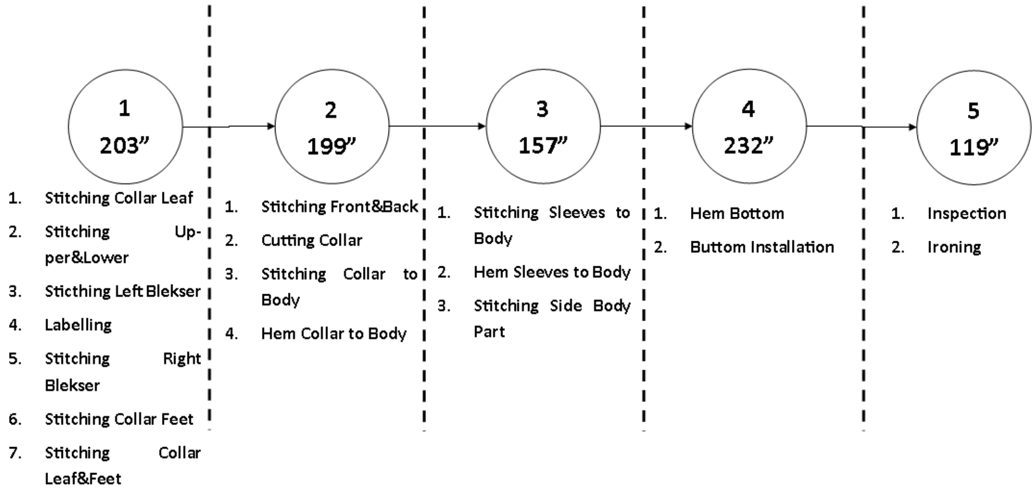


Figure IV.19 Precedence DIagram After Moodie-Young

After done line balancing using RPW method, the new workstation formed is 5 workstation. The explanation of each station will be explained below.

1. Worstation 1 consist of 7 WS combined as 1 station, the WS is stitching upper and lower part, labelling, stitching left blekser, stitching right blekser, stitching collar leaf, stitching collar feet, and stitching collar leaf and feet with total cycle time is 203 seconds. Those station will be done by 1 operator only.

2. Worstation 2 consist of 4 WS combined as 1 station, the WS is stitching front and back part, cut the excess collar feet fabric, stitching collar to the body, hem collar to the body with total cycle time is 199 seconds. Those station will be done by 1 operator only.
3. Worstation 3 consist of 3 WS combined as 1 station, the WS is stitching sleeves to the body, hem, stitching side body part with the total cycle time is 157 seconds. Those station will be done by 1 operator only.
4. Worstation 4 consist of 2 WS combined as 1 station, the WS is hem bottom part of shirt, and button installation with total cycle time is 232 second. Those station will be done by 1 operator for hem bottom and 3 operator for button installation because the process is done by 3 different machine.
5. Worksation 5 consist of 2 WS combined as 1 station, the WS is Inspection and Ironing with the total cycle time is 119 seconds. Those station will be done by 1 operator for ironing and 2 operator for inspection.

Table IV.20 Moodie Young Station Efficiency and Idle Time Calculation

Station	Work Station	Station Time	Workstation Efficiency (%)	Idle Time
1	SCL	221	95%	11
	SUL			
	SLB			
	SRB			
	SCF			
	S			
	L			
2	SFB	181	78%	51
	CUT			
	SCOL			
	HCOL			

Table IV.20 Moodie Young Station Efficiency and Idle Time Calculation

(cont.)

Station	Work Station	Station Time	Workstation Efficiency (%)	Idle Time
3	SSLE	157	68%	75
	HSLE			
	SIDE			
4	HBO	119	51%	113
5	BI	232	100%	0
	INS			
	IR			

Furthermore, the calculation of line efficiency, balance delay, and smoothest index after the line balancing using Moodie-Young method.

a. Line Efficiency

$$LE = \frac{\sum_{i=1}^{K} ST_i}{(K)(CT)} \times 100$$

$$LE = \left(\frac{910}{5x240}\right) x100\% = 78{,}4\%$$

b. Balance Delay

$$BD = \frac{(K \times CT) - \sum_{i=1}^{n} ti}{(K \times CT)} \times 100\%$$

$$BD = \left(\frac{5x240 - 910}{5x240}\right) x100\% = 21{,}6\%$$

c. Smoothest Index

$$\text{SI} = \sqrt{\sum_{i=1}^{n} (STi\ \text{max} - STi)^2}$$

SI= 145,3135

After the line balancing using Moodie-Young, it can be seen that the value of line efficiency rose from the previous value of 78.4%. While the balance balance and smoothest index value decreased to 21.61% and 145.3135.

IV.2.9 Selection of Line Balancing Method

After conducting line balancing using 3 methods: Helgeson Birnie (Positional Weight), Killbridge-Wester (Region Approach), and Moodie-Young, obtained the result of Line Efficiency, balance delay, and Smoothest index of each method. The results of the three values are then compared with the results that will be compared with the Line Efficiency, balance delay, and Smoothest index on the existing company condition. The comparison of the results will be shown in the table below.

Table IV.21 Comparison Between Line Balancing Method

No	Criteria	Existing	RPW	RA	Moodie-Young
1	The Amount of Workstation	18	5	4	5
2	Line Efficiency (%)	42,48%	78,4%	95,2%	78,4%
3	Balance Delay (%)	57,5%	21,6%	4,8%	21,6%
4	Smoothest Index	314,0031847	142,5622	35,0713	145,3134

The table above shows that there are significant changes from the results of the three criteria after the method of line balancing in the production process. It can be seen that the optimum result resulted from the method of Killbridge-Wester or Region Approach that forming work station at least 4 work station with line efficiency 95,2%, balance delay 4,8%, smoothest index 35, 0713. Then the preferred method is the Killbridge-Wester method as the preferred method to be implemented on the CV.CJM shirt production line.

After an improvement with line balancing, the workstation cycle time in shirting is not far below takt time. The cycle time and takt time comparison chart value will be shown in the figure below.

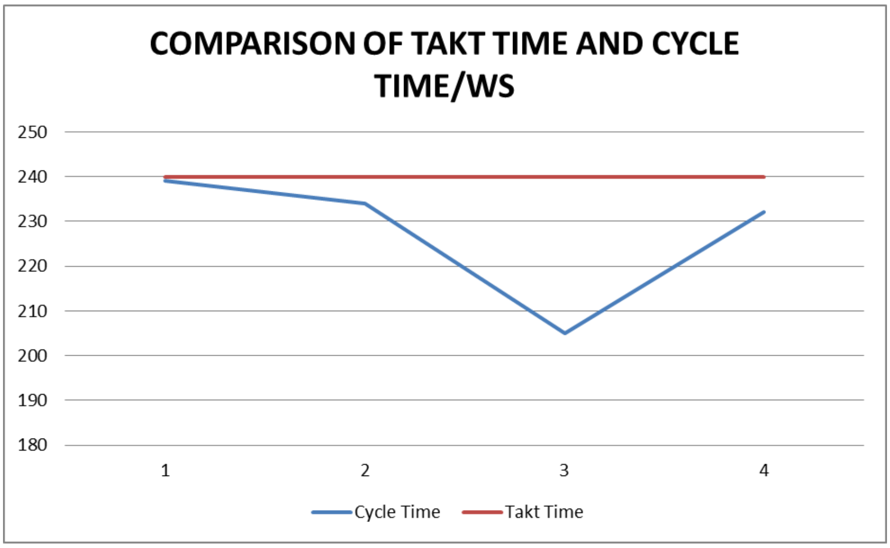


Figure IV.20. Comparison of Takt Time and Cycle Time After Line Balancing

IV.2.9.1 Comparison of WIP Amount Before and After Line Balancing

Below is shown the number of product results that can be produced by each workstation obtained from the calculation of work time available per day divided by the cycle time of each work station.

