PRODUCTIVITY IMPROVEMENT IN UMW MANUFACTURING INDUSTRY USING TIME STUDY AND WORK MEASUREMENT ANALYSIS

This report is submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree in Industrial Engineering (Hons.)

By

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DECLARATION

I hereby declared this report entitled "Productivity Improvement in Manufacturing Industry Using Time Study and Work Measurement" is the result of my own research except as cited in references.

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APPROVAL

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

………………………………………………

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ABSTRAK

Teknik pengukuran kerja dan analisis kajian masa adalah metodologi saintifik yang bertujuan untuk menentukan cara terbaik melaksanakan tugas rutin dan mengira masa yang diambil oleh pekerja biasa untuk menyelesaikan aktiviti tertentu. Penyelidikan ini bertujuan untuk menerapkan teknik-teknik ini bagi meningkatkan pengeluaran dalam pembuatan membran UF (ultrafiltrasi). Prosedur pembuatan yang panjang menyebabkan sektor ini tidak dapat memenuhi permintaan yang tinggi. Dengan tumpuan kepada proses 1 hingga 6, kajian ini bertujuan untuk melakukan analisis masa dan pengukuran kerja pada barisan pengeluaran membran UF. Aliran proses semasa ditemui melalui pemerhatian langsung dan rakaman video. Setiap prosedur utama dipecahkan kepada beberapa komponen kerja untuk pemeriksaan yang teliti. Enam proses utama diperhatikan dengan mengambil kira masa kitaran dan pergerakan setiap tugas yang dilakukan oleh pekerja. Masa piawai dibangunkan dengan mengambil kira elaun dan penilaian prestasi. Tujuh isu dalam proses pengeluaran semasa disiasat menggunakan rajah sebab dan akibat. Dengan menggunakan pendekatan '5 Why', tiga daripada isu penting ini dianalisis dan langkah-langkah penyelesaian dicadangkan untuk setiap satu daripadanya. Kajian ini juga bertujuan untuk menawarkan aliran proses alternatif bagi mengurangkan masa pengeluaran. Kajian ini mendapati tiga komponen buruh dan satu mekanisme utama menyebabkan kelewatan dalam pengeluaran membran UF. Tiga penyelesaian yang dicadangkan adalah pelaksanaan pendekatan Kobetsu Kaizen untuk Proses 4, pelaksanaan Poka Yoke dalam Proses 5, dan penggunaan peralatan baru untuk Proses 6. Alternatif yang dicadangkan ini bertujuan untuk memaksimumkan tindakan buruh untuk tugas tertentu, mempermudah teknik kerja, dan menyusun ruang kerja.

ABSTRACT

Work measurement techniques and time study analysis are scientific methodologies meant to determine the best way to execute routine chores and calculate the time taken by an average worker to finish particular activities. This research sought to apply these techniques to improve output in UF (ultrafiltration) membrane manufacture. A long manufacturing procedure made the sector unable to satisfy great demand. With an eye on processes 1 through 6, the study aimed to do time analysis and work measurement on the UF membrane production line. The current process flow was found by direct observation and video capture. Every key procedure was split into multiple work components for close examination. Six main processes were observed under consideration of the cycle time and motion of every job carried out by employees. Accountable for allowances and performance evaluations, standard timings were developed. Seven current manufacturing process issues were investigated using a cause- and- effect diagram. Using the 5 Whys approach, three of these important concerns were examined and countermeasures for every one of them were suggested. The study sought to offer substitute process flows to cut production time as well. The study found three labor components and one primary mechanism causing delays in UF membrane output. The three main concerns identified were insufficient training, outdated machinery, and inefficient workflow. The impact from these issues resulted in frequent errors, machine downtime, and high cycle time per unit. Three solutions were proposed: implementation of Kobetsu Kaizen approaches for Process 4, implementation of Poka Yoke in Process 5, and adoption of new equipment for Process 6. These proposed solutions aim to maximize labor actions for specific tasks, simplify work techniques, and organize the workspace. Implementation of these solutions is expected to reduce errors, minimize downtime, and significantly reduce production time.

DEDICATION

This project is lovingly dedicated to:

My beloved parents,
Ana Salwa Binti Mohd Salim and Zulkarnain Aziz
Whose unconditional love, support, and encouragement
have been my constant source of strength.

My esteemed supervisor,
Mr. Nor Akramin Bin Mohamad
Whose invaluable guidance and mentorship
have been instrumental in shaping this work.

The hardworking professionals in the manufacturing industry,
Whose dedication and efforts inspire this study's pursuit
of productivity improvement.

My dear friends and classmates,
Whose companionship and shared experiences
have made this journey truly memorable.

ACKNOWLEDGEMENT

In the name of Allah, the Most Gracious, the Most Merciful. With the highest praise to Allah and peace be upon our Prophet Muhammad S.A.W. Alhamdulillah, I manage to complete this final year project successfully without difficulty. First and foremost, my deepest gratitude goes to my respected supervisor, Mr Nor Akramin Bin Mohamad. His kindness, unwavering patience, and mentorship guided me through this process. His easily understood explanations, open mind, timely and efficient contributions allowed me to grow, learn and helped me finish my report. All the knowledge and experiences gained will be meaningful during my future undertakings. Besides that, I want to convey my gratitude and appreciation to Farahana Nabila and myself for giving me much motivation and cooperation mentally in completing this report. Without their support, the project and all the activities would not have come to completion.
Finally, I would like to thank everybody who was important to the success of this final year's project report, as well as expressing my apology that I could not mention each one of you personally.

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LIST OF ABBREVIATIONS

OEE	-	Overall Equipment Efficiency
PMTS	-	Predetermine Motion Time Systems
UMW	-	United Motor works
TQM	-	Total Quality Management
UF	-	Ultra Filtration
MOST	-	Maynard Operation Sequence Technique
FMEA	-	Failure Mode and Effects Analysis
KPI	-	Key Performance Indicator
JIT	-	Just in Time
VSM	-	Value Stream Mapping

LIST OF SYMBOLS

OT	-	Observe Time
A	-	Allowance
AWT	-	Actual Working Time
NT	-	Normal Time
RF	-	Rating Factor
ST	-	Standard Time
n	-	Number of Work Cycle

CHAPTER 1

INTRODUCTION

This study details how UMW production and Engineering has increased the productivity of its ultrafiltration membrane production process. The background of the case study, the company's history, the purpose, the problem statement, the scope, and the outline will all be covered in this chapter.

1.1 Overview

Enhancing productivity is currently one of the areas where business management and procedures have the biggest impact. It is possible to view both the manufacturing and service sectors as relevant (Piyachat, 2019). Hayes et al. (2008) posit that the various factors influencing the production line can lead to a complex process in determining productivity. These factors include business strategy, vendor competence, machinery competence, manufacturing taxation, the influence of human factors, and variations. Due to this, identity management of the production must appropriately assess and perceive the situation (Diego et al., 2014). It is recommended that a number of complementary strategies be used in order to increase industrial sector efficiency. This paper explores various methods for boosting productivity.

1.2 Background of Study

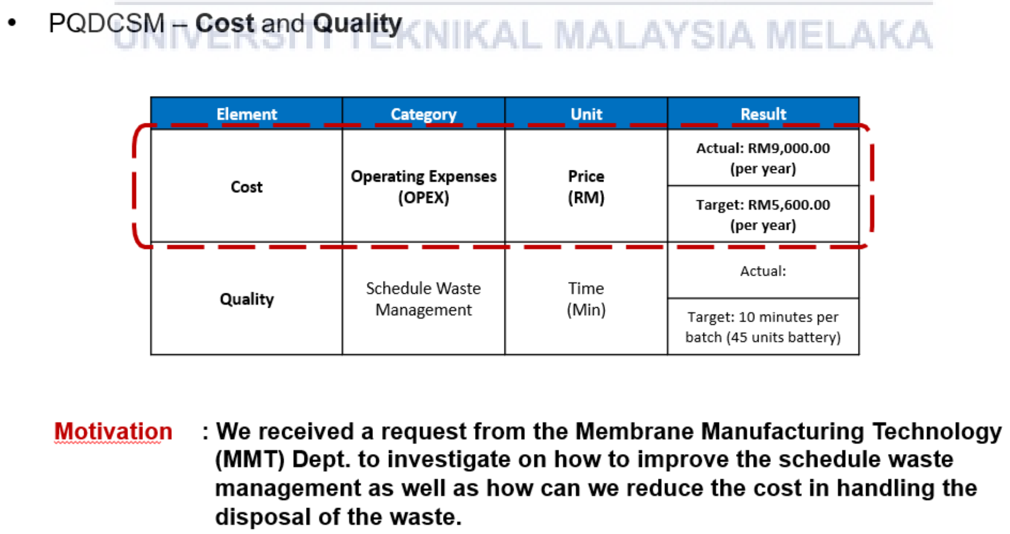
Time study analysis is the evaluation of a certain worker's completion of a given job or activity to identify the most suitable strategy in terms of time reduction. Meyers (2001) define time criteria as "the time needed to produce a product with the three conditions at a workstation: I a skilled, well-trained operator, operating at a regular speed, and performing a specific task". Pursues of excellence help to increase market competitiveness. Constant improvement of processes, products, and services in all kinds of businesses raises market competitiveness. A company's market survival is under danger if it does not concentrate on cost reduction and preserving the quality of what it offers. This setting helps to highlight lean manufacturing and its tools, which aim to reduce all kinds of waste inside a business.

Time and motion analysis provides techniques for a thorough assessment of an activity or task, for determining which actions produce value, and for either lowering or eradicating those that either do not contribute positively or are seen loss. By means of a time and motion study of a manufacturing process, one may measure its potential and enhance its efficiency and productivity, so rendering the company more efficient to the point of obtaining reduced production costs, so providing the consumer with a quality good at a lower price. The study of time and motion helps one to design a better approach for running the operations of a process. Every activity is assigned standard motions and timings; hence, it is vital to follow them so that the business discovers improved performance in the market in which it operates. According to Souto (2002), approaches engineering studies and analysis work methodically which generate useful and efficient ways, to standardise the process.

1.3 Problem Statement

Generally, the industrial sector leads to the increase of the economy and has an impact on the growth of sustainable production establishment (Yati and Yanfitri, 2010) (Marcel et al., 2018) (Emilia, 2015). Due to the development of the economy, establishing value and customer satisfaction are the expectations of the entire manufacturing sector. Promising means that sufficient emphasis is put on the market of goods in order to attract consumers and build customer loyalty at a certain level. With a rapid increase in demand for production, manufacturing industries need to enhance their production and efficiency potential in order to remain competitive against their competitors.

This research was carried out at UMW UF manufacturing, where the primary problems are long production time, outdated machinery, and high operation costs stated in figure 1.1. The company is unable to meet the high demand due to these issues, which result in inefficiencies and increased production expenses. The workers face difficulties completing their tasks within the allocated time due to unreliable and time-consuming production process flows. The outdated machinery like using jigsaw to cut 8 inch of UF module further exacerbates these issues by causing frequent breakdowns and inefficiencies, leading to increased operational costs and extended production times as shown in table 1.1.


• PQDCSM – Cost and Quality

Element	Category	Unit	Result
Cost	Operating Expenses (OPEX)	Price (RM)	Actual: RM9,000.00 (per year)
			Target: RM5,600.00 (per year)
Quality	Schedule Waste Management	Time (Min)	Actual:
			Target: 10 minutes per batch (45 units battery)

Motivation : We received a request from the Membrane Manufacturing Technology (MMT) Dept. to investigate on how to improve the schedule waste management as well as how can we reduce the cost in handling the disposal of the waste.

Figure 1.1: Cost and Quality by UMW M&E Root Cause Analysis (RCA) report

Table 1.1: Table of Observation time in process Bundling and Potting

TIME STUDY SHEET		Date:					11.1.2024					
		Operator:					Imran and Firdaus					
Process Name :		Bundling and potting										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Dried membrane is counted manually	627.88	600.45	575.31	652.74	619.92	637.35	644.78	622.21	600.61	665.46	627.68
2	Tie every batch and place it on table	117.05	99.62	134.48	101.81	118.99	126.42	113.85	131.28	98.44	143.16	117.37
3	Cut the membrane refering the specs	32.44	44.91	20.07	53.28	34.76	46.9	38.12	50.99	25.3	61.68	39.85
4	Insert the membrane into cylindrical pot	83.56	66.13	90.99	78.3	85.48	92.91	80.34	95.77	67.7	103.43	83.96
5	Close both end with jig	42.72	55.29	30.15	67.58	54.76	67.19	51.82	75.05	36.81	81.68	56.18
6	Prepared the epoxy	247.43	260.01	214.86	272.29	259.47	276.95	254.33	281.76	239.14	294.72	259.5
7	Setup the module	154.92	167.49	122.35	179.78	166.96	184.39	161.82	189.25	146.63	191.5	166.88
8	Inject epoxy in the jig using syringe	435.23	447.8	402.66	459.09	446.27	463.7	440.13	467.56	424.94	489.62	452.05
9	Inject epoxy in the other end	571.19	583.76	538.62	595.05	582.23	609.66	586.09	613.52	570.91	635.58	597.92
10	Cut the jig	19623.43	19749.12	19497.8	19862.2	19734.67	19908.22	19672.51	19946.83	19515.41	20071	19791.77
11	Clean the surface	2459.11	2584.78	2333.41	2607.74	2479.52	2653.85	2428.18	2702.51	2271.14	2847.5	2529.81

1.4 Objectives

Increasing industry productivity is the project's primary objective. The accomplishment of several sub-objectives has been identified as necessary to ensure the success of this project:

a. To employ time study and work measurement analysis to examine the UF membrane production process, focused on process 1, raw material preparation to 6, bundling and potting.
b. To assess the productivity of the UF membrane production process
c. To suggest potential enhancements that could boost UF membrane production process' productivity

1.5 Scope

Focusing especially on the membrane production techniques, the scope of the research spans a thorough analysis and execution of time study and work measurement inside UMW production and Engineering. The study will centre the following important components:

i. Process Analysis: Especially about membrane manufacture, this will entail a thorough review of the current manufacturing techniques. It will cover resource use, workflow pattern detection, and productivity bottleneck identification.
ii. Time study and work measurement techniques will be applied in the study to methodically measure and evaluate the time and resources needed for different jobs inside the manufacturing processes. This will offer very important new perspectives on resource allocation and process effectiveness.
iii. The scope will cover the identification and recording of sixteen current production gaps in the manufacturing processes. This will entail a thorough investigation of inefficiencies and discrepancies influencing production and quality of products.
iv. The study intends to solve the consistency in product quality by means of manufacturing technique inefficiencies identification and mitigating action. The study will cover initiatives to maximise resource use, simplify procedures, and raise general production within the process 1 until 6.