Table IV.22 Output of Each WS Existing Condition

	TASK	TIME (s)	Output / Day
SCL	Stitching collar leaf (inside and outside)	39	738
SCF	Stitching collar feet (inside and outside)	15	1920
S	Stitching Collar leaf and feet	18	1600
CUT	Cut the excess colar feet fabric	18,0	1600
SRB	Stitching front right and blekser	33	873
SLB	Stitching front Left and blekser	37	778
SUL	Stitching Upper and Lower Back Part	38	758
L	Labelling	41	702
SFB	Stitching Front and Back Part by Shoulder	45	640

Table IV.22 Output of Each WS Existing Condition

(cont.)

	TASK	**TIME (s)**	**Output / Day**
SCOL	Collar Stitching to the Body	51	565
HCOL	Hem Collar to the Body	67	430
SSLE	Stitching Body with Left and Right Sleeves by Shoulder	71	406
HSLE	Hem End Sleeves	46	626
SIDE	Close Arm and Side Body Part	40	720
HBO	Hem Bottom	119	242
BI	Button Installation	113	255
INS	Inspection	74	389
IR	Ironing	45	640

Based on the table above, the result of the product that can be produced by each workstation can predict how much inventory work in process is produced per day based on the difference of cycle time each workstatsion by way of maximal product minus the minimum product that can be in production of each station work.

$$Work - in - Process = Max - Min$$

$$Work - in - Process = 1920 - 242 = 1678$$

Below is the number of products that can be produced by each workstation after the line balancing using Killbridge-Wester method obtained from the calculation of time available per day divided with the cycle time of each work station

Table IV.23. Output of Each WS After Line Balancing

Station	Work Element	Time (S)	Station Time	Output/Day
1	SCL	39	239	121
	SCF	15		
	SRB	33		
	SLB	37		
	SUL	38		
	S	18		
	L	41		
	CUT	18		
2	SFB	45	234	123
	SCOL	51		
	HCOL	67		
	SSLEE	71		
3	HSLEE	46	205	140
	SSIDE	40		
	HBOM	119		
4	BI	113	232	124
	INS	74		
	IR	45		

Based on the table above, will be conducted the amount of inventory work in process.

$$Work - in - Process = Max - Min$$

$$Work - in - Process = 140 - 121 = 20$$

Based on work-in-process calculations, there is a significant decrease in the number of work in processes of the CV.CJM shirt production process. In addition, if the output is compared with the daily demand of 120 pcs, then the excess production produced only 1 pcs. Below is the table of total decreasing work in process number before and after line balancing.

Table 4. WIP Existing and After Line Balancing Comparison

	Capacity Production Max	Capacity Production Min	%Decreasing Percentage
Before Line Balancing	1920	242	99%
After Line Balancing	140	121	

Based on the table above, it can be seen that the decreasing of work in process number after line balancing is 99%.

CHAPTER V ANALYSIS

Based on the data collection and processing in the previous chapter, this chapter will do the analyze towards the result of proposal improvement in chapter IV.

V.I Line Balancing Analysis

After doing the line balancing by using Killbridge-Wester method, furthermore there will be comparison of line efficiency, balance delay, smoothest index, and idle time production line between existing production line and after line balancing. Here is a comparison table.

Table V.1 Choosen Method Comparison

No	**Criteria**	**Existing**	**Killbridge-Wester (RA)**
1	The Amount of Workstation	18	4
2	Line Efficiency (%)	42,48%	78,4%
3	Balance Delay (%)	57,5%	21,6%
4	Smoothest Index	314,0031847	145,3134
5	Idle Time	104 sec	46 sec
6	The Amount of WIP	1678 pcs	20 pcs

Based on the table above, there are several points that can be concluded as follows:

1. The number of workstations was significantly reduced from a total of 18 workstations to 5 workstations. The reduction of this workstation can suggest the reduction of operators based on the workstations formed to maximize operator efficiency and generalize the workload of each operator. Below is a table number of operators before and after doing line balancing.

Table V.2. Amount of Operator

No	Workstation	Amount of Operator	No	Workstation	Amount of Operator
1	SCL	**1**	1	SCL	1
2	SCF	**1**		SCF	
3	S	**1**		SRB	
4	CUT	**1**		SLB	
5	SRB	**1**		SUL	
6	SLB	**1**		S	
7	SUL	**1**		L	
8	L	**1**		CUT	
9	SFB	**1**	2	SFB	1
10	SCOL	**1**		SCOL	
11	HCOL	**1**		HCOL	
12	SSLE	**1**		SSLEE	
13	HSLE	**1**	3	HSLEE	1
14	SIDE	**1**		SSIDE	
15	HBO	**1**		HBOM	
16	BI	**3**	4	BI	6
17	INS	**2**		INS	
18	IR	**1**		IR	
	Total	**21**		**Total**	9

2. Based on the table, it can be seen that the number of operators before is 21 operators and after the line balancing becomes 9 operators. The operator in station 1,2, and 3 will only has 1 operator each while in the ws 4 which is the installation button, inspection, and the ironing is still 6 operators because the machine on the button installation consists of 3 different machines that have different functions
3. There was a significant increase in line efficiency results before and after the line balancing, before line balancing the result of line efficiency was

42.48% and increased to 78.4% after the line balancing was held. The closer to 100% the better the line efficiency.

4. For balance delay decrease on the existing system is 57.5% while in the proposed 21.6%. This means that at the proposed condition of the allocation of work stations is better than existing condition. The closer it is to 0% the better.
5. The decreasing of Smoothest index from existing condition is 314,0031 become 145,3134 after line balancing, it means that the relative condition of proposed condition is better than existing condition. The closer the value of smoothest index to 0 the result is better.
6. There was a decrease in total idle time in the existing condition and after the line balancing which is 104 seconds on the existing and 46 seconds after line balancing conducted.

V.2 Advantages and Disadvantages of Proposal Analysis

In this sub-chapter we will analyze the advantages and disadvantages of the proposed improvement design using line balancing on the production process of short-sleeves shirts in CV. CJM. The following table is the analysis of the advantages and disadvantages for the proposed improvement design.

Table V.3. Advantages and Disadvantages

Advantages	Disadvantages
• There are decreasing number of idle time in each Worstation. • The workload between each operator is almost similar. • It can reduce the amount of inventory work in process between each workstation. • It can reduce the number of operators required for each workstation so another workstation can be distribute to a new line in order to prevent the unfullfilled production target.	• If the proposed improvement is implemented further, its require the adjustments of operators and companies due to workstation merging and reducing the number of operators required for each workstation. • The operator might need adaptation because they required to do more than one process.

Line balancing by using Killbridge-Wester method aims to make workload between workstations more evenly and minimize idle time resulting in reduction of work-in-process inventory. Some work stations are put together by paying attention to the rules of line balancing which is the time of each station does not exceed the cycle time. After the merger, the results of the number of work stations decreased which initially was 18 work stations into 4 work stations.

CHAPTER VI CONCLUSION AND SUGGESTION

VI.1 CONCLUSION

Based on the research that conducted in the production process of short-sleeves shirt in CV. CJM, it is concluded that:

1. The waste inventory work in process is caused by two factors, which is method factor and man factor. For method factor, there is unbalanced workload in each sewing workstation with various cycle time. this can cause the buildup of work in process inventory in each sewing workstation. For the man factor, the operator who is absent is one of the reason why the work in process inventory occurred. It’s because the work of that absent operator needs to be done by another operator who is not proficient in doing those process so that it often cause the process to stagnate and takes time longer than usual. .
2. Proposed improvements to minimize waste inventory in the process of making short sleeve shirts are using heuristic line balancing (Positional Weight, Killbridge-Wester, and Moodie Young). Then select one of the methods that produce the best result of balance delay, line efficiency, and smoothest index. In this research, the best method choosen to be implemented is using Killbridge-Wester of Region Approach method.

VI.2 Suggestion

VI.2.1 Suggestion for CV.CJM

1. The company can implement the proposed line balancing on the short sleeve shirt production process so the company can reduce the amount of waste inventory work in process and reduce idle time.
2. The company concern about the workload of each sewing workstation because it has different cycle time so it will produce different output and effect to the output production per day.

VI.2.1 Suggestion for Further Research

1. The further research is expected to discuss the financial aspects to calculate the losses caused by waste inventory, calculate the cost to be incurred if the implementation is done, and calculate the profits earned by the company if implementing the proposals given.
2. The further research is expected to conduct research up to the implementation stage with the company.

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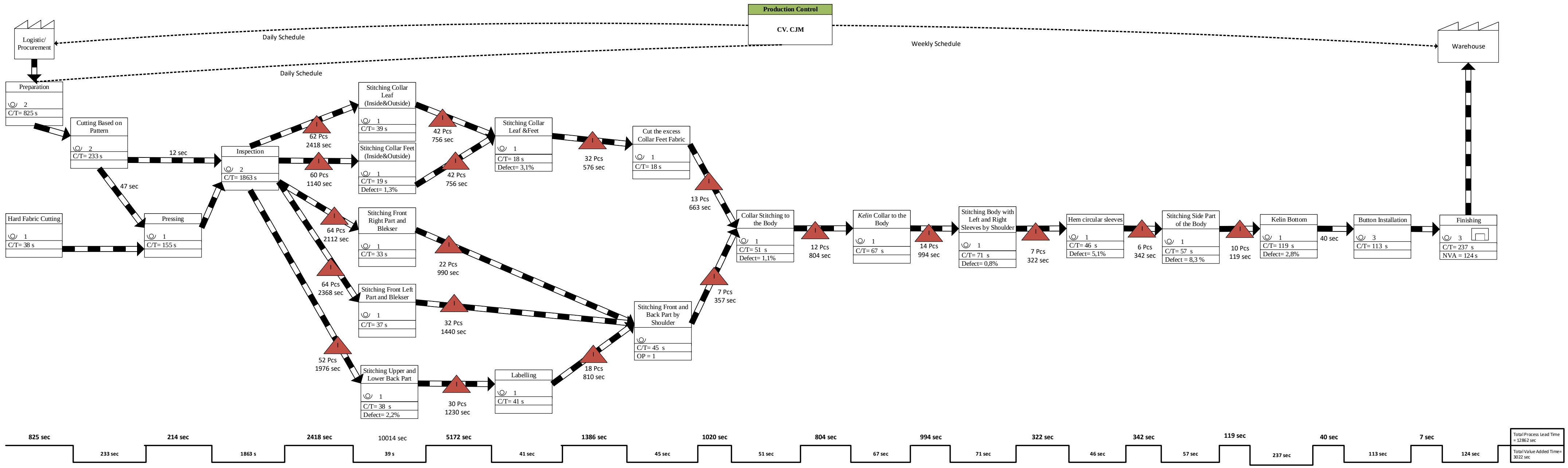
APPENDIX A

Value Stream Mapping

Process Activity Mapping

A. Value Stream Mapping



B. Process Activity Mapping

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
1	preparation	Searching for Pattern	173	825	Table,Cutting Machine, Chalk, Scissors, Ruler, Pokayoke	D		2	NNVA
		Pattern Positioning in Fabric Sheet	74			O			VA
		Marking	371			O			VA
		Cutting Preparation (Sheet Conformity with Spreading Machine, Mark Margins, Add Weight)	108			O			NNVA
		Cut the Sheet with Pattern	5			O			VA
		Take Sheet from Rolled Fabric	81			O			NNVA
		Tidy Up Surface	13			O			NNVA
2	Cutting based on pattern	Cut Sheet	50	233	Table,Cutting Machine,	O			VA
		Bundle the cut fabric, grouping it by the size and	126			O			NNVA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
		part			Chalk, Scissors, Ruler, Pokayoke				
		Moving bundled fabric to Inspection&Pressing Area	57			T	5		NNVA
3	Hard Fabric Cutting	Hard Fabric Cutting for blekser, collar leaf, and collar feet	38	38	Pokayoke, Scissors	O		1	VA
4	Pressing	Hard fabric and blekser fabric preparation	11	155	Pressing Machine, Scissors	O		1	NNVA
		Hard fabric and Collar fabric preparation	5			O			NVA
		Pressing preparation (tidy up the remaining yarn)	24			O			NNVA
		Alligning collar leaf	8			O			NNVA
		putting hard fabric above the collar leaf	4			O			NVA
		Pressing Process	22			O			VA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
		Alligning collar feet	10			O			NVA
		Putting hard fabric above the collar feet	5			O			NNVA
		Pressing Process	22			O			NNVA
		Alligning Blekser	17			O			VA
		putting hard fabric above the blekser	7			O			NNVA
		Pressing Process	22			O			NNVA
4	Inspection	Mark Size in Front Right Part	120	1863	Labelling Machine	O		2	VA
		Mark Size in Front Left Part	122			O			VA
		Mark Size in Upper Back Part	122			O			VA
		Mark Size in Lower Back Part	132			O			VA
		Mark Size in Right Arm Part	111			O			VA
		Mark Size in Left Arm Part	115			O			VA
		Check Size Conformity with Marking (Front Right)	145			I			NNVA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
		Check Size Conformity with Marking (Front Left)	142			I			NNVA
		Check Size Conformity with Marking (Upper Back)	143			I			NNVA
		Check Size Conformity with Marking (Lower Back)	156			I			NNVA
		Check Size Conformity with Marking (Right Arm)	155			I			NNVA
		Check Size Conformity with Marking (Left Arm)	155			I			NNVA
		Bundling Collar Leaf	62			O			NNVA
		Bundling Collar Feet	66			O			NNVA
		Bundling Blekser	53			O			NNVA
		Moving bundled fabric to Sewing Area	64			T	12		NNVA
Sewing									
5	Sticthing collar leaf	Taking the fabric bundle	8	39	Sewing	T		1	NNVA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
	(inside and outside)	Put Inner Collar Leaf below the Outer Collar Leaf Back to Back	2		Machine, Scissors, Sewing lamp	O			NNVA
		Start Sewing	21			O			VA
		Put Pokayoke for Pointy Collar Ends	4			O			NNVA
		Start Sewing	9			O			VA
		Turn the Collar Inside Out	3			O			VA
6	Stitching collar feet (inside and outside)	Taking the fabric bundle	12	19	Sewing Machine, Scissors, Sewing lamp	T		1	NNVA
		Put both part of Collar Feet Back to Back	13			O			NNVA
		Start Sewing	6			O			VA
7	Stitching Collar leaf and feet	Put the Upper Collar Feet inside Bottom Collar Leaf	9	18	Sewing Machine, Scissors, Sewing	T		1	NNVA
		Ensure Position	4			O			NNVA
		Start Sewing	5			O			VA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
					lamp				
8	Cut the excess color feet fabric	Ensure Position	7	18	Sewing Machine, Scissors, Sewing lamp	O		1	NNVA
		Cut Excess Collar Feet Part	10			O			VA
9	Stitching Front Right Part and Blekser	Taking the fabric bundle	13	33	Sewing Machine, Scissors, Sewing lamp	T		1	NNVA
		Ensure Cleanliness	18			O			NNVA
		Ensure Position of Front Right Part and Blekser	5			O			NNVA
		Start Sewing	11			O			VA
10	*Stitching* Front Left and Blekser	Taking the fabric bundle	8	37	Sewing Machine, Scissors, Sewing lamp	T		1	NNVA
		Ensure Cleanliness	12			O			NNVA
		Ensure Position of Front Left Part and Blekser	5			O			NNVA
		Start Sewing	12			O			VA
11	Stitching Upper and	Taking the fabric bundle	15	38		T			NNVA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
	Lower Back Part	Combine between the back and shoulders	3		Sewing Machine, Scissors, Sewing lamp	O		1	NNVA
		Sewing process	16			O			VA
		Smoothed the folds of the back	3			O			NNVA
		Continuing Sewing Process	14			O			VA
		Cutting the yarn	2			O			VA
12	Labelling	Balancing the fabric for labeling	17	41	Sewing Machine, Scissors, Sewing lamp	O		1	NNVA
		Taking a label	3			T			NNVA
		Balancing the size of the cloth	3			O			NNVA
		Sewing process	16			O			VA
		Cutting the yarn	2			O			VA
13	Stitching Front and Back Part by Shoulder	Sewing the front left and back of the fabric	14	45	Sewing Machine, Scissors,	O		1	VA
		Sewing the front right and	14			O			VA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
		back of the fabric			Sewing lamp				
		Cutting the yarn	1			O			VA
		Sewing combined from the outer side of the fabric	14			O			VA
		Cutting the yarn	2			O			VA
14	Collar Stitching to the Body	Mark the collar	12	51	Sewing Machine, Scissors, Sewing lamp	O		1	NNVA
		Sewing combined collars and shirts	39			O			VA
15	Hem Collar to the Body	Sewing up the collar cap on the shirt	57	67	Sewing Machine, Scissors, Sewing lamp	O		1	VA
		Sewing the collar edge on the shirt	10			O			VA
16	Stitching Body with Left and Right Sleeves by	Sewing process	71	71	Sewing Machine,	O		1	VA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
	Shoulder				Scissors, Sewing lamp				
17	Hem Circular Sleeves	Sewing Process	46	46	Sewing Machine, Scissors, Sewing lamp	O		1	VA
18	Stitching Side Part of The Body	Sewing the side part of the arm	27	57	Sewing Machine, Scissors, Sewing lamp	O		1	VA
		Sewing the side part of body	30			O			
19	*Keling* Bottom	Cutting the excessive yarn	5	119	Sewing Machine, Scissors, Sewing	O		1	VA
		folded a little part of fabric on the bottom	8			O			
		Sewing Process	62			O			