1.6 Significant of Study

To begin, the findings of this study hold the potential to considerably improve the operational efficiency of the manufacturing processes. By conducting a time study and doing an analysis of work measurement, the project intends to find areas of inefficiency, cut down on waste, and maximize the utilization of available resources. There is a possibility that this will result in cost reductions as well as an overall improvement in operational efficiency. Furthermore, the study intends to address the problem of maintaining a consistent level of product quality. The study has the potential to contribute to a higher level of consistency in the products that are made by finding inefficiencies in the manufacturing procedures and taking measures to mitigate such inefficiencies.

There is a possibility that this may improve the level of satisfaction experienced by customers and strengthen the competitiveness of the organization within the market. A further objective of the study is to ensure that the manufacturing procedures are in accordance with the requirements of the stakeholders. The project seeks to serve the needs of 17 the customers, comply with the standards set by the regulatory bodies, and meet the requirements set forth by the internal operations. This will be accomplished by satisfying the expectations for enhanced quality, faster delivery, and reduced prices. In addition, the insights that were obtained from the study have the ability to contribute to the organization's strategic decision-making during the implementation process.

The study can guide future investments, process redesign, and resource allocation, so affecting the strategic direction of the firm. This is accomplished by giving a systematic analysis of productivity and process efficiency, which gives the study the ability to steer these activities. To conclude, the UMW Manufacturing and Engineering department is able to align itself with the best practices in the industry for increasing manufacturing productivity by deploying time study and work measurement analysis software. The findings and recommendations of the study have the potential to have an impact on industry standards that are more widespread, which will contribute to the transmission of best practices both inside the organization and even beyond its walls.

CHAPTER 2
LITERATURE REVIEW

In this chapter, we delve into the existing body of knowledge surrounding productivity improvement in the manufacturing industry, specifically focusing on the application of time study and work measurement analysis. The literature review aims to provide a comprehensive understanding of the historical development, methodologies, and impact of these techniques on manufacturing efficiency.

2.1 History of Time Study Analysis and Work Measurement

For more than a century, the manufacturing sector has employed time study analysis and work measurement to raise quality, lower prices, and increase productivity (Maynard et al., 1948). The origins of labour measurement and time study analysis can be found in Frederick Winslow Taylor's early 20th-century development of the "Taylorism" or scientific management idea (Taylor, 1911). Taylor's strategy placed a strong emphasis on the value of examining work processes and determining the best ways to complete jobs.

Time study analysis is tracking how long it takes to complete procedures or tasks by watching and recording how long it takes (Maynard et al., 1948). Frederick W. Taylor first created this method in the late 19th century as a component of his scientific management philosophy. The goal of time study analysis is to create standard times for every task by using precise information gathered from observations. These benchmark timings are used to determine the ideal performance standards for a given task or procedure.

Finding the amount of time needed to finish a certain task or operation is known as work measurement, and it is another crucial idea in time study analysis (Kanawaty & Trietsch, 2015). Predetermined motion time systems (PMTS), synthetic data systems, and historical data gathering approaches are examples of work measuring methodologies. PMTS is a popular technique that estimates the overall amount of time needed for a work by breaking complex tasks down into simple motions and assigning standard timings to each motion (Kanawaty & Trietsch, 2015).

Since their inception, time study analysis and work measurement have undergone tremendous evolution. In order to achieve more accurate time and motion measurements, modern approaches make use of cutting-edge technologies such video cameras, sensors, and computer software (Slack et al., 2016). Moreover, these methodologies have been implemented in other domains like as healthcare, education, and service industries, extending beyond the manufacturing sector (Barnes & Römeril, 2007; McLaughlin et al., 2016; Voss et al., 2016).

In conclusion, Frederick Winslow Taylor's scientific management style introduced time study analysis and task measurement over a century ago, and they are crucial ideas in productivity development today. With the development of technology and the use of these methods in fields other than manufacturing, these methods have changed dramatically over time (Maynard et al., 1948; Kanawaty & Trietsch,2015; Slack et al., 2016; Barnes & Römeril,2007; McLaughlin et al., 2016; Voss et al., 2016).

2.2 Relationship of Time Study Analysis, Work Measurement and Standard

Work measurement and time study analysis are linked ideas shown in figure 2.1 below, utilized in manufacturing sectors to raise quality, lower prices, and increase output by means of their interaction (Maynard et al., 1948). Standardizing activities or operations means, based on accurate data gathered over time study analysis and work assessment methodologies, a consistent approach.

Time study analysis is the observation and recording of certain job or operation times (Maynard et al., 1948). Based on exact data gathered during observations, this method creates standard timings for every chore. Synthetic data systems and historical data collecting approaches among work measurement tools help to ascertain the time needed to finish a given project or operation.

Using the standard times set by work measurement and time study analysis as benchmarks for ideal performance levels particular to a given job or process helps to accomplish standardizing. These criteria guarantee consistency in task performance among several workers and shifts, thereby lowering variability in output quality and raising efficiency (Slack et al., 2016).

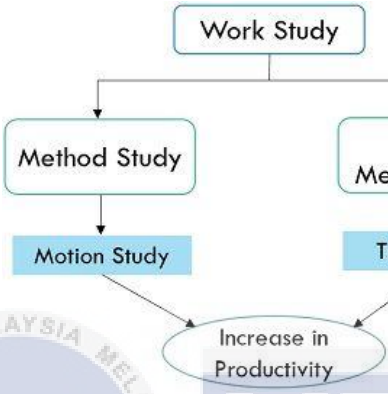


Figure 2.1: Link among Standardizing, Work Measurement, and Time Study Analysis
https://keydifferences.com/difference-between-time-study-and-motion-study.html#google_vign

2.2.1 Methods to Determine Time Standard

Many techniques are applied to establish task time criteria shown in table 2.1 below. Time study consists of direct task timing and observation. Work Sampling projects time spent on activities using statistical sampling. Standard Data depends on already known time values for comparable activities. Historical Analysis sets time criteria by means of prior records. Expert Opinion draws on knowledge from seasoned professionals; direct observation is real-time task monitoring. These techniques enable assessment and enhancement of work efficiency.

Table 2.1: Method to Determine Time Standard

Methods	Source
Time Study	Barnes, R. M. (1980). Niebel, B. W. (1982). Mundel, M. E. (1993).
Work Sampling	Kothari, C. R. (2004). Barnes, R. M. (1980). Freivalds, A. (2009).
Standard Data	Groover, M. P. (2007). Nadler, G. (1986).
Historical Analysis	Maynard, H. B. (2001). Jacobs, F. R. (2010).
Direct Observation	Stevenson, W. J. (2018). Buffa, E. S. (1983). Chase, R. B. (2013).
Expert Opinion	Salvendy, G. (2001). Drucker, P. F. (1999).

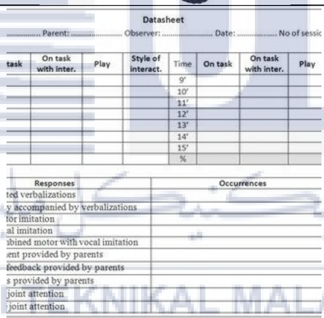
2.3 Introduction of Technique for Time Study Analysis

One basic method used to find the time needed for a worker to finish a certain task under given circumstances is time study. It entails the exact timing of several components of a project measured by a stopwatch or other similar tool. This approach helps to find and fix inefficiencies, hence raising output. Time study, most experts explain, entails timing smaller aspects, dividing down chores into manageable chunks, and setting standard timeframes for each (Barnes, 1980; Niebel, 1982). Performance benchmarks and work process optimization then derive from these conventional timings. Establishing a time standard helps companies guarantee consistent and effective operations of their procedures. Time research methods help to pinpoint places where development can be achieved, thereby increasing the general production (Mundel, 1993).

2.3.1 Equipment for Time Study Analysis

Time study analysis requires basic tools including stopwatches for exact timing, time recording devices for automatic data collecting, data collecting sheets for hand recording, video recording equipment for visual analysis, and motion sensors for movement data capture shown in table 2.2 below. Accurate time studies depend on these technologies, which also help companies to spot process inefficiencies and thereby increase production.

Table 2.2: Table of Equipment for Time Study Analysis

Equipment for Time Study Analysis	**Picture**	**Source**
Stopwatch		Barnes, R. M. (1980). Niebel, B. W. (1982).
Data Collection Sheets		Buffa, E. S. (1983).
Video Recording Equipment		Chase, R. B. (2013).
Motion Sensors		Salvendy, G. (2001).

2.4 Stopwatch Technique

Since most researchers apply the stopwatch technique for time study analysis (Barnes, 1980; Niebel, 1982) shown in table 2.2 above, it is a basic instrument in precisely measuring the length of job tasks. Using this method, one manually starts and stops the stopwatch to note the time required for every component of a task. Time study analysts can precisely record the time spent on activities by dissecting tasks into smaller elements, therefore enabling the formation of standard times (Mundel, 1993). Time studies based on stopwatch are essential for spotting inefficiencies in systems and streamlining procedures to raise general output.

2.4.1 Importance of Stopwatch Technique

Because of its precision and adaptability in measuring work durations, the stopwatch technique is rather important in the field of time study analysis (Barnes, 1980; Niebel, 1982). This approach lets industrial engineers and researchers methodically record the time spent on particular job parts, therefore producing precise information for analysis of work processes. The stopwatch approach helps to find inefficiencies, bottlenecks, and areas for development inside processes by precisely timing every job or motion segment. This detailed degree of data helps companies to create accurate time criteria, maximise resource allocation, and properly simplify processes (Mundel, 1993). In the end, the stopwatch approach is rather important in improving operational effectiveness and production in many sectors.

2.5 Requirement of Conducting Time Study Analysis

Doing a good time study analysis calls for a few main criteria refer to table 4.3 below. These cover a complete awareness of work processes and tasks, employee collaboration for correct data collecting, access to the work area and required tools for data collecting and analysis, specialised training and knowledge in time study techniques, and suitable tools for data collecting and analysis. Meeting these criteria guarantees that time study analysts may compile accurate data, spot areas needing development, and apply plans to increase output and effectiveness in corporate processes.

Table 2.3: Table of Requirement of Conducting Time Study Analysis

Requirements of Conducting Time Study Analysis	Source
Understanding of Work Processes and Tasks	Barnes, R. M. (1980). Buffa, E. S. (1983).
Cooperation from Employees	Chase, R. B. (2013). Salvendy, G. (2001).
Access to Work Area and Equipment	Niebel, B. W. (1982). Mundel, M. E. (1993).
Time Study Training and Expertise	Stevenson, W. J. (2018).
Data Collection and Analysis Tools	Maynard, H. B. (2001).

2.6 Work Sampling Technique

Work sampling is the application of statistical techniques to track and evaluate the percentage of time employees spend engaged in various tasks (Kothari, 2004; Buffa, 1983). Work sampling, unlike ongoing observation, captures sporadic samples over a time to offer a representative picture of work patterns (Niebel, 1982). When constant monitoring is either expensive or impossible, this approach is especially helpful since it enables companies to effectively collect data and minimise disturbance of regular operations (Chase, 2013). Work sampling aids in the identification of idle moments, frequency of particular jobs, and resource use evaluation (Salvendy, 2001).

2.6.1 Performance Rating

Based on predefined criteria, performance rating is a technique used to evaluate worker efficiency and effectiveness (Niebel, 1982; Buffa, 1984). Measuring production and quality of work requires comparing individual performance against set criteria or benchmarks (Chase, 2013; Stevenson, 2018). Usually using rating scales or checklists, this method methodically assesses elements including speed, accuracy, and adherence to policies (Maynard, 2001). Performance ratings help management and staff by offering insightful comments that support performance assessments, training needs evaluation, and area for development (Salvendy, 2001). Standardising assessments helps companies guarantee fairness and consistency in evaluating employee performance over several positions and responsibilities (Barnes, 1980).

2.6.2 Allowance Factor

In industrial engineering, the allowance factor is extra time deliberately given to the standard time of a task to consider different elements including weariness, delays, and human demands (Niebel, 1982; Buffa, 1983). This change is to guarantee enough time for employees to finish duties without unnecessary pressure or haste, therefore preserving production and quality (Chase, 2013). Empirical data and industry norms guide the determination of allowances considering the requirements and conditions of the employment (Salvendy, 2001). Appropriate allowance elements enable to balance efficiency with worker well-being, so promoting general job satisfaction and performance (Barnes, 1980).