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
		Cutting the yarn	4		lamp	O			
		Moving finishied shirt to button installation area	40			T	6		NNVA
20	Button Installation	Button Marking	27	113	Button Installation Machine, Buttonhole Sewing Machine	O			VA
		Button Attaching	57			O			VA
		Button Holing	29			O			VA
21	Inspection	Inspection Process	74	74	Lamp, Lable	I			NNVA
		Rework	124	124	Sewing Machine, Scissors, Sewing lamp	O			NVA

No	Workstation	Activities	Activity Time (s)	Cycle Time (s)	Tools & Machines	Type of Activity (O/T/I/D/S)	Distance (m)	Amount of Operator	Category of Activity
		Moving to Finishing	63	63	Lamp, Lable	T			NNVA
22	Finishing	Ironing Process	45	151	Iron Steam, Scissors	O	4	1	VA
		Cleaning the excessive yarn	7			O		3	NNVA
		Insert lable on the shirt	9			O			VA
		Folded finished shirt	72			O			VA
		Packaging process	18			O			VA
23	Final Inspection	Inspection Process	12	12	Lamp, Lable	I			NNVA

Based on table above , obtained results from process activity mapping ie is known that there are five streams activities among others is operation, transportation, inspection, storage, and delay. Besides that could is known grouping activities berdasrakan VA, NNVA, and NVA. Following is time from each Flow activities .

Table IV.2. Persentase O,T,I,S,D

Aliran	Time (s)	Percentage (%)

Operation	2827	66,14%
Transportation	292	6,83%
Inspection	982	22,98%
Storage	-	-
Delay	173	4,05%
Total	4274	

Table classification activities based on Value added, Necessary Non Value Added, and Non Value Added will displayed on table as follow.

Table IV.3. Persentase VA, NVA, NNVA

Kategori	**Jumlah Waktu (S)**	**Persentase**
Value Added	2087	48,83%
Necessary Non Value Added (NNVA)	2168	50,72%
Non Value Added (NVA)	19	0,44%
Total	4274	

APPENDIX B

Uniformity Test

No	Activity	Uniformity Test					
		Cycle Time	σ	σx	BKA	BKB	Result
1	Searching for Pattern	173	0,33	0,15	173,0	172,2	UNIFORM
2	Pattern Positioning in Fabric Sheet	74	0,55	0,24	74,5	73,0	UNIFORM
3	Marking	371	0,53	0,24	372,0	370,6	UNIFORM
4	Cutting Preparation (Sheet Conformity with Spreading Machine, Mark Margins, Add Weight)	108	0,16	0,07	108,0	107,5	UNIFORM
5	Cut the Sheet with Pattern	5	0,17	0,07	5,1	4,7	UNIFORM
6	Take Sheet from Rolled Fabric	81	0,48	0,21	82,0	80,7	UNIFORM
7	Tidy Up Surface	13	0,49	0,22	13,2	11,8	UNIFORM
8	Cut Sheet	50	0,48	0,22	50,2	48,9	UNIFORM
9	Bundle the cut fabric, grouping it by the size and part	126	0,22	0,10	126,5	125,9	UNIFORM
10	Moving bundled fabric to Inspection&Pressing Area	57	0,45	0,20	57,6	56,4	UNIFORM
11	Hard Fabric Cutting for blekser, collar leaf, and collar feet	38	0,49	0,22	38,6	37,2	UNIFORM
12	Hard fabric and blekser fabric preparation	11	0,41	0,18	11,5	10,4	UNIFORM
13	Hard fabric and Collar fabric preparation	5	0,21	0,09	5,4	4,9	UNIFORM
14	Pressing preparation (tidy up the remaining yarn)	24	0,15	0,07	23,8	23,4	UNIFORM
15	Alligning collar leaf	8	0,43	0,19	8,1	7,0	UNIFORM
16	putting hard fabric above the collar leaf	4	0,23	0,10	4,3	3,7	UNIFORM
17	Pressing Process	22	0,80	0,36	22,6	20,5	UNIFORM
18	Alligning collar feet	10	0,44	0,20	10,4	9,2	UNIFORM
19	Putting hard fabric above the collar feet	5	0,21	0,09	5,4	4,9	UNIFORM
20	Pressing Process	22	0,53	0,24	22,9	21,5	UNIFORM