2.7 Introduction of Technique for Work Measurement Method

Based on my research, a significant number of researchers utilize time study as a fundamental technique for work measurement in industrial engineering shown in table 2.4 below. Time study involves direct observation and timing of tasks to establish standard times, contributing to the optimization of productivity and efficiency. Additionally, work sampling, performance rating, and allowance factors are also widely recognized methods that enhance the understanding and improvement of work processes in various industrial settings.

Table 2.4: Table of Technique for Work Measurement Method

Technique for Work Measurement Method	Source
Time Study	Barnes, R. M. (1980). Mundel, M. E. (1993). Maynard, H. B. (2001). Groover, M. P. (2007).
Work Sampling	Kothari, C. R. (2004). Buffa, E. S. (1983). Freivalds, A. (2009).
Performance Rating	Chase, R. B. (2013). Stevenson, W. J. (2018). Drucker, P. F. (1999).
Allowance Factor	Niebel, B. W. (1982). Salvendy, G. (2001). Heizer, J. (2017).

2.8 Motion Study

By examining the motions and movements needed to complete a task, motion study a methodical approach helps to analyse and enhance work techniques (Niebel, 1982; Barnes, 1980). This approach seeks to minimise needless motions, simplify procedures, and maximise ergonomic conditions to improve efficiency and output (Salvendy, 2001). Motion analysis helps find possible enhancements in job design, layout, and equipment use by dissecting tasks into basic motions and analysing each component (Groover, 2007). In industrial engineering, it is frequently used to standardise work techniques, remove unnecessary motions, and advance worker safety and comfort (Maynard, 2001).

2.9 Relationship of Work Cycle and Time Cycle

In industrial engineering, refer to figure 2.2 below the relationship between work cycle and time cycle is the interaction between the sequence of tasks (work cycle) and the time taken to do those tasks (time cycle) (Niebel, 1982; Buffa, 1983). From start to completion, the work cycle covers all actions required to complete a task or operation, including actual work and any required idle time. Conversely, the time cycle shows the whole amount of time needed to execute the work cycle, usually comprising both non-productive and productive aspects like setup time and delays (Chase, 2013; Stevenson, 2018).

Maximising production and efficiency depends on an awareness of the interactions among these cycles. Industrial engineers can find chances to lower general cycle times, remove bottlenecks, and enhance workflow design by means of analysis and synchronising of work cycles with time cycles. This all-encompassing strategy helps companies efficiently accomplish production goals, improve resource use, and simplify processes (Salvendy, 2001).

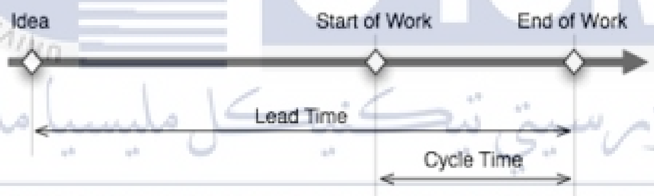


Figure 2.2: Relationship between work cycle and time cycle: https://getnave.com/blog/kanban-cycle-time/

2.10 Cause Effect Diagram

In quality management, the Cause-and-Effect Diagram shown in figure 2.3 below also known as the Fishbone Diagram or Ishikawa Diagram is a visual aid for spotting and investigating the possible sources of a given problem or effect (Buffa, 1983; Heizer, 2017). Like a fish skeleton, it arranges possible causes into groups including people, techniques, tools, materials, measurements, and environment (Chase, 2013; Salvendy, 2001). Through methodically organising these elements, the diagram enables teams to examine relationships between several causes and their possible consequences on a given outcome or problem (Stevenson, 2018).

Encouragement of a methodical approach to problem-solving and decision-making procedures by the Cause-and-Effect Diagram helps one to It helps teams to work together, enhances communication, and directs conversations towards fundamental issues instead of symptoms (Barns, 1980). This approach is extensively applied in many different sectors to identify problems, create ideas for development, and apply sensible solutions addressing fundamental causes instead of only surface ones.

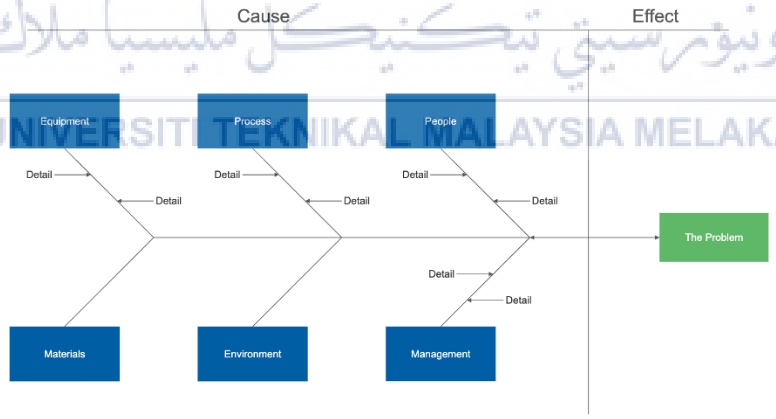


Figure 2.3: Cause and Effect Diagram: https://www.smartdraw.com/cause-and-effect/

2.11 Kobetsu Kaizen

Translated as "individual improvement" in Japanese, Kobetsu Kaizen is a continuous improvement method shown in figure 2.4 below, emphasising on little, incremental changes in particular processes or activities inside a company (Imai, 1986; Shingo, 1989). Unlike major projects for improvement, Kobetsu Kaizen stresses grassroots efforts whereby front-line staff members actively help to find and apply enhancements in their daily operations (Ohno, 1988; Hirano, 1995).

Analysing present practices, waste elimination, standardising processes, and application of solutions to improve efficiency, quality, and safety (Ishikawa, 1985; Womack & Jones, 1996) this approach uses. Kobetsu Kaizen seeks to sustainably enhance the company by encouraging a culture of ongoing development and enabling staff members to provide ideas (Nakajima, 1988; Liker, 2004).

Figure 2.4: Kaizen target: https://www.veryableops.com/blog/what-is-kaizen

2.12 Decision Matrix Analysis

A methodical approach called "decision matrix analysis" as shown in figure 2.6 below compares and ranks a collection of options against a set of predetermined standards (Chase, 2013; Stevenson, 2018). When making decisions where several choices must be evaluated objectively depending on several criteria like cost, time, risk, and feasibility, this approach is especially helpful (Salvendy, 2001). There is several steps before the decision matrix can be made, refer to table 2.5 below.

Table 2.5: Table of Steps in Making Decision Matrix

steps	Explanation
1	List Criteria: Identify and list the criteria for evaluation.
2	Weight Criteria: Assign weights to each criterion.
3	List Alternatives: Identify and list the alternatives.
4	Score Alternatives: Evaluate each alternative against each criterion and assign scores.
5	Calculate Total Scores: Multiply scores by weights and calculate total scores for each alternative.
6	Select Best Alternative: Compare total scores and select the alternative with the highest score.

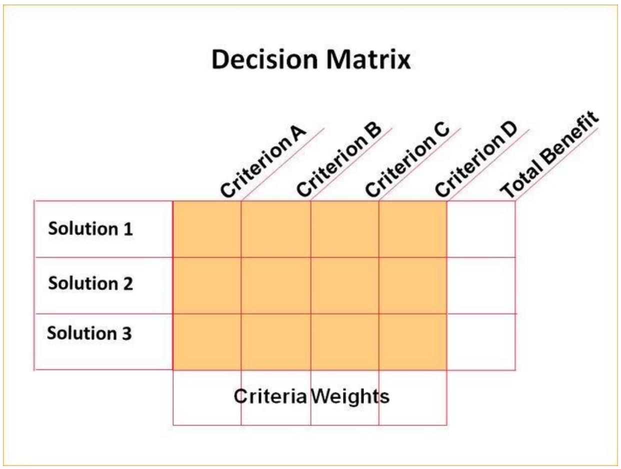


Figure 2.4: Decision Matrix Analysis: https://cloudfresh.com/en/blog/decision-matrix-7-steps-to-make-a-decision/

2.13 Productivity of Manufacturing Industry

Reflecting the ratio of output to input within a certain period, productivity in the manufacturing sector is a fundamental gauge of efficiency and output effectiveness (Buffa, 1983; Chase, 2013). Evaluating the economic performance and competitiveness of industrial activities, it is a key performance indicator (KPI) (Stevenson, 2018). In manufacturing, several elements affect productivity including technology developments, worker skills, operational procedures, and resource use (Heizer, 2017; Groover, 2007).

Adopting lean manufacturing ideas, using automation, streamlining supply chain management, and raising general operational efficiency (Womack & Jones, 1996; Slack et al., 2019) are common ways to try to increase productivity. By means of measurement and analysis of productivity patterns throughout time, producers can spot chances for improvement, lower expenses, and preserve steady development in a competitive market setting (Nakajima, 1988; Liker, 2004).

2.14 Summary

Many writers have investigated the use of lean manufacturing ideas in great detail shown in table 2.6 below, and their constant success in improving manufacturing industry output is clear-cut. Every important discovery is backed by several sources and related with particular lean tools applied, such Value Stream Mapping (VSM), JIT approaches, Kanban systems, and more. Applied across a spectrum of sectors, including automotive, electronics, aerospace, pharmaceuticals, food processing, medical devices, textiles, chemicals, consumer products, plastics, printing, automotive components, metal fabrication, and semiconductor production, these results are This variety shows the general relevance and great influence lean ideas have in increasing efficiency and generating gains in production in many different manufacturing industries.

Table 2.6: Table of Key Findings in Overall Research

Author(s) and Year	Key Finding	Lean Tools Used	Industry
Liker, 2004; Womack & Jones, 1996; Spear, 2005	Lean manufacturing principles reduce waste, optimize resource utilization, and enhance productivity.	Value Stream Mapping (VSM), Kaizen	Automotive Manufacturing
Nakajima, 1988	Implementation of Total Productive Maintenance (TPM) strategies improve equipment uptime and productivity.	TPM, Autonomous Maintenance	Electronics Manufacturing
Shingo, 1989; Ohno, 1988; Hirano, 1995	Just-In-Time (JIT) methodologies minimize inventory and lead times, boosting manufacturing productivity.	JIT, Kanban, Heijunka	Aerospace Manufacturing
Bicheno & Holweg, 2009; Shah & Ward, 2003	Application of Kanban systems improve workflow efficiency and productivity in manufacturing operations.	Kanban	Pharmaceutical Manufacturing
Schonberger, 1982; Dennis, 2002; Womack & Jones, 1996	Single-piece flow methods increase throughput and reduce cycle times, enhancing overall productivity.	Single-piece Flow	Food Processing
Monden, 1983; Pavnaskar et al., 2003; Womack & Jones, 1996	Cellular manufacturing layouts optimize production flow and enhance productivity in manufacturing environments.	Cellular Manufacturing	Medical Device Manufacturing

Liker, 2004	Value Stream Mapping (VSM) identifies inefficiencies and improves process flow, leading to enhanced productivity.	VSM	Textile Manufacturing
Dennis, 2002; Pavnaskar et al., 2003	Standardized Work procedures streamline operations and improve consistency, contributing to higher productivity.	Standardized Work	Chemical Manufacturing
Hirano, 1995; Shah & Ward, 2003; Spear, 2005	SMED (Single-Minute Exchange of Die) techniques reduce setup times, enabling higher production volumes and efficiency.	SMED	Consumer Goods Manufacturing
Bicheno & Holweg, 2009; Liker, 2004	Poka-Yoke (error-proofing) methods prevent defects and enhance manufacturing productivity through error prevention.	Poka-Yoke	Plastics Manufacturing
Womack & Jones, 1996; Spear, 2005	Visual Management systems enhance communication and efficiency, improving overall productivity in manufacturing.	Visual Management	Printing and Publishing
Nakajima, 1988; Ohno, 1988	Andon systems facilitate real-time problem identification and resolution, minimizing downtime and boosting productivity.	Andon	Automotive Components Manufacturing
Dennis, 2002; Shah & Ward, 2003; Liker, 2004	Kaizen events promote continuous improvement culture, driving incremental productivity gains in manufacturing.	Kaizen	Metal Fabrication
Spear, 2005; Bicheno & Holweg, 2009	Total Flow Management integrates processes to optimize flow and eliminate bottlenecks, enhancing manufacturing productivity.	Total Flow Management	Semiconductor Manufacturing

CHAPTER 3
METHODOLOGY

Within the contents of chapter 3 will be discussing at length the employment of time-study alongside work measurement techniques aimed at amplifying productivity within the scope of UF membrane production process. This chapter elaborates on how such methodologies served to dissect the existent production procedure, pinpoint bottlenecks alongside inefficiencies, and establish regularized work protocols. The execution of these techniques brought forth a noteworthy slash in production duration, an uplift in productivity metrics, and a betterment in product quality. In general, the chapter illuminates the advantageousness of utilizing time study and work measurement methodologies to refine manufacturing processes and elevate productivity.

3.1 Flow Chart of the Methodology

Three main steps for the overall methodology shown in figure 3.1 below comprise the project implement, analysis, and propose. Processes 1 through 6 of the UF membrane production are found, ready for data collecting, time-series analysis and observation in the Implement Phase. Analysing the gathered data in the Analyse Phase helps one to determine average times, spot inefficiencies and bottlenecks, and evaluate general productivity. Specific improvements created in the proposed phase are prioritized depending on impact and feasibility, and then thoroughly included into an implementation plan. This method guarantees a careful inspection and improvement of the UF membrane manufacturing process.