No	Activity	Uniformity Test					
		Cycle Time	σ	σx	BKA	BKB	Result
21	Alligning Blekser	17	0,45	0,20	17,8	16,6	UNIFORM
22	putting hard fabric above the blekser	7	0,33	0,15	7,3	6,4	UNIFORM
23	Pressing Process	22	0,54	0,24	22,3	20,8	UNIFORM
24	Mark Size in Front Right Part	120	0,50	0,22	120,8	119,4	UNIFORM
25	Mark Size in Front Left Part	122	0,27	0,12	122,6	121,9	UNIFORM
26	Mark Size in Upper Back Part	122	0,33	0,15	122,8	121,9	UNIFORM
27	Mark Size in Lower Back Part	132	0,39	0,18	132,4	131,3	UNIFORM
28	Mark Size in Right Arm Part	111	0,16	0,07	111,6	111,1	UNIFORM
29	Mark Size in Left Arm Part	115	0,55	0,24	115,6	114,2	UNIFORM
30	Check Size Conformity with Marking (Front Right)	145	0,39	0,17	145,5	144,4	UNIFORM
31	Check Size Conformity with Marking (Front Left)	142	0,55	0,24	142,6	141,2	UNIFORM
32	Check Size Conformity with Marking (Upper Back)	143	0,41	0,19	143,7	142,5	UNIFORM
33	Check Size Conformity with Marking (Lower Back)	156	0,22	0,10	156,5	155,9	UNIFORM
34	Check Size Conformity with Marking (Right Arm)	155	0,45	0,20	155,7	154,5	UNIFORM
35	Check Size Conformity with Marking (Left Arm)	155	0,48	0,21	155,6	154,3	UNIFORM
36	Bundling Collar Leaf	62	0,77	0,34	63,1	61,1	UNIFORM
37	Bundling Collar Feet	66	0,43	0,19	66,1	65,0	UNIFORM
38	Bundling Blekser	53	0,21	0,09	53,5	53,0	UNIFORM
39	Moving bundled fabric to Sewing Area	64	0,45	0,20	64,5	63,3	UNIFORM
40	Taking the fabric bundle	8	0,70	0,31	9,3	7,4	UNIFORM
41	Put Inner Collar Leaf below the Outer Collar Leaf Back to Back	2	0,10	0,05	2,1	1,8	UNIFORM
42	Start Sewing	21	0,39	0,18	22,0	20,9	UNIFORM

No	Activity	Uniformity Test					
		Cycle Time	σ	σx	BKA	BKB	Result
43	Put Pokayoke for Pointy Collar Ends	4	0,23	0,10	4,3	3,7	UNIFORM
44	Start Sewing	9	0,62	0,28	9,4	7,8	UNIFORM
45	Turn the Collar Inside Out	3	0,21	0,09	3,3	2,8	UNIFORM
46	Taking the fabric bundle	12	0,59	0,26	12,3	10,7	UNIFORM
47	Put both part of Collar Feet Back to Back	13	0,22	0,10	13,1	12,5	UNIFORM
48	Start Sewing	6	0,39	0,17	6,6	5,5	UNIFORM
49	Put the Upper Collar Feet inside Bottom Collar Leaf	9	0,64	0,29	9,5	7,8	UNIFORM
50	Ensure Position	4	0,13	0,06	4,0	3,6	UNIFORM
51	Start Sewing	5	0,58	0,26	5,5	3,9	UNIFORM
52	Ensure Position	7	0,43	0,19	7,4	6,3	UNIFORM
53	Cut Excess Collar Feet Part	10	0,32	0,14	10,0	9,1	UNIFORM
54	Taking the fabric bundle	13	0,13	0,06	12,8	12,4	UNIFORM
55	Ensure Cleanliness	18	0,53	0,24	18,5	17,1	UNIFORM
56	Ensure Position of Front Right Part and Blekser	5	0,29	0,13	5,4	4,6	UNIFORM
57	Start Sewing	11	0,53	0,24	11,5	10,1	UNIFORM
58	Taking the fabric bundle	8	0,41	0,18	8,5	7,4	UNIFORM
59	Ensure Cleanliness	12	0,45	0,20	12,7	11,5	UNIFORM
60	Ensure Position of Front Left Part and Blekser	5	0,25	0,11	5,3	4,7	UNIFORM
61	Start Sewing	12	0,48	0,22	13,0	11,7	UNIFORM
62	Taking the fabric bundle	15	0,36	0,16	15,7	14,7	UNIFORM
63	Combine between the back and shoulders	3	0,10	0,05	3,0	2,7	UNIFORM
64	Sewing process	16	0,41	0,18	16,4	15,3	UNIFORM
65	Smoothed the folds of the back	3	0,13	0,06	3,2	2,8	UNIFORM
66	Continuing Sewing Process	14	0,39	0,18	14,0	13,0	UNIFORM

No	Activity	Uniformity Test					
		Cycle Time	σ	σx	BKA	BKB	Result
67	Cutting the yarn	2	0,13	0,06	2,2	1,8	UNIFORM
68	Balancing the fabric for labeling	17	0,43	0,19	17,1	16,0	UNIFORM
69	Taking a label	3	0,20	0,09	3,1	2,6	UNIFORM
70	Balancing the size of the cloth	3	0,15	0,07	3,0	2,6	UNIFORM
71	Sewing process	16	0,79	0,35	17,1	14,9	UNIFORM
72	Cutting the yarn	2	0,10	0,05	2,2	1,9	UNIFORM
73	Sewing the front left and back of the fabric	14	0,37	0,16	14,5	13,5	UNIFORM
74	Sewing the front right and back of the fabric	14	0,66	0,30	14,5	12,7	UNIFORM
75	Cutting the yarn	1	0,00	0,00	1,0	1,0	UNIFORM
76	Sewing combined from the outer side of the fabric	14	0,30	0,14	14,3	13,5	UNIFORM
77	Cutting the yarn	2	0,10	0,05	2,1	1,8	UNIFORM
78	Mark the collar	12	0,32	0,14	12,5	11,6	UNIFORM
79	Sewing combined collars and shirts	39	0,59	0,26	39,8	38,2	UNIFORM
80	Sewing up the collar cap on the shirt	57	0,45	0,20	57,7	56,5	UNIFORM
81	Sewing the collar edge on the shirt	10	0,28	0,13	10,0	9,2	UNIFORM
82	Sewing process	71	0,64	0,29	71,4	69,7	UNIFORM
83	Sewing Process	46	0,50	0,22	46,5	45,2	UNIFORM
84	Sewing the side part of the arm	27	0,16	0,07	27,2	26,7	UNIFORM
85	Sewing the side part of body	30	0,27	0,12	30,2	29,5	UNIFORM
86	Cutting the excessive yarn	5	0,23	0,10	5,3	4,7	UNIFORM
87	folded a little part of fabric on the bottom	8	0,45	0,20	8,7	7,5	UNIFORM
88	Sewing Process	62	0,39	0,18	62,6	61,5	UNIFORM
89	Cutting the yarn	4	0,22	0,10	4,3	3,7	UNIFORM
90	Moving finishied shirt to button installation area	40	0,39	0,18	40,4	39,3	UNIFORM

No	Activity	Uniformity Test					
		Cycle Time	σ	σx	BKA	BKB	Result
91	Button Marking	27	0,23	0,10	27,5	26,9	UNIFORM
92	Button Attaching	57	0,50	0,22	57,5	56,2	UNIFORM
93	Button Holing	29	0,34	0,15	29,2	28,3	UNIFORM
94	Inspection Process	74	0,41	0,18	74,5	73,4	UNIFORM
95	Moving to Finishing	63	0,34	0,15	63,6	62,7	UNIFORM
96	Ironing Process	45	0,37	0,17	45,2	44,2	UNIFORM
97	Cleaning the excessive yarn	7	0,22	0,10	7,7	7,1	UNIFORM
98	Insert lable on the shirt	9	0,34	0,15	9,9	9,0	UNIFORM
99	Folded finished shirt	72	0,20	0,09	72,5	72,0	UNIFORM
100	Packaging process	18	0,16	0,07	18,29	17,85	UNIFORM
101	Inspection Process	12	0,11	0,05	11,85	11,55	UNIFORM

APPENDIX C

Sufficiency Test

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
1	Searching for Pattern	893764	5178	26811684	0,074	SUFFICIENT
2	Pattern Positioning in Fabric Sheet	163134	2212	4892944	0,352	SUFFICIENT
3	Marking	4135200	11138	124055044	0,012	SUFFICIENT
4	Cutting Preparation (Sheet Conformity with Spreading Machine, Mark Margins, Add Weight)	348210	3232	10445824	0,073	SUFFICIENT
5	Cut the Sheet with Pattern	733	147	21609	28,210	SUFFICIENT
6	Take Sheet from Rolled Fabric	198643	2441	5958481	0,217	SUFFICIENT
7	Tidy Up Surface	4699	375	140625	3,925	SUFFICIENT
8	Cut Sheet	73644	1486	2208196	0,814	SUFFICIENT
9	Bundle the cut fabric, grouping it by the size and part	477812	3786	14333796	0,063	SUFFICIENT
10	Moving bundled fabric to Inspection&Pressing Area	97605	1711	2927521	0,344	SUFFICIENT
11	Hard Fabric Cutting for blekser, collar leaf, and collar feet	43113	1137	1292769	0,769	SUFFICIENT

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
12	Hard fabric and blekser fabric preparation	3631	329	108241	10,185	SUFFICIENT
13	Hard fabric and Collar fabric preparation	796	154	23716	11,064	SUFFICIENT
14	Pressing preparation (tidy up the remaining yarn)	16763	709	502681	0,665	SUFFICIENT
15	Alligning collar leaf	1735	227	51529	16,177	SUFFICIENT
16	putting hard fabric above the collar leaf	495	121	14641	22,840	SUFFICIENT
17	Pressing Process	13940	646	417316	3,389	SUFFICIENT
18	Alligning collar feet	2910	294	86436	15,993	SUFFICIENT
19	Putting hard fabric above the collar feet	796	154	23716	11,064	SUFFICIENT
20	Pressing Process	14847	667	444889	1,874	SUFFICIENT
21	Alligning Blekser	8885	515	265225	7,993	SUFFICIENT
22	putting hard fabric above the blekser	1436	206	42436	24,281	SUFFICIENT
23	Pressing Process	13983	647	418609	3,367	SUFFICIENT
24	Mark Size in Front Right Part	433703	3604	12988816	0,065	SUFFICIENT
25	Mark Size in Front Left Part	448488	3668	13454224	0,049	SUFFICIENT

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
26	Mark Size in Upper Back Part	448982	3670	13468900	0,067	SUFFICIENT
27	Mark Size in Lower Back Part	521682	3956	15649936	0,054	SUFFICIENT
28	Mark Size in Right Arm Part	371868	3340	11155600	0,063	SUFFICIENT
29	Mark Size in Left Arm Part	396079	3447	11881809	0,076	SUFFICIENT
30	Check Size Conformity with Marking (Front Right)	630485	4349	18913801	0,063	SUFFICIENT
31	Check Size Conformity with Marking (Front Left)	604085	4257	18122049	0,044	SUFFICIENT
32	Check Size Conformity with Marking (Upper Back)	614347	4293	18429849	0,049	SUFFICIENT
33	Check Size Conformity with Marking (Lower Back)	731974	4686	21958596	0,045	SUFFICIENT
34	Check Size Conformity with Marking (Right Arm)	722012	4654	21659716	0,048	SUFFICIENT
35	Check Size Conformity with Marking (Left Arm)	720461	4649	21613201	0,047	SUFFICIENT
36	Bundling Collar Leaf	115749	1863	3470769	0,784	SUFFICIENT
37	Bundling Collar Feet	128866	1966	3865156	0,341	SUFFICIENT

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
38	Bundling Blekser	85146	1598	2553604	0,486	SUFFICIENT
39	Moving bundled fabric to Sewing Area	122535	1917	3674889	0,505	SUFFICIENT
40	Taking the fabric bundle	2108	250	62500	18,944	SUFFICIENT
41	Put Inner Collar Leaf below the Outer Collar Leaf Back to Back	114	58	3364	26,635	SUFFICIENT
42	Start Sewing	13860	644	414736	4,105	SUFFICIENT
43	Put Pokayoke for Pointy Collar Ends	495	121	14641	22,840	SUFFICIENT
44	Start Sewing	2254	258	66564	25,383	SUFFICIENT
45	Turn the Collar Inside Out	286	92	8464	21,928	SUFFICIENT
46	Taking the fabric bundle	4001	345	119025	13,510	SUFFICIENT
47	Put both part of Collar Feet Back to Back	4930	384	147456	4,818	SUFFICIENT
48	Start Sewing	1111	181	32761	27,789	SUFFICIENT
49	Put the Upper Collar Feet inside Bottom Collar Leaf	2269	259	67081	23,589	SUFFICIENT
50	Ensure Position	440	114	12996	25,115	SUFFICIENT
51	Start Sewing	742	148	21904	26,004	SUFFICIENT
52	Ensure Position	1434	206	42436	22,019	SUFFICIENT

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
53	Cut Excess Collar Feet Part	2791	287	82369	26,437	SUFFICIENT
54	Taking the fabric bundle	4794	378	142884	10,481	SUFFICIENT
55	Ensure Cleanliness	9517	533	284089	8,003	SUFFICIENT
56	Ensure Position of Front Right Part and Blekser	751	149	22201	23,711	SUFFICIENT
57	Start Sewing	3499	323	104329	9,830	SUFFICIENT
58	Taking the fabric bundle	1921	239	57121	14,257	SUFFICIENT
59	Ensure Cleanliness	4392	362	131044	8,742	SUFFICIENT
60	Ensure Position of Front Left Part and Blekser	642	138	19044	18,147	SUFFICIENT
61	Start Sewing	4584	370	136900	7,246	SUFFICIENT
62	Taking the fabric bundle	6950	456	207936	4,340	SUFFICIENT
63	Combine between the back and shoulders	250	86	7396	22,499	SUFFICIENT
64	Sewing process	7559	475	225625	8,120	SUFFICIENT
65	Smoothed the folds of the back	274	90	8100	23,704	SUFFICIENT
66	Continuing Sewing Process	5503	405	164025	10,389	SUFFICIENT
67	Cutting the yarn	122	60	3600	26,667	SUFFICIENT
68	Balancing the fabric for labeling	8271	497	247009	7,261	SUFFICIENT

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
69	Taking a label	245	85	7225	27,682	SUFFICIENT
70	Balancing the size of the cloth	245	85	7225	27,682	SUFFICIENT
71	Sewing process	7736	480	230400	11,667	SUFFICIENT
72	Cutting the yarn	130	62	3844	23,309	SUFFICIENT
73	Sewing the front left and back of the fabric	5927	421	177241	5,137	SUFFICIENT
74	Sewing the front right and back of the fabric	5625	409	167281	14,051	SUFFICIENT
75	Cutting the yarn	30	30	900	0,000	SUFFICIENT
76	Sewing combined from the outer side of the fabric	5817	417	173889	5,714	SUFFICIENT
77	Cutting the yarn	114	58	3364	26,635	SUFFICIENT
78	Mark the collar	4367	361	130321	8,459	SUFFICIENT
79	Sewing combined collars and shirts	45775	1171	1371241	2,344	SUFFICIENT
80	Sewing up the collar cap on the shirt	97730	1712	2930944	0,522	SUFFICIENT
81	Sewing the collar edge on the shirt	2794	288	82944	16,898	SUFFICIENT
82	Sewing process	149280	2116	4477456	0,337	SUFFICIENT
83	Sewing Process	63065	1375	189062	1,121	SUFFICIENT