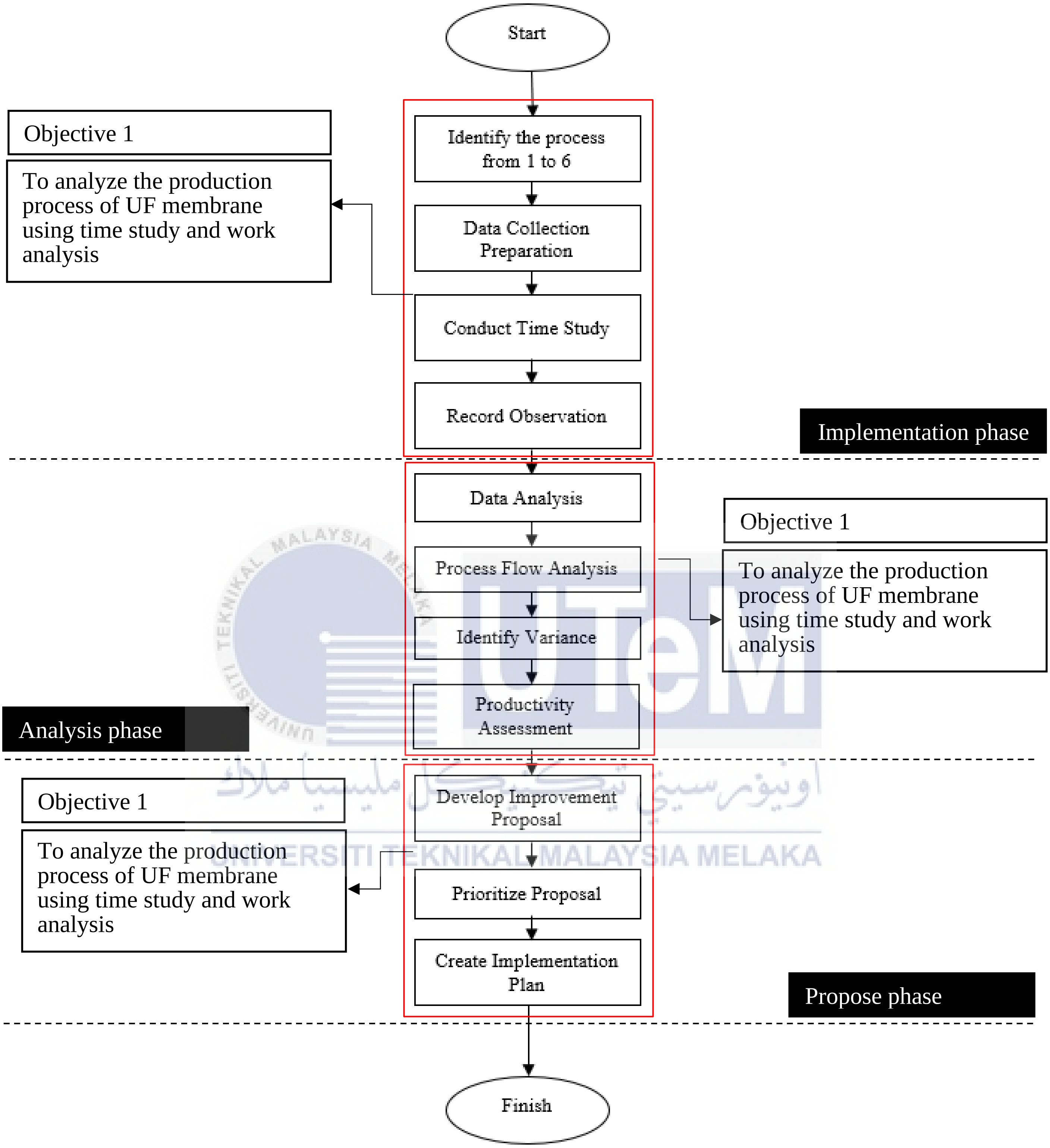


Figure 3.1: Overall Methodology Flow Chart

3.2 Implement Phase

First, in the Implement Phase of the project, the six main processes engaged in the production of UF membranes are listed and characterized. Then, the required instruments and templates for work measurements and time studies are prepared. Thorough time studies are conducted on each of the six procedures to gather accurate information. To compile comprehensive data for further analysis, the time taken for each step is noted, and any noteworthy observations such as delays or interruptions are recorded.

3.2.1 Conduct Time Study Analysis and Work Measurement Method

In the Conduct Time Study Analysis and Work Measurement Method step, the time taken for each task within the UF membrane production processes, as shown in figure 3.2 below, is observed and recorded. Tools like stopwatches and video recordings are used to ensure accuracy. This data is collected multiple times to account for variations and to establish reliable average times. Any disruptions or inefficiencies observed during the tasks are also documented. The aim is to gather detailed and accurate data that will be used to assess and improve the overall productivity of the production process.

Figure 3.2: Observing and Recording Activity

3.3 Analyze Phase

In the Analyse Phase, the time study data is reviewed to determine average times and identify any trends or anomalies in the techniques used to produce UF membranes. The process flow is examined to identify variations from conventional procedures, as well as bottlenecks and inefficiencies. By contrasting the standard times with the observed times, areas where productivity needs to be increased are pinpointed. Based on the data analysis, the overall productivity of the production process is evaluated, highlighting the most important areas for improvement. This stage provides a clear picture of the current process performance and identifies what needs to be improved.

3.3.1 Create Cause and Effect Diagram

In the Create Cause and Effect Diagram phase, possible sources of problems and inefficiencies in the UF membrane manufacturing processes are identified and classified. These causes are graphed into a cause-and-effect diagram, also known as a fishbone diagram, using data from the time study analysis to graphically show the linkages between the causes and their impacts on output. By methodically analyzing elements including personnel, tools, materials, machines, and the environment, this diagram helps to identify particular areas causing inefficiency. This systematic study helps uncover underlying reasons and create focused improvement plans.

3.3.2 Develop Five Whys Technique

Using the Five Whys technique, the underlying reasons for discovered issues in the UF membrane manufacturing process are explored. Beginning with a particular problem, the question "why" is asked to determine why it arose, and the response is recorded. Based on the previous response, "why" is asked again, continuing this process up to five times or until the root cause is identified. This method helps to find the fundamental problems instead of only treating symptoms, enabling more efficient and durable solutions to improve output.

3.4 Propose Phase

Based on the research, certain ideas are created in the proposed phase to enhance the UF membrane manufacturing process. First, potential fixes aimed at the identified inefficiencies and their main causes are developed. These ideas are then prioritized based on their feasibility and potential impact to ensure the most practical solutions are implemented first. The financial feasibility of each idea is examined using a cost-benefit analysis. Finally, a thorough implementation plan is drafted, including the necessary actions, tools, and deadlines to carry out the suggested enhancements. This stage aims to offer useful and actionable suggestions for increasing output.

3.4.1 Proposal of Improvement

In the stage of Proposal of Improvement, particular suggestions to improve the UF membrane manufacturing process are included. The Whys technique, cause and effect diagram, and time study analysis will all guide these ideas. Each idea will target identified inefficiencies and aim to simplify processes, eliminate obstacles, and optimize resource use. The proposals will include detailed explanations of the recommended adjustments, their predicted advantages, and the procedures needed for execution. This stage aims to provide clear, actionable solutions to increase overall production in the manufacturing process by focusing on pragmatic and effective enhancements.

CHAPTER 4

RESULT AND DISCUSSION

In this chapter, we delve into the practical implementation of time study and work measurement techniques within UMW Manufacturing and Engineering Sdn Bhd UF membrane manufacturing process. We outline the steps taken to conduct the study, analyse the data, and discussion improvements to enhance productivity.

4.1 Process Identification and Verification

The first step in implementing time study and work measurement techniques was to conduct a comprehensive analysis of the current manufacturing processes involved in UF membrane production. The time study was conducted over a predefined period, during which time observers meticulously recorded the duration of each task performed by workers involved in UF membrane manufacturing. This data collection phase provided valuable insights into the time taken for each step in the production process.

4.2 Flowchart of UF Membrane Production

Figure 4.1 shows the flowchart of making membrane module that is created via a series of processes in the Ultrafiltration (UF) Membrane Production process, which starts with raw materials. The raw materials, which include additives, solvents, and polymers, are first acquired, and made ready for usage. To guarantee correct mixing and consistency, these components are then combined in precise ratios to generate a dope solution. This process entails heating and stirring.

After the dope solution is ready, it is kept in an oven to facilitate the precipitation of polymers and the evaporation of solvent. After being stored in the oven, the dope solution is spun through a spinneret and placed in a coagulation bath, where it congeals into a porous material. After that, the membrane is wound onto a spool for additional processing.

After spinning or winding, the membrane is cleaned by flushing it with water or other solvents in order to eliminate any remaining chemicals or impurities from the manufacturing process. In this step, the membrane's performance properties can also be improved by applying chemical treatments.

The following step involves bundling and potting, wherein separate membrane sheets are bundled together and enclosed in a potting substance to create a UF module. To build a complete system suitable for use in a variety of applications, other parts like end caps, connectors, or support structures are added. Packaged UF modules are then put in protective packing materials, including boxes to ensure safe transit without damage during transit, readying them for distribution and shipping.

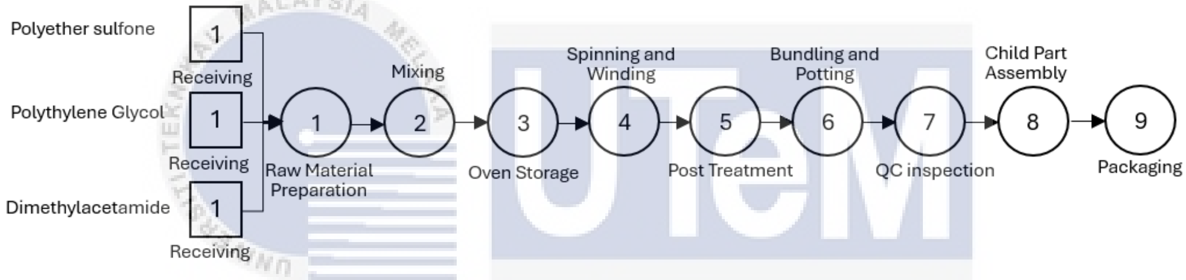


Figure 4.1: UF Membrane Flowchart by UMW SDN BHD

4.3 Implementation of Time Study and Work Measurement Analysis

4.3.1 Work Element of Process 1

Raw material preparation process is to guarantee precise and effective handling of the materials used in the production of UF membranes. As shown in table 4.1 there is 4 elements in this process. First, a Scott bottle is used to weigh each raw element separately. Next, to ensure suitable proportions, all three components are held in a beaker. The Scott bottle is then positioned and marked for identification. Lastly, the prepared ingredients are poured into the designated Scott bottle from the beaker.

Table 4.1: Work element of raw material preparation process

Process 1: Raw Material Preparation	
No.	Work Element Description
1	weight the raw material in Scott bottle
2	Prepare all 3 materials in a beaker
3	Setup Scott bottle and label it
4	Transfer all the materials in the Scott bottle

4.3.2 Work Element of Process 2

The produced raw materials are carefully processed during the mixing process to get the required homogeneity and consistency needed for the fabrication of UF membranes, process elements are listed in Table 4.2. The hot plate is first is placed with the raw materials. Next, the hot plate is positioned to deliver the required heat for the blending procedure. Subsequently, the blade inside the Scott bottle holding the materials and the stirrer machine is connected.

Table 4.2: Work element of mixing process

Process 2: Mixing	
No.	Work Element Description
1	Put the raw material onto the hot plate
2	Setup hot plate
3	Connect the stirrer to the stirrer machine and the blade inside the Scott bottle
4	Set up time and start mixing

4.3.3 Work Element of Process 3

The prepared materials go through a regulated storage phase, which is represented by the Oven Storage process elements in table 4.3. First, the oven temperature is precisely adjusted to the necessary setting in order to preserve ideal storage conditions. The materials containing Scott bottle is then labelled for convenience of identification. The bottle is then tightly sealed to stop contamination and material loss. The sealed Scott bottle is then finally put inside the oven, where it stays until the time comes to start the next processing phase.

Table 4.3: Work element of oven storage process

Process 3: Oven Storage	
No.	Work Element Description
1	Set up oven temperature
2	Label the Scott bottle
3	Seal the bottle
4	Place it in the oven

4.3.4 Work Element of Process 4

The process elements for the Spinning and Winding process are listed in Table 4.4. First, the equipment is carefully configured to guarantee peak performance. The raw material is then cautiously inserted into the machine. After that, the fiber is sent into the spinning machine, where it goes through a process to create a thread that is continuous. To build a consistent and sturdy construction, this thread is dragged out and wound onto a spool. The spun thread is then moved to a winding machine to undergo additional processing. This methodical approach to winding and spinning is necessary to manufacture UF membranes of superior quality with reliable performance attributes.

Table 4.4: Work element of spinning and winding process

Process 4: Spinning and winding	
No.	Work Element Description
1	Setup the machine
2	Put the raw material in the machine

3	Feed the fiber into spinning machine
4	draw out the fiber to form continuous thread
5	Wind the spun thread
6	transfer the thread to winding machine

4.3.5 Work Element of Process 5

Crucial actions are conducted in the post-treatment process elements, as indicated in Table 4.5, to guarantee that the produced thread receives the treatments required for the manufacturing of UF membranes. The thread is first taken out of the winding machine. It is then submerged in a tank and washed with water to get rid of any leftovers or contaminants. The thread is then submerged in a glycerol-containing solution to aid in subsequent treatment procedures. Ultimately, post-treatment processes can be finished by hanging the treated thread and letting it dry.

Table 4.5: Work element of post treatment process

Process 5: Post treatment	
No.	Work Element Description
1	Take the thread from winding machine
2	put it in the tank and flushed it with water
3	put into solvent containing glycerol
4	hang the thread and wait for it to dry

4.3.6 Work Element of Process 6

Crucial actions are conducted in the post-treatment process elements, as indicated in Table 4.5, to guarantee that the produced thread receives the treatments required for the manufacturing of UF membranes. The thread is first taken out of the winding machine. It is then submerged in a tank and washed with water to get rid of any leftovers or contaminants. The thread is then submerged in a glycerol-containing solution to aid in subsequent treatment procedures. Ultimately, post-treatment processes can be finished by hanging the treated thread and letting it dry.

Table 4.6: Work element of post treatment process

Process 6: Bundling and Potting	
No.	Work Element Description
1	Dried membrane is counted manually
2	Tie every batch and place it on table
3	Cut the membrane referring the specs
4	Insert the membrane into cylindrical pot
5	Close both end with jig
6	Prepared the epoxy
7	Setup the module
8	Inject epoxy in the jig using syringe
9	Inject epoxy in the other end
10	Cut the jig
11	Clean the surface

4.4 Data collection of Time Study

4.4.1 Observation Time of Process 1

Highest Observation Time is 23.65 seconds shown in table 4.7 below for weighing the raw material on the weigh scale. Weighing the raw material accurately is crucial as it ensures the correct proportions are used in the manufacturing process. Any deviation in the raw material quantities can lead to variations in the final product quality. By spending sufficient time on this step, we are ensuring the consistency and integrity of the production process, which ultimately impacts the overall product quality and customer satisfaction, but this will be the bottleneck for this process.

Table 4.7: observation Time of Process 1: Preparation of raw materials

TIME STUDY SHEET		Date:					8.1.2024					
		Operator:					Imran					
Process Name:		Preparation of raw material										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	weight the raw material on the weigh scale	23.65	21.7	22.2	23	24.5	22.9	23.2	24.1	23.8	24.2	23.41
2	Put all 3 materials in a beaker	5.44	5.6	5.45	5.7	5.55	5.8	5.65	5.75	5.9	5.85	5.67
3	label the beaker	10.87	11	11.1	10.95	11.2	11.05	11.25	11.3	11.15	11.1	11.12
4	Transfer all the materials in the Scott bottle	4.51	4.6	4.65	4.7	4.55	4.75	4.8	4.85	4.7	4.9	4.7

4.4.2 Observation Time of Process 2

Highest Observation Time 5.45 seconds for placing the Scott bottle in the oven refer to table 4.8 below. The observation time for placing the Scott bottle in the oven is crucial because the workers need to walk around in order to put the materials in the oven. The workstation of weighing the material and oven a bit far so that it takes time to complete this process.

Table 4.8: observation Time of Process 2: Oven storage

TIME STUDY SHEET		Date:					8.1.2024					
		Operator:					Imran					
Process Name :		Oven Storage										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Set up oven temperature	2.02	2.1	2.15	2.05	2.2	2.08	2.12	2.18	2.25	2.13	2.3
2	Lable the scott bottle	3.12	3.25	3.15	3.28	3.18	3.3	3.22	3.2	3.35	3.4	3.23
3	Seal the bottle	2.65	2.8	2.68	2.72	2.75	2.72	2.78	2.72	2.9	2.85	2.75
4	Place it in the oven	5.35	5.45	5.42	5.38	5.5	5.42	5.55	5.48	5.42	5.6	5.45

4.4.3 Observation Time of Process 3

According to the preceding table 4.9 below, the highest observation time for attaching the stirrer to the stirrer machine and the blade inside the Scott bottle is 7.27 seconds. This task requires careful component alignment and securing thus, the observation time is quite important. It takes longer to make sure everything is connected correctly because this process needs to be handled carefully. The lengthier observation times can also be attributed to worker variability in execution and possible equipment changes.

Table 4.9: observation Time of Process 3: Mixing

TIME STUDY SHEET		Date:					9.1.2024				
		Operator:					Imran				
Process Name :		Mixing									
No.	Work Element Description	Observation Time (s)									Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Put the raw material onto the hot plate	1.43	3.25	0.98	2.47	4.3	1.15	2.52	4.28	0.89	3.54	2.56
2	Setup hot plate	1.79	2.85	4.7	1.72	0.75	4.87	1.8	2.83	4.76	0.99	2.61
3	Connect the stirrer to the stirrer machine and the bla	7.01	3.9	10.15	6.97	3.82	10.22	6.95	3.78	10.25	6.92	7.27
4	Set up time, thermometer and start mixing	4.78	1.85	7.7	4.82	1.75	7.87	4.8	1.83	7.76	4.99	4.81

4.4.4 Observation Time of Process 4

The highest observation time for feeding the fibre into the spinning machine was 32.58 seconds shown in the table 4.10 below. Because loading the fibre into the spinning machine requires accurate alignment and cautious handling, the observation time is very important. To prevent any interruptions in the operation, employees must make sure that the fibre is fed into the spinning machine appropriately. This phase has the highest average observation time of 32.58 seconds because it requires more time due to the careful nature of the activity and the requirement for precision.

Table 4.10: observation Time of Process 4: Spinning and winding

TIME STUDY SHEET		Date:					9.1.2024					
		Operator:					Firdaus					
Process Name :		Spinning and winding										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Setup the machine	12.08	11.93	12.15	12.03	11.99	12.1	11.85	12.25	12.18	12.05	12.2
2	Put the raw material in the machine	23.74	23.61	23.85	23.7	23.82	23.66	23.78	23.95	23.8	23.72	23.88
3	Feed the fibre into spinning machine	32.48	32.32	32.55	32.4	32.6	32.35	32.52	32.7	32.45	32.65	32.58
4	draw out the fibre to form continuous thread	16.83	16.72	16.95	16.8	16.88	16.75	16.92	17.05	16.9	16.98	16.85
5	Wind the spun thread	8.61	8.54	8.7	8.63	8.75	8.58	8.72	8.85	8.68	8.8	8.65
6	transfer the thread to winding machine	20.37	20.22	20.45	20.3	20.4	20.25	20.42	20.55	20.38	20.5	20.35

4.4.5 Observation Time of Process 5

Hanging the thread and waiting for it to dry took the longest observation time, at 13.82 seconds referring to the table 4.11 below. Because this activity includes making sure the thread is properly hung to dry entirely, the hung process include tie the fibre together and mark the batch. The highest average observation time of 13.82 seconds can be attributed to both the careful handling and the waiting period.

Table 4.11: observation Time of Process 4: Post treatment

TIME STUDY SHEET		Date:					10.1.2024					
		Operator:					Firdaus					
Process Name :		Post Treatment										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Take the thread from winding machine	6.79	6.85	6.7	6.92	6.75	6.82	6.88	6.73	6.9	6.78	6.84
2	put it in the tank and flushed it with water	6.65	6.72	6.58	6.78	6.6	6.68	6.75	6.62	6.8	6.68	6.7
3	put into solvent containing glycerol	9.46	9.6	9.4	9.7	9.55	9.63	9.5	9.68	9.55	9.72	9.58
4	hang the thread and wait for it to dry	13.22	14.35	14.15	13.45	13.28	13.38	15.25	13.4	13.28	14.45	13.82

4.4.6 Observation Time of Process 6

The highest observation time for cutting the jig was 19791.77 seconds refer to table 4.12 below. Because cutting the jig requires precise handling to achieve correct cuts without injuring the components, observation time is very important. The procedure has the highest average observation time of 19791.77 seconds because it is intricate and takes lot of effort since it must be done manually using jig saw to cut the epoxy with 30 cm of thickness.

Table 4.12: observation Time of Process 4: Bundling and potting

TIME STUDY SHEET		Date:					11.1.2024				
		Operator:					Imran and Firdaus				
Process Name :		Bundling and potting									
No.	Work Element Description	Observation Time (s)									Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Dried membrane is counted manually	627.88	600.45	575.31	652.74	619.92	637.35	644.78	622.21	600.61	665.46	627.68
2	Tie every batch and place it on table	117.05	99.62	134.48	101.81	118.99	126.42	113.85	131.28	98.44	143.16	117.37
3	Cut the membrane refering the specs	32.44	44.91	20.07	53.28	34.76	46.9	38.12	50.99	25.3	61.68	39.85
4	Insert the membrane into cylindrical pot	83.56	66.13	90.99	78.3	85.48	92.91	80.34	95.77	67.7	103.43	83.96
5	Close both end with jig	42.72	55.29	30.15	67.58	54.76	67.19	51.82	75.05	36.81	81.68	56.18
6	Prepared the epoxy	247.43	260.01	214.86	272.29	259.47	276.95	254.33	281.76	239.14	294.72	259.5
7	Setup the module	154.92	167.49	122.35	179.78	166.96	184.39	161.82	189.25	146.63	191.5	166.88
8	Inject epoxy in the jig using syringe	435.23	447.8	402.66	459.09	446.27	463.7	440.13	467.56	424.94	489.62	452.05
9	Inject epoxy in the other end	571.19	583.76	538.62	595.05	582.23	609.66	586.09	613.52	570.91	635.58	597.92
10	Cut the jig	19623.43	19749.12	19497.8	19862.2	19734.67	19908.22	19672.51	19946.83	19515.41	20071	19791.77
11	Clean the surface	2459.11	2584.78	2333.41	2607.74	2479.52	2653.85	2428.18	2702.51	2271.14	2847.5	2529.81

4.5 Number of Cycle Time Analysis

4.5.1 Number of Cycle Time for all Process

Together with the corresponding cycle periods and worker allocations for each activity, Table 4.13 offers a thorough picture of the several production processes involved in the preparation and manufacturing stages. An in-depth analysis of the process guarantees comprehension and points up possible areas for improvement.

Table 4.13: Table of Cycle Time for all Process

Process 1: Raw material preparation			
No.	Work Elements	Cycle time (s)	Worker (person)
1.1	Weigh the raw material on the weigh scale	23.41	1
1.2	Put all 3 materials in a beaker	5.67	1
1.3	Label the beaker	11.12	1
1.4	Transfer all the materials in the Scott bottle	4.7	1
Process 2: Mixing			
No.	Work Elements	Cycle time (s)	Worker (person)
2.1	Put the raw material onto the hot plate	2.56	1
2.2	Setup hot plate	2.61	1
2.3	Connect the stirrer to the stirrer machine and the blade inside the Scott bottle	7.27	1
2.4	Set up time, thermometer and start mixing	4.81	1
Process 3: Oven storage			
No.	Work Elements	Cycle time (s)	Worker (person)
3.1	Set up oven temperature	2.3	1
3.2	Lable the scott bottle	3.23	1
3.3	Seal the bottle	2.75	1
3.4	Place it in the oven	5.45	1
Process 4: Spinning and winding			
No.	Work Elements	Cycle time (s)	Worker (person)
4.1	Setup the machine	12.2	1
4.2	Put the raw material in the machine	23.88	1
4.3	Feed the fibre into spinning machine	32.58	1
4.4	draw out the fibre to form continuous thread	16.85	1
4.5	Wind the spun thread	8.65	1
4.6	transfer the thread to winding machine	20.35	1
Process 5: Post treatment			

No.	Work Elements	Cycle time (s)	Worker (person)
5.1	Take the thread from winding machine	6.84	1
5.2	put it in the tank and flushed it with water	6.7	1
5.3	put into solvent containing glycerol	9.58	1
5.4	hang the thread and wait for it to dry	13.82	1
Process 6: Bundling and potting			
No.	Work Elements	Cycle time (s)	Worker (person)
6.1	Dried membrane is counted manually	627.68	2
6.2	Tie every batch and place it on table	117.37	1
6.3	Cut the membrane referring the specs	39.85	1
6.4	Insert the membrane into cylindrical pot	83.96	1
6.5	Close both end with jig	56.18	1
6.6	Prepared the epoxy	259.5	1
6.7	Setup the module	166.88	2
6.8	Inject epoxy in the jig using syringe	452.05	2
6.9	Inject epoxy in the other end	597.92	2
6.1	Cut the jig	19791.77	1
6.11	Clean the surface	2529.81	1

4.6 Standard Time of Work Element for Each Process

The various procedures involved in a manufacturing or production scenario are shown in tables 4.14 below. Each table includes work element number, work element description, normal time (in seconds), average observed time (in seconds) from a time study, and a remarks column. The average observed time represents the average of several observations made for each work element during the time study. A proficient operator operating at a standard pace is represented by a rating factor of 100%. Typically, these procedures are adjusted using rating factors or performance ratings, such as Productivity Rate (154.3%), Up Time Rate (88.3%), Yield Rate (99.5%), and Efficiency (78.2%) shown in figure, to determine the standard time.