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
				5		
84	Sewing the side part of the arm	21828	808	652864	4,843	SUFFICIENT
85	Sewing the side part of body	26780	896	802816	1,164	SUFFICIENT
86	Cutting the excessive yarn	753	149	22201	28,035	SUFFICIENT
87	folded a little part of fabric on the bottom	1991	243	59049	18,452	SUFFICIENT
88	Sewing Process	115592	1862	3467044	0,330	SUFFICIENT
89	Cutting the yarn	488	120	14400	26,667	SUFFICIENT
90	Moving finishied shirt to button installation area	47700	1196	1430416	0,653	SUFFICIENT
91	Button Marking	22147	815	664225	0,446	SUFFICIENT
92	Button Attaching	96931	1705	2907025	0,498	SUFFICIENT
93	Button Holing	24861	863	744769	2,279	SUFFICIENT
94	Inspection Process	164004	2218	4919524	0,194	SUFFICIENT
95	Moving to Finishing	119725	1895	3591025	0,323	SUFFICIENT
96	Ironing Process	59967	1341	1798281	0,649	SUFFICIENT

No	Activities	Sufficiency Data			N'	Result
		∑(X²)	∑(X)	(∑X)²		
97	Cleaning the excessive yarn	1650	222	49284	7,012	SUFFICIENT
98	Insert lable on the shirt	2677	283	80089	4,415	SUFFICIENT
99	Folded finished shirt	155828	2162	4674244	0,204	SUFFICIENT
100	Packaging process	9738	540	291600	2,962963	SUFFICIENT
101	Inspection Process	4171	353	124609	6,689725	SUFFICIENT

APPENDIX D
DATA NORMALIZATION TEST

A. Preparation

One-Sample Kolmogorov-Smirnov Test

		searching_for_pattern	pattern_positioning	marking	cutting_preparation	cut_the_sheet_with_pattern	take_sheet_from_rolled_fabric	tidy_up_surface
N		30	30	30	30	30	30	30
Normal Parameters[a,b]	Mean	172,6000	73,7333	371,2667	107,7333	4,9000	81,3667	12,5000
	Std. Deviation	1,19193	1,11211	1,04826	,73968	,66176	,96431	,62972
Most Extreme Differences	Absolute	,213	,206	,258	,273	,293	,215	,353
	Positive	,193	,179	,220	,273	,273	,215	,220
	Negative	-,213	-,206	-,258	-,207	-,293	-,178	-,353
Kolmogorov-Smirnov Z		1,168	1,128	1,413	1,493	1,607	1,176	1,934
Asymp. Sig. (2-tailed)		,131	,157	,037	,023	,011	,126	,001

a. Test distribution is Normal.

b. Calculated from data.

B. Cutting Based on Pattern

One-Sample Kolmogorov-Smirnov Test

		cut_sheet	bundle_the_cut_fabric	moving_bundled_fabric
N		30	30	30
Normal Parameters[a,b]	Mean	49,5333	126,2000	57,0333
	Std. Deviation	1,13664	,80516	,85029
Most Extreme Differences	Absolute	,181	,273	,239
	Positive	,181	,165	,221
	Negative	-,168	-,273	-,239
Kolmogorov-Smirnov Z		,989	1,496	1,308
Asymp. Sig. (2-tailed)		,282	,023	,065

a. Test distribution is Normal.

b. Calculated from data.

C. Hard Fabric Cutting

One-Sample Kolmogorov-Smirnov Test

		hard_fabric_cutting
N		30
Normal Parameters[a,b]	Mean	37,9000
	Std. Deviation	,84486
Most Extreme Differences	Absolute	,257
	Positive	,257
	Negative	-,204
Kolmogorov-Smirnov Z		1,406
Asymp. Sig. (2-tailed)		,038

a. Test distribution is Normal.

b. Calculated from data.

D. Pressing

One-Sample Kolmogorov-Smirnov Test

		hard_fabric_and_blekser_preparation	pressing_process	alligning_collar_feet	alligning_blekser
N		30	30	30	30
Normal Parameters[a,b]	Mean	10,9667	21,5333	9,8000	17,1667
	Std. Deviation	,88992	1,00801	,99655	1,23409
Most Extreme Differences	Absolute	,261	,202	,246	,213
	Positive	,261	,202	,154	,187
	Negative	-,244	-,178	-,246	-,213
Kolmogorov-Smirnov Z		1,431	1,104	1,348	1,166
Asymp. Sig. (2-tailed)		,033	,174	,053	,132

a. Test distribution is Normal.

b. Calculated from data.

E. Inspection

One-Sample Kolmogorov-Smirnov Test

		mark_size_front_part	mark_size_back_part	mark_size_arm_part	check_size_front_part	check_size_back_part	check_size_arm_part
N		30	30	30	30	30	30
Normal Parameters[a,b]	Mean	119,9667	122,3333	111,3333	144,9667	143,1000	155,1333
	Std. Deviation	,85029	,80230	,71116	,92786	,80301	,86037
Most Extreme Differences	Absolute	,239	,330	,292	,285	,235	,276
	Positive	,239	,203	,214	,285	,183	,206
	Negative	-,221	-,330	-,292	-,267	-,235	-,276
Kolmogorov-Smirnov Z		1,308	1,809	1,602	1,559	1,290	1,514
Asymp. Sig. (2-tailed)		,065	,003	,012	,016	,072	,020

a. Test distribution is Normal.

b. Calculated from data.

F. Stitching Collar Leaf

One-Sample Kolmogorov-Smirnov Test

		taking_the_fabric_bundle	put_inner_collar_leaf	start_sewing
N		30	30	30
Normal Parameters[a,b]	Mean	8,3333	1,9333	21,4667
	Std. Deviation	,92227	,25371	1,10589
Most Extreme Differences	Absolute	,274	,537	,197
	Positive	,274	,396	,197
	Negative	-,192	-,537	-,152
Kolmogorov-Smirnov Z		1,503	2,941	1,078
Asymp. Sig. (2-tailed)		,022	,000	,196

a. Test distribution is Normal.

b. Calculated from data.

G. Stitching Collar Feet

One-Sample Kolmogorov-Smirnov Test

		taking_the_fabric_bundle	put_both_part_of_collar	sewing_process
N		30	30	30
Normal Parameters[a,b]	Mean	11,5000	12,8000	6,0333
	Std. Deviation	1,07479	,71438	,80872
Most Extreme Differences	Absolute	,212	,244	,217
	Positive	,152	,235	,199
	Negative	-,212	-,244	-,217
Kolmogorov-Smirnov Z		1,164	1,334	1,190
Asymp. Sig. (2-tailed)		,133	,057	,117

a. Test distribution is Normal.

b. Calculated from data.

H. Stitching Collar Leaf and Feet

One-Sample Kolmogorov-Smirnov Test

		put_the_upper_collar_feet_inside	ensure_position	sewing_process
N		30	30	30
Normal Parameters[a,b]	Mean	8,6333	3,8000	4,7000
	Std. Deviation	1,06620	,48423	1,20773
Most Extreme Differences	Absolute	,235	,427	,259
	Positive	,137	,306	,219
	Negative	-,235	-,427	-,259
Kolmogorov-Smirnov Z		1,285	2,338	1,419
Asymp. Sig. (2-tailed)		,074	,000	,036

a. Test distribution is Normal.

b. Calculated from data.

I. Stitching Front Part

One-Sample Kolmogorov-Smirnov Test

		taking_the_fabric_bundle	ensure_cleanliness	ensure_position	sewing_process
N		30	30	30	30
Normal Parameters[a,b]	Mean	12,6000	17,7667	4,9667	10,7667
	Std. Deviation	1,03724	1,27802	,61495	,85836
Most Extreme Differences	Absolute	,185	,159	,322	,314
	Positive	,185	,159	,312	,314
	Negative	-,183	-,139	-,322	-,191
Kolmogorov-Smirnov Z		1,014	,871	1,762	1,720
Asymp. Sig. (2-tailed)		,255	,434	,004	,005

a. Test distribution is Normal.

b. Calculated from data.