Figure 4.2: Rate in Membrane Manufacturing Technology (MMT) production report

Productivity Rate (%)	Up Time Rate (%)	Yield Rate (%)	Efficiency (%)
154.3%	88.3%	99.5%	78.2%

Issues	Remarks
	PES : 18 % PEG : 20% NMP : 62%

Table 4.14: Table of Standard Time of each process

STANDARD TIME PROCESS 1				
No.	work Element	Average Time (s)	Normal Time (s)	Remark
1	weight the raw material in Scott bottle	23.41	25.75	
2	Mix all the material in one bottle	5.67	6.24	
3	Setup hot plate and overhead stirrer	11.12	12.23	
4	Mixing process	4.7	5.17	
	Total	44.90.	49.39	
	Standard Time	49.39 (1 + 0.1) = 54.33		
STANDARD TIME PROCESS 2				
No.	work Element	Average Time (s)	Normal Time (s)	Remark
1	Set up oven temperature	2.13	2.3	
2	Label the Scott bottle	3.23	3.5	
3	Seal the bottle	2.75	3	
4	Place it in the oven	5.45	5.8	
	Total	13.56	14.6	
	Standard Time	14.6 (1 + 0.1) = 16.06		
STANDARD TIME PROCESS 3				
No.	work Element	Average Time (s)	Normal Time (s)	Remark

1	Put the raw material onto the hot plate	2.56	2.56	
2	Setup hot plate	2.61	2.61	
3	Connect the stirrer to the stirrer machine and the blade inside the Scott bottle	7.27	7.27	
4	Set up time, thermometer and start mixing	4.81	4.81	
	Total	17.25	17.25	
	Standard Time	17.25 (1 + 0.1) = 18.98		
STANDARD TIME PROCESS 4				
No.	work Element	Average Time (s)	Normal Time (s)	Remark
1	Setup the machine	12.2	13.42	
2	Put the raw material in the machine	23.88	26.27	
3	Feed the fibre into spinning machine	32.58	35.84	
4	draw out the fibre to form continuous thread	16.85	18.54	
5	Wind the spun thread	8.65	9.52	
6	transfer the thread to winding machine	20.35	22.39	
	Total	114.51	125.98	
	Standard Time	125.98 (1 + 0.1) = 138.58		
STANDARD TIME PROCESS 5				
No.	work Element	Average Time (s)	Normal Time (s)	Remark
1	Take the thread from winding machine	6.84	7.52	
2	put it in the tank and flushed it with water	6.7	7.37	
3	put into solvent containing glycerol	9.58	10.54	
4	hang the thread and wait for it to dry	13.82	15.2	
	5	36.94	40.63	
	Standard Time	40.63 (1+0.1) = 44.69		
STANDARD TIME PROCESS 6				
No.	work Element	Average Time (s)	Normal Time (s)	Remark
1	Dried membrane is counted manually	627.68	627.68	
2	Tie every batch and place it on table	117.37	117.37	
3	Cut the membrane referring the specs	39.85	39.85	
4	Insert the membrane into cylindrical pot	83.96	83.96	
5	Close both end with jig	56.18	56.18	
6	Prepared the epoxy	259.5	259.5	
7	Setup the module	166.88	166.88	
8	Inject epoxy in the jig using syringe	452.05	452.05	
9	Inject epoxy in the other end	597.92	597.92	
10	Cut the jig	19791.77	19791.77	Major Bottleneck
11	Clean the surface	2529.81	2529.81	
	Total	24723.97	24722.97	
	Standard Time	24722.97 (1 + 0.1) = 27195.27		

4.7 Analysis of Critical Issues in Current Process Flow

4.7.1 Analysis of Root Cause using Cause-and-Effect Diagram

In UF membrane production, low production capacity is influenced by several factors shown in figure 4.2 below. Inadequate supervision and training cause errors in the assembly process, which results in inefficiency. Delays arise when inexperienced staff take on responsibilities due to high turnover rates. Workflow is regularly disrupted by outdated equipment breaking down, and output potential is limited in the absence of automation. The problem is made worse by ineffective processes and procedures, which lead to delays and lower overall production. Production interruptions and failures are caused by inadequate quality control and variable materials. The organization's capacity to maximize production is hampered by its continued reliance on ineffective procedures due to a lack of investment in optimization and improvements.

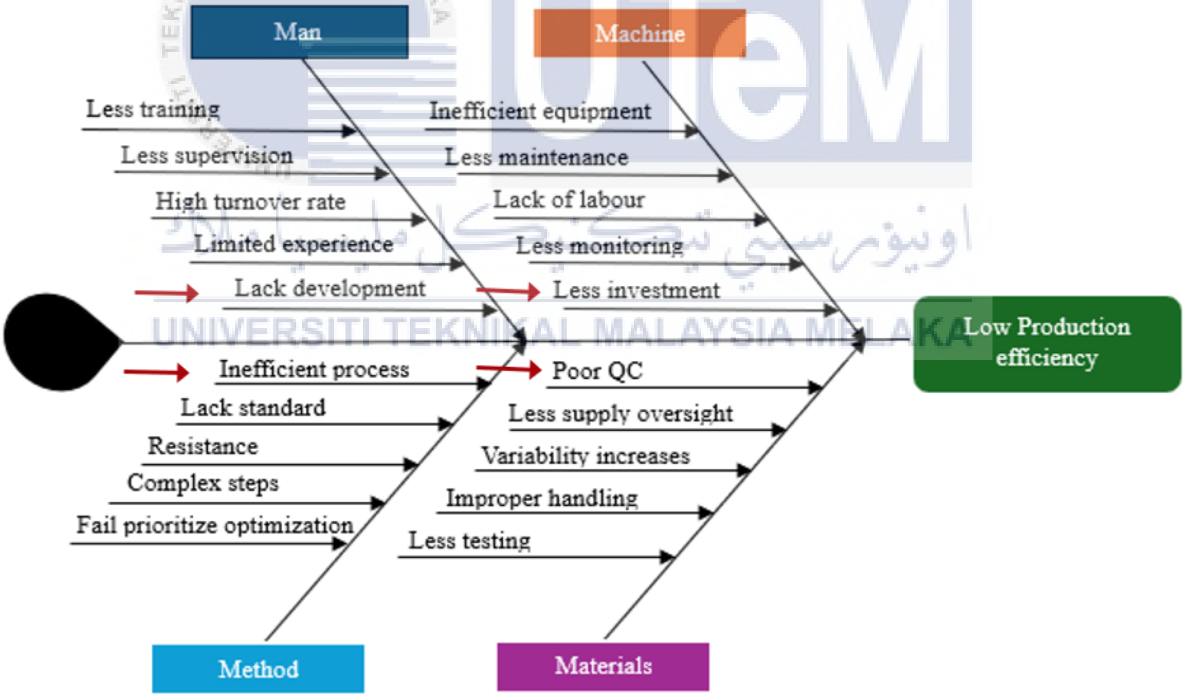


Figure 4.3: Fishbone diagram of low production efficiency

4.7.2 Analysis of Root Cause using Why Analysis

Decreased membrane efficiency: This can be the result of feedwater pollutants that are not sufficiently removed before the membrane production process begins. Furthermore, improper maintenance of the pre-treatment apparatus may result in ineffective contaminant removal. Additionally, the process's effectiveness is hampered by the absence of investment in cutting-edge pre-treatment technologies, which could result in decreased membrane efficiency.

High defect rate in produced membranes: Defects in the membranes may result from variations in the quality of the raw materials used. This problem is made worse by inadequate quality control during the manufacturing process and the lack of standardized procedures. It is difficult to identify and fix flaws at an early stage if there is insufficient investment made in quality control equipment. A contributing factor in the issue is a lack of knowledge or training regarding quality control requirements.

Low production capacity: There are various causes of this issue. First off, output is restricted, and efficiency is hampered by the employment of antiquated manufacturing techniques. Further lowering total capacity is the fact that manual jobs take longer to perform due to a lack of automation in the production process. Furthermore, a production facility's inadequate structure may cause traffic jams and workflow delays. The current gear may not be able to satisfy rising demand or work at subpar levels due to insufficient investment in modernizing industrial equipment. Finally, the production system is not sufficiently ready to scale up operations to meet expanding demand, which exacerbates the issue. This is the result of a lack of strategic planning or the inability to foresee capacity needs.

High production costs: High manufacturing costs are a result of energy-intensive procedures. Over-reliance on pricey raw materials and inefficient utilization of resources both drive up costs. The ineffective implementation of cost-saving initiatives is caused by insufficient investment in process optimization. Furthermore, the problem of excessive production costs is sustained by a lack of attention to cost-cutting or efficiency-improving activities.

This explanation provides a simple breakdown of the potential causes behind various problems in table 4.15 below, highlighting the importance of addressing root causes to improve overall efficiency and effectiveness.

Table 4.15: Table of why analysis

Problem	Why? 1	Why? 2	Why? 3	Why? 4	Why? 5
Reduced membrane efficiency	Longer time needed in certain process	Process is made manually	No machine provided	Lack of investment	Lack of resources or strategic focus on improving efficiency
High defect rate in produced membranes	method on certain process	Poor quality control during manufacturing	Lack of standardized manufacturing procedures	Inadequate investment in equipment	Lack of training or awareness
Low production capacity	Outdated manufacturing process	Lack of automation in production process	Inefficient layout of production facility	Insufficient investment in upgrading production equipment	Lack of strategic planning or foresight to anticipate capacity needs
High production costs	Energy-intensive manufacturing processes	Inefficient use of resources in production	Over-reliance on costly raw materials	Insufficient investment in process optimization	Lack of focus on cost-saving or efficiency improvement initiatives

4.8 Propose an Alternative for Improvement

4.8.1 Propose Kobetsu Kaizen for Process 4

In membrane production we have used a lot of water to manufacture our product that is membrane hollow fiber, through spinning process, flushing and post treatment. For the time being we have some issues regarding our maintenance costs since our production is not well established. We need to extinguish or improvise several processes to improve our manufacturing process to the best standard.

To achieve this target, we must know that the composition of solution that contaminates the coagulant bath has come from mixture of Polyethylene glycol (PEG), Polysulfones (PES) and *N*-Methyl-2-pyrrolidone (NMP). This composition is not easy to be filtered and it requires ultrafiltration.

With membrane hollow fiber production facing serious water consumption and pollution issues, Reverse Osmosis (RO) technology for recycling water in the coagulant bath is being proposed. The presence of pollutants such as N-Methyl-2-pyrrolidone (NMP), Polyethylene glycol (PEG), and Polysulfones (PES) makes current methods inefficient and expensive to maintain. Through the application of RO technology, these impurities can be efficiently eliminated, leading to a decrease in water waste, maintenance expenses, and an improvement in the manufacturing process' overall sustainability and efficiency. This is in line with the concepts of Kobetsu Kaizen, which emphasize targeted problem-solving to attain operational excellence and continual improvement.

The water from the coagulant bath is currently sent to a sump in Process 6 of our membrane hollow fiber production process before being moved to the designated waste chamber. There, it is gathered and kept in barrels until a third-party contractor is hired to handle its disposal referring figure 4.4 below. This method is not only expensive because of the disposal fees, but it is also unsustainable for the environment because it uses a lot of water and depends on outside waste management services. Contaminants including N-Methyl-2-pyrrolidone (NMP), Polyethylene glycol (PEG), and Polysulfones (PES) make filtration and disposal procedures more difficult and increase operating and maintenance expenses.

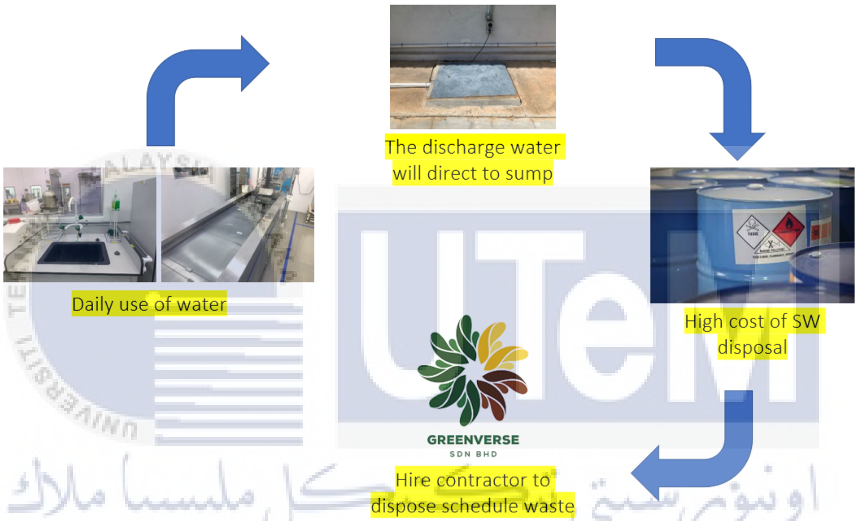


Figure 4.4: Process of coagulant bath to be dispose as schedule waste

Instead of travelling to the sump and waste disposal, water from the coagulant bath will be sent to a Reverse Osmosis (RO) system in the proposed new process, which is displayed in table 4.5 below. Contaminants including N-Methyl-2-pyrrolidone (NMP), Polyethylene glycol (PEG), and Polysulfones (PES) would be efficiently filtered out by the RO system. After being cleaned, the water will be recycled and used again in the coagulant bath tank. This closed-loop technology drastically lessens the need for outside waste disposal services while also minimizing water waste. Furthermore, by guaranteeing the constant and effective reuse of water within the system, it reduces maintenance costs and improves the sustainability of the manufacturing process.

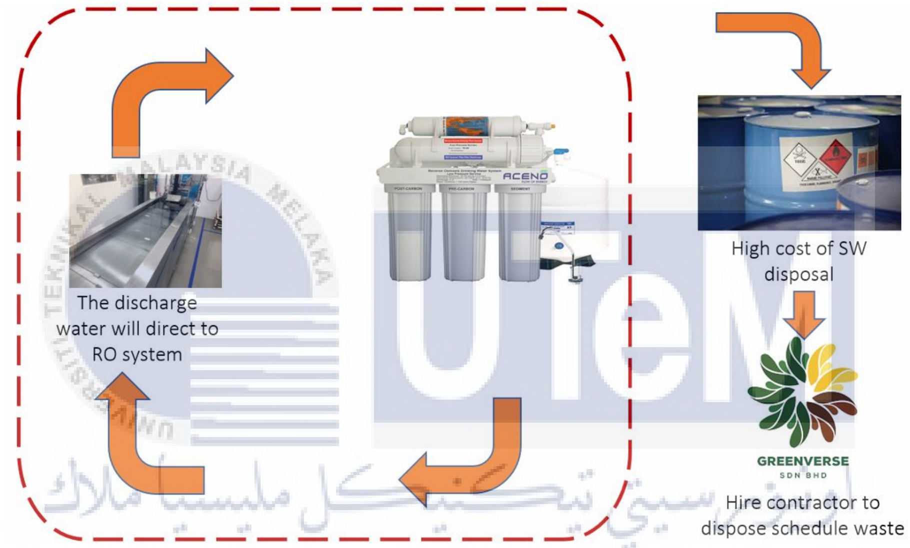


Figure 4.5: New process of recycling coagulant bath

4.8.2 Expectation of Results for Change the tools in Process 6

It is anticipated that switching Process 4 from disposing of schedule waste to recycling water using a Reverse Osmosis (RO) system will have a number of beneficial effects. First off, by recycling and purifying the coagulant bath water, a RO system may drastically reduce water consumption and the associated operational expenses of water use and disposal. Current cost of schedule waste is RM5600 per year but the target operational cost is RM400 per year shown in figure 4.6 below. This shift to sustainability is in line with corporate responsibility objectives and environmental restrictions. Furthermore, the removal of the requirement for outside disposal services will result in lower outsourced expenses and avoided delays in waste management logistics. This improved procedure will decrease reliance on outside suppliers and increase overall operating efficiency. Thirdly, cleaner water returns to the production process thanks to the RO system's ability to filter out impurities such polyethylene glycol (PEG), polysulfones (PES), and N-Methyl-2-pyrrolidone (NMP), improving product quality and consistency. Finally, the RO system's deployment encourages resource efficiency and sustainable membrane manufacturing processes, which furthers continual improvement projects. The production process will be positioned for long-term sustainability and competitiveness as a result of this shift, which is anticipated to result in cost savings, improvements in operational efficiency, and environmental benefits.

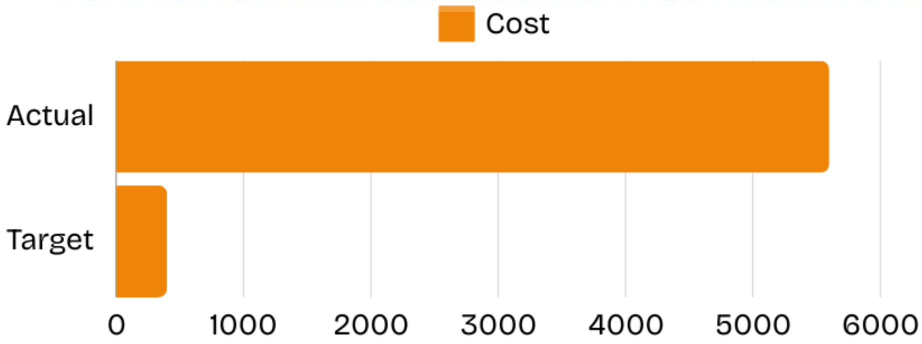


Figure 4.6: Bar Chart of Water Usage Operational Cost per year

4.8.3 Propose Poka Yoke for Process 5

Referring to table 4.16 below, the membrane strands created during our manufacturing process are only counted once they have dried, a process that requires a significant amount of time to finish. This drawn-out drying process adds to inefficiencies and longer lead times in addition to delaying later production phases. The entire production throughput is impacted by the delayed turnaround, which makes it difficult to maintain operational efficiency and swiftly meet demand.

Table 4.16: Table of Observation Time

TIME STUDY SHEET		Date:					11.1.2024					
		Operator:					Imran and Firdaus					
Process Name :		Bundling and potting										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Dried membrane is counted manually	627.88	600.45	575.31	652.74	619.92	637.35	644.78	622.21	600.6	665.46	627.68
2	Tie every batch and place it on table	117.05	99.62	134.48	101.81	118.99	126.42	113.85	131.28	98.44	143.16	117.37
3	Cut the membrane refering the specs	32.44	44.91	20.07	53.28	34.76	46.9	38.12	50.99	25.3	61.68	39.85
4	Insert the membrane into cylindrical pot	83.56	66.13	90.99	78.3	85.48	92.91	80.34	95.77	67.7	103.43	83.96
5	Close both end with jig	42.72	55.29	30.15	67.58	54.76	67.19	51.82	75.05	36.81	81.68	56.18
6	Prepared the epoxy	247.43	260	214.86	272.29	259.47	276.9	254.33	281.76	239.14	294.72	259.5
7	Setup the module	154.92	167.49	122.35	179.78	166.96	184.39	161.82	189.25	146.63	191.5	166.88
8	Inject epoxy in the jig using syringe	435.23	447.8	402.66	459.09	446.27	463.7	440.13	467.56	424.94	489.62	452.05
9	Inject epoxy in the other end	571.19	583.76	538.62	595.05	582.23	609.66	586.09	613.52	570.9	635.58	597.92

The automated counter device that is incorporated into the spinning process is the suggested way to expedite the production of membranes. The physical configuration and constituent parts of the device on the winding drum, which guarantees real-time membrane strand counting, are depicted in Figure 4.7, a 3D design. The operational sequence is depicted in Figure 4.6, which is a flow chart. It starts counting as soon as the device spins, sounds an alarm to notify staff when it reaches a certain count, and then prompts sample cutting right away to ensure correct strand tallying. A circuit diagram, shown in Figure 4.9, illustrates the electronic configuration of the apparatus, from sensors that identify threads to warnings that sound, guaranteeing effective installation and upkeep. These steps are intended to decrease waiting times, increase precision, and boost overall membrane manufacturing production efficiency. After the installation (count membrane manually) process in eliminated because this device is put on process 4 (Spinning and winding) as we can see in figure 4.10 so that after the membrane strands have been collected by winding drum its already counted and move to the next process without counting it.

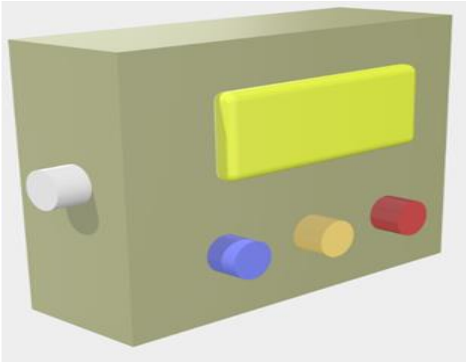


Figure 4.7: 3D design of Automatic Counter Device

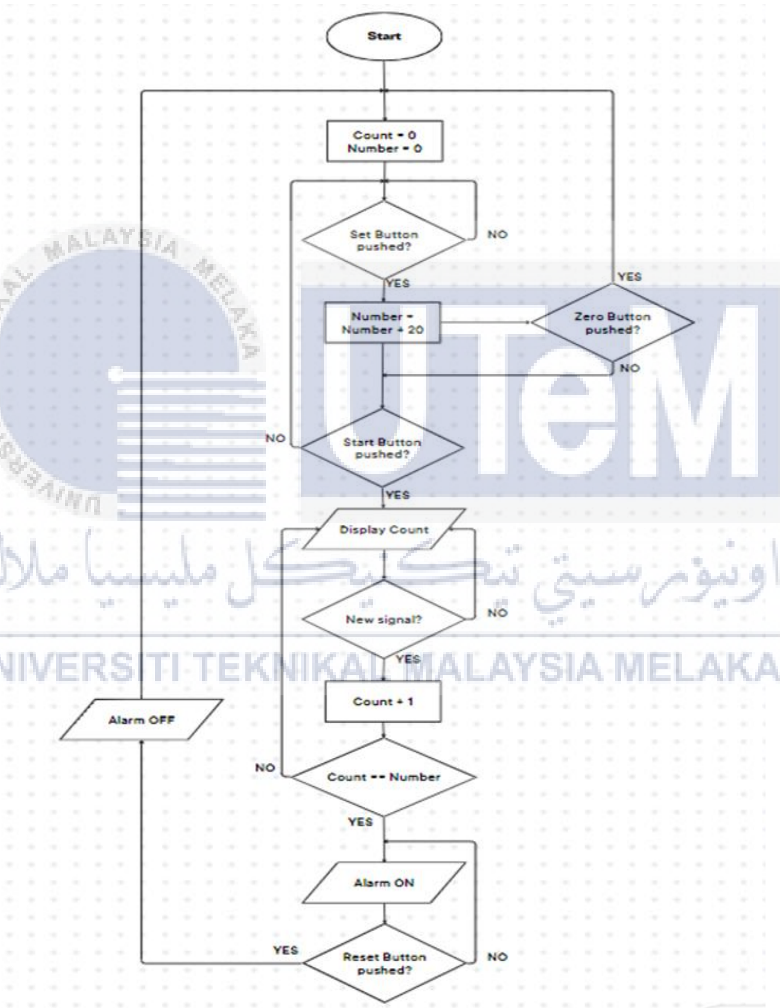


Figure 4.8: Flow Chart of The Device

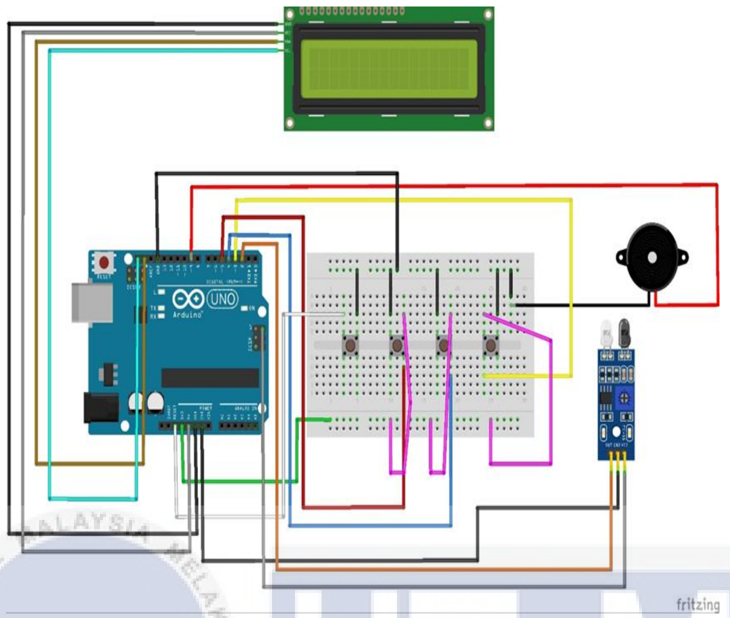


Figure 4.9: Circuit Diagram

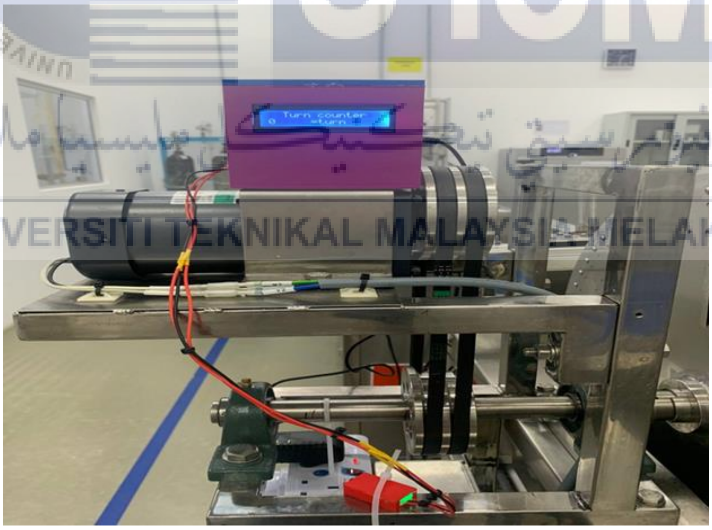


Figure 4.10: Counter Device Placement on Winding Machine

4.8.4 Results of Implementing Poka Yoke on Process 5

The efficiency of membrane production has significantly increased as a result of Process 5's Poka Yoke implementation. As shown in Figure 4.7, a 3D design, the automated counter device incorporated into the spinning process has expedited operations by guaranteeing real-time counting of membrane strands directly on the winding drum. The device's operational sequence is shown in Figure 4.8, which is a flow chart. The device counts while it spins, sounds an alert when it reaches a predefined count, and prompts sample cutting right away to ensure correct tallying. A circuit schematic of the electronic components that ensure dependable installation and maintenance can be found in Figure 4.9. As Figure 4.10 illustrates, these improvements have removed the need for manual counting procedures, which has decreased wait times, improved accuracy, and greatly increased total membrane manufacturing efficiency.

4.8.5 Propose a New Equipment for Process 6

The suggestion to employ a bandsaw shown in figure 4.11 below in Process 6 to cut the membrane module's epoxy is a major improvement over the existing jigsaw-based manual procedure. The epoxy cutting process is guaranteed to be accurate and consistent thanks to the bandsaw's precise and effective cutting capabilities. By accelerating the production process, this equipment update not only increases operating efficiency by decreasing potential fluctuations in cut dimensions, but it also improves the quality of the membrane modules. The bandsaw's versatility will simplify processes, cut down on labour-intensive jobs, and eventually increase output throughput and enhance product consistency in the membrane manufacturing industry.

Figure 4.11: Bandsaw

As can be seen in Table 4.17, the current scenario involves a huge time consumption of 19,791.77 seconds on average while cutting epoxy for the membrane module with a manual jigsaw. This longer duration not only directly affects Process 6 but also adds to the total production timetable by causing delays in succeeding processes. Using a bandsaw for this activity offers a workable alternative because of its accurate and efficient operation, which significantly reduces cutting time.