J. Stitching Back Part

One-Sample Kolmogorov-Smirnov Test

		combine_the_back_and_shoulder	sewing_process	smoothed_the_folds_of_the_back
N		30	30	30
Normal Parameters[a,b]	Mean	2,8667	15,8333	3,0000
	Std. Deviation	,34575	1,14721	,37139
Most Extreme Differences	Absolute	,517	,224	,433
	Positive	,350	,155	,433
	Negative	-,517	-,224	-,433
Kolmogorov-Smirnov Z		2,831	1,229	2,373
Asymp. Sig. (2-tailed)		,000	,097	,000

a. Test distribution is Normal.

b. Calculated from data.

K. Labelling

One-Sample Kolmogorov-Smirnov Test

		balancing_the_fabric	sewing_process
N		30	30
Normal Parameters[a,b]	Mean	16,5667	16,0000
	Std. Deviation	1,13512	1,38962
Most Extreme Differences	Absolute	,249	,231
	Positive	,183	,231
	Negative	-,249	-,164
Kolmogorov-Smirnov Z		1,362	1,264
Asymp. Sig. (2-tailed)		,049	,082

a. Test distribution is Normal.

b. Calculated from data.

L. Collar Stitching to the Body

One-Sample Kolmogorov-Smirnov Test

		mark_the_collar	sewing_process
N		30	30
Normal Parameters[a,b]	Mean	12,0333	39,0333
	Std. Deviation	,88992	1,51960
Most Extreme Differences	Absolute	,261	,185
	Positive	,244	,185
	Negative	-,261	-,169
Kolmogorov-Smirnov Z		1,431	1,014
Asymp. Sig. (2-tailed)		,033	,256

a. Test distribution is Normal.

b. Calculated from data.

M. Stitching Side Part of the Body

One-Sample Kolmogorov-Smirnov Test

		sewing_the_side_part_of_the_arm	sewing_the_side_part_of_body
N		30	30
Normal Parameters[a,b]	Mean	26,9333	29,8667
	Std. Deviation	1,50707	,81931
Most Extreme Differences	Absolute	,200	,255
	Positive	,200	,255
	Negative	-,184	-,183
Kolmogorov-Smirnov Z		1,097	1,396
Asymp. Sig. (2-tailed)		,180	,041

a. Test distribution is Normal.

b. Calculated from data.

N. Kelin Bottom

One-Sample Kolmogorov-Smirnov Test

		cutting_the_excessive_yarn	sewing_process
N		30	30
Normal Parameters[a,b]	Mean	4,9667	62,0667
	Std. Deviation	,66868	,90719
Most Extreme Differences	Absolute	,287	,282
	Positive	,280	,247
	Negative	-,287	-,282
Kolmogorov-Smirnov Z		1,569	1,542
Asymp. Sig. (2-tailed)		,015	,017

a. Test distribution is Normal.

b. Calculated from data.

O. Button Installation

One-Sample Kolmogorov-Smirnov Test

		button_marking	button_attaching	button_holing
N		30	30	30
Normal Parameters[a,b]	Mean	27,1667	56,8333	28,7667
	Std. Deviation	,46113	1,01992	1,10433
Most Extreme Differences	Absolute	,508	,232	,250
	Positive	,508	,135	,145
	Negative	-,359	-,232	-,250
Kolmogorov-Smirnov Z		2,781	1,268	1,371
Asymp. Sig. (2-tailed)		,000	,080	,047

a. Test distribution is Normal.

b. Calculated from data.

APPENDIX E

INTERVIEW

Observation Time	25 September 2017
Respondent	Production Supervisor
Question	**Answer**
1. Apa saja kendala dalam proses produksi yang dihadapi?	- Dari bahan masih banyak yang cacat, dikarenakan bahan ditumpuk digudang sehingga tidak terlihat adanya cacat dan operator yang lalai saat proses inspeksi. - Kendala ada pada karyawan, terkadang karyawan masih kurang dikarenakan ada yang tidak hadir sehingga karyawan yang lain harus mengerjakan pekerjaan yang lain. - Meski karyawab sudah hadir semua, tetap ada karyawan yang menunggu untuk bekerja karena karyawan tersebut belum mendapatkan part. - Meski sudah ditargetkan satu operator untuk memproduksi 12 kemeja. Dimana target tersebut didapat dari hasil perhitungan perusahaan, namun operator terkadang masih tidak bisa memenuhi target tersebut. - Pelanggan terkadang masih ada yang complain karena masih ada yang kemeja salah memasang size. Operator harus mengerjakakan kembali barang reject sehingga waktu produksi barang lain tertunda. - Operator lembur dari jam 5 hingga jam 8 dikarenakan target tidak tercapai atau dikarenakan meningkatnya demand.
2. Apakah cacat bahan dapat masuk ke proses produksi?	Dapat masuk, karna biasanya adanya keteledoran operator dalam proses pengecekan (inspeksi)
3. Selain bahan, apa saja penyebab cacat yang lainnya?	Ada, yaitu cacat pada area penjahitan seperti jahitan yang melenceng, jahitan yang lepas.
4. Apa yang menyebabkan cacat pada area penjahitan?	Cacat dikarenakan operator pada saat oenjahitan tidak teliti dalam proses menjahit dan terjadinya kerusakan pada mesin dikarenakan mesin yang dipakai terus menerus dan tidak adanya pengecekan
5. Apakah perusahaan merugi jika operator lembur?	Jika operator tidak memenuhi kewajiban yaitu 12 pcs per operator, maka itu kesalahan karyawan sehingga lembur tersebut tidak dibayar.
6. Apa saja yang sudah dilakukan oleh perusahaan untuk mengantisipasi permasalahan?	- Mengusahakan supaya target tersebut terkejar - Membuat operator kerja lembur

Observation Time	25 September 2017
Respondent	Sewing Operator
Question	**Answer**
1. Apakah kendala selama proses penjahitan?	**Operator 1** Terkadang saya harus mengerjakan pekerjaan operator lain dikarenakan operator tersebut tidak hadir, sehingga membutuhkan waktu tambahan untuk saya mengerjakan perkerjaan tersebut karna saya belum terlalu mahir dalam mengerjakannya **Operator 2** Terkadang saya belum bisa melanjutkan pekerjaan saya karena kekurangan bahan dari WS sebelumnya. Saya bisa saja pulang dahulu untuk menunggu material ada, atau membantu WS lain
2. Apakah kesulitan pekerjaan tiap-tiap WS memiliki tingkat kesulitan yang sama?	**Operator 1** Tentunya berbeda, ada yang proses menjahitnya lama ada juga yang hanya sebentar. **Operator 1** Berbeda, karena tingkat kesulitannya pun berbeda. Contohnya WS saya (Menjahit Blekser) membutuhkan waktu yang agak lama dibandingkan dengan WS kerah karena blekser memiliki permukaan yang lebih besar untuk dijahit dibandingkan dengan kerah.
3. Kami mendapatkan informasi dari supervisor bahwa operator terkadang tidak memenuhi target dan harus lembur namun tidak dibayar, apakah operator tidak merasa rugi?	Tentu rugi, kami tidak memenuhi target dikarenakan harus menutupi pekerjaan operator lain saat operator yang bersangkutan tidak hadir oleh sebab itu membutuhkan waktu proses yang lebih lama.
4. Namun bukankah perusahaan menetapkan target produksi berdasarkan operator yang hadir? Seharusnya meski operator tidak hadir tidak berpengaruh ke ketercapaian targetnya.	Tapi nyatanya, contohnya jika salah satu operator proses blekser tidak hadir, maka operator yang lain harus mengerjakan 2 proses yaitu menjahit blekser kanan dan blekser kiri. Karna statsiun kerja blekser membutuhkan 2 operator.