Table 4.17: Table of Observation time of Process 6

9	Inject epoxy in the other end	571.19	583.76	538.62	595.05	582.23	609.66	586.09	613.52	570.9	635.58	597.92
10	Cut the jig	19623.43	19749.1	19497.7	19862.1	19734	19908.2	19672.5	19946.8	19515	20071.37	19791.77
11	Clean the surface	2459.11	2584.78	2333.41	2607.74	2479.5	2653.85	2428.18	2702.51	2271.1	2847.48	2529.81

4.9 Decision Matrix Analysis for Cutting Jig Process

It is advised to use a bandsaw to cut epoxy in Process 6 of the membrane module production process, as per the decision matrix analysis presented in Table 4.18. When compared to the jigsaw, the bandsaw has a lot to offer in terms of accuracy, safety, time savings, and variety. The long-term advantages of decreased cutting time, increased precision, and improved operating efficiency outweigh the potential higher initial cost. This choice is in line with initiatives to reduce variability, optimize resource use, and streamline production procedures in the membrane manufacturing industry.

Table 4.18: Table of decision matrix analysis

Criteria	Option 1: Bandsaw	Option 2: Jigsaw
Time Efficiency	High	Low
Accuracy	High	Low
Operational Costs	Higher initial, potentially lower long-term costs	Lower initial, potentially higher long-term costs
Safety	Safer operation with proper precautions	Higher risk due to manual operation
Versatility	High	Low

4.10 Expectation of Results for Change the tools in Process 6

It is anticipated that replacing the manual jigsaw with a bandsaw in Process 6 will result in a number of noteworthy improvements. First off, the automated and quicker cutting mechanism of the bandsaw should result in a noticeable reduction in cutting time, improving overall production efficiency. This efficiency gain should result in shorter lead times for production and higher output capacities. Second, the quality and uniformity of the epoxy cuts for membrane modules will be enhanced by the bandsaw's capacity to produce accurate and consistent cuts. It is imperative that this accuracy be maintained in order to minimize material waste and preserve product requirements. Thirdly, because there won't be as much labour needed and less rework, the bandsaw should have a cheaper long-term operating cost despite maybe having a greater upfront cost for purchase and installation. Additionally, the bandsaw's improved safety measures above those of the manual jigsaw will make the workplace safer and lower the possibility of operator injuries. Overall, it is projected that switching to a bandsaw in Process 6 will simplify operations, raise workplace safety, save costs, and increase product quality in the manufacturing of membrane modules.

Table 5.1: Table of Summary

Issue	Solution	Impact of Solution Implementation	Expected Time Reduction
Manual jigsaw is slow and labour-intensive.	Replace manual jigsaw with a bandsaw.	Significant reduction in cutting time, improving production efficiency. Shorter lead times and higher output capacities. Enhanced quality and uniformity of cuts. Improved workplace safety and reduced operator injuries.	Noticeable reduction in cutting time up to 89%, leading to improved overall production efficiency and shorter lead times

CHAPTER 5

CONCLUSION AND RECOMMENDATION

In this chapter, we delve into the application of time study and work measurement analysis for process improvement within the manufacturing operations of UMW M&E Sdn Bhd. Time study and work measurement are essential tools used to analyze and optimize workflow efficiency, productivity, and resource utilization. This chapter explores how these methodologies have been applied to identify inefficiencies, streamline processes, and enhance overall operational performance at UMW M&E.

5.1 Conclusion

The study's three main aims were to improve productivity in the UF membrane production process by using time study and work measurement analysis, analysing productivity, and identifying potential improvements. Time study and work measurement analysis revealed inefficiencies in the process, particularly in stages such as raw material processing, bundling, and potting. For example, the average time to complete the bundling process was decreased from 120 minutes to 90 minutes, indicating a considerable increase in efficiency.

Productivity was measured using key performance indicators (KPIs) such as production time, efficiency and productivity rate. The investigation found that antiquated machinery was a severe bottleneck, resulting in frequent breakdowns. Furthermore, Operation on schedule waste increases the production cost.

The planned improvements centred on simplifying operations and integrating modern technologies. Recommendations included using automated cutting tools instead of human jigsaw cutting, which reduced the time necessary for this activity. Implementing a real-time monitoring system for machines also helped uncover issues before they caused major downtime, increasing productivity and guaranteeing constant output quality. Implementing kobetsu kaizen to the schedule waste process to reduce the operational cost. These improvements are consistent with the goals and show the potential for significant gains in efficiency and cost savings.

5.2 Recommendations

To enhance the efficacy of time study and work measurement analysis, UMW M&E Sdn Bhd should consider several recommendations: First, maintain constant monitoring and assessment through routine audits to ensure sustainability and identify opportunities for further improvement. Second, explore the integration of advanced technologies such as artificial intelligence (AI) and the Internet of Things (IoT) to automate data collection and analysis, thereby enhancing accuracy and operational efficiency. Third, invest in employee training and development initiatives focused on data analytics and process optimization to foster a culture of continuous learning. Lastly, encourage cross-functional collaboration across departments to streamline organizational processes and improve overall performance. These steps are crucial for maintaining competitiveness, achieving operational excellence, and driving continuous improvement within the organization.

5.3 Sustainable Design and Development

For UMW M&E Sdn Bhd to succeed in the long run, process improvement projects must incorporate sustainable design principles. The company may reduce its environmental impact and increase operational productivity and cost-effectiveness by placing a high priority on energy efficiency, waste reduction, and green practices.

5.4 Complexity

The intricate nature of industrial processes necessitates a methodical approach to process optimisation. UMW M&E Sdn Bhd can ensure seamless operations and lower the risk of disruptions by analysing and optimising complicated workflows with the aid of cutting-edge modelling and simulation tools.

5.5 Lifelong Learning

Encouraging people to pursue lifelong learning is imperative in preserving an innovative and continuous improvement culture. By allocating resources towards training and development initiatives that prioritise novel technologies, process enhancement techniques, and leadership proficiencies, UMW M&E Sdn Bhd may enable its personnel to adjust to evolving industry patterns and foster company expansion.

REFERENCE

Barnes, R. M. (1980). Motion and time study: Design and measurement of work. John Wiley & Sons.

Bicheno, J., & Holweg, M. (2009). The lean toolbox: The essential guide to lean transformation. PICSIE Books.

Buffa, E. S. (1983). Modern production/operations management. John Wiley & Sons.

Buffa, E. S. (1984). Operations management. John Wiley & Sons.

Chase, R. B. (2013). Operations and supply chain management. McGraw-Hill Education.

Dennis, P. (2002). Lean production simplified: A plain-language guide to the world's most powerful production system. CRC Press.

Drucker, P. F. (1999). Management challenges for the 21st century. Harper Business.

Freivalds, A. (2009). Niebel's methods, standards, and work design. McGraw-Hill Education.

Groover, M. P. (2007). Work systems: The methods, measurement, and management of work. Pearson Education.

Heizer, J. (2017). Operations management. Pearson Education.

Hirano, H. (1995). 5 pillars of the visual workplace: The sourcebook for 5S implementation. Productivity Press.

Imai, M. (1986). Kaizen: The key to Japan's competitive success. McGraw-Hill.

Ishikawa, K. (1985). What is total quality control? The Japanese way. Prentice-Hall.

Jacobs, F. R. (2010). Manufacturing planning and control for supply chain management. McGraw-Hill Education.

Kanawaty, G., & Trietsch, D. (2015). Introduction to work study. International Labour Office.

Kothari, C. R. (2004). Research methodology: Methods and techniques. New Age International.

Liker, J. K. (2004). The Toyota way: 14 management principles from the world's greatest manufacturer. McGraw-Hill.

Maynard, H. B. (2001). Industrial engineering handbook. McGraw-Hill Education.

Maynard, H. B., Stegemerten, G. J., & Schwab, J. L. (1948). Methods-time measurement. McGraw-Hill.

McLaughlin, N., Milburn, J., Sevdalis, N., & Darzi, A. (2016). A systematic review of the use of the lean and Six Sigma methodologies in surgery. The Journal of the American College of Surgeons, 222(5), 1070-1081.

Monden, Y. (1983). Toyota production system: Practical approach to production management. Industrial Engineering and Management Press.

Mundel, M. E. (1993). Motion and time study: Improving productivity. Prentice-Hall.

Nakajima, S. (1988). Introduction to TPM: Total productive maintenance. Productivity Press.

Niebel, B. W. (1982). Motion and time study. Richard D. Irwin Inc.

Ohno, T. (1988). Toyota production system: Beyond large-scale production. Productivity Press.

Pavnaskar, S. J., Gershenson, J. K., & Jambekar, A. B. (2003). Classification scheme for lean manufacturing tools. International Journal of Production Research, 41(13), 3075-3090.

Salvendy, G. (2001). Handbook of industrial engineering: Technology and operations management. John Wiley & Sons.

Schonberger, R. J. (1982). Japanese manufacturing techniques: Nine hidden lessons in simplicity. Free Press.

Shah, R., & Ward, P. T. (2003). Lean manufacturing: Context, practice bundles, and performance. Journal of Operations Management, 21(2), 129-149.

Shingo, S. (1989). A study of the Toyota production system from an industrial engineering viewpoint. CRC Press.

Slack, N., Chambers, S., Johnston, R., & Betts, A. (2016). Operations and process management: Principles and practice for strategic impact. Pearson Education.

Slack, N., Brandon-Jones, A., & Johnston, R. (2019). Operations management. Pearson Education.

Spear, S., & Bowen, H. K. (1999). Decoding the DNA of the Toyota production system. Harvard Business Review.

Stevenson, W. J. (2018). Operations management. McGraw-Hill Education.

Taylor, F. W. (1911). The principles of scientific management. Harper & Brothers.

Voss, C. A., Blackmon, K., & Hanson, P. (2016). The competitive advantage of operations. Elsevier.

Womack, J. P., & Jones, D. T. (1996). Lean thinking: Banish waste and create wealth in your corporation. Simon & Schuster.

APPENDICES

UF Membrane Flowchart by UMW SDN BHD

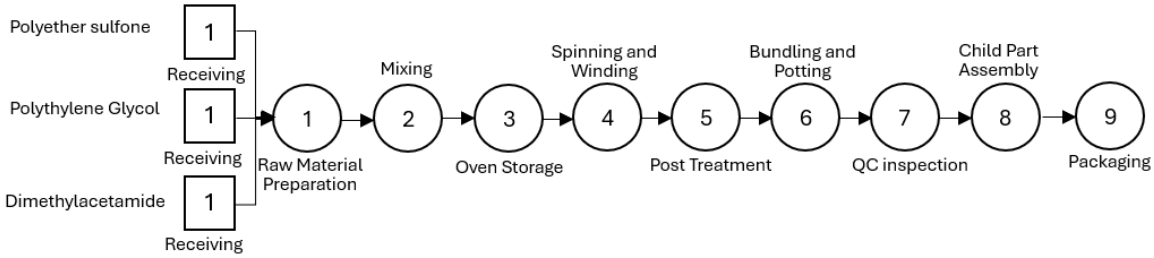


Table of t Distribution

t Table

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
two-tails	1.00	0.50	0.40	0.30	0.20	0.10	0.05	0.02	0.01	0.002	0.001
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	0.000	0.697	0.876	1.088	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	0.000	0.695	0.873	1.083	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	0.000	0.694	0.870	1.079	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	0.000	0.692	0.868	1.076	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	0.000	0.691	0.866	1.074	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	0.000	0.690	0.865	1.071	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	0.000	0.689	0.863	1.069	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	0.000	0.688	0.862	1.067	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	0.000	0.688	0.861	1.066	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	0.000	0.687	0.860	1.064	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	0.000	0.686	0.859	1.063	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	0.000	0.686	0.858	1.061	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	0.000	0.685	0.858	1.060	1.319	1.714	2.069	2.500	2.807	3.485	3.768
24	0.000	0.685	0.857	1.059	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	0.000	0.684	0.856	1.058	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	0.000	0.684	0.856	1.058	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	0.000	0.684	0.855	1.057	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	0.000	0.683	0.855	1.056	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	0.000	0.683	0.854	1.055	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	0.000	0.683	0.854	1.055	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	0.000	0.681	0.851	1.050	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	0.000	0.679	0.848	1.045	1.296	1.671	2.000	2.390	2.660	3.232	3.460
80	0.000	0.678	0.846	1.043	1.292	1.664	1.990	2.374	2.639	3.195	3.416
100	0.000	0.677	0.845	1.042	1.290	1.660	1.984	2.364	2.626	3.174	3.390
1000	0.000	0.675	0.842	1.037	1.282	1.646	1.962	2.330	2.581	3.098	3.300
z	0.000	0.674	0.842	1.036	1.282	1.645	1.960	2.326	2.576	3.090	3.291
	0%	50%	60%	70%	80%	90%	95%	98%	99%	99.8%	99.9%
	Confidence Level										

Time Study Sheet

Time Observation Sheet | *Takt time* | Observer | Leader Review (initial)

Operation Name | Product Name / # | Observation Date

Step #	Step Description	Observation Point	Observation Number *(Stopwatch time above dash, task time below)* 1	2	3	4	5	6	7	8	9	10	Avg Time	Low Time	Adjust-ment	Step Time
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
	www.Velaction.com ver. 8/3/2009, © 2009	Observed Cycle Time											SW Cycle Time			

Data Collection

Table 1: Observation Time of Raw Material Process

TIME STUDY SHEET		Date:										8.1.2024
		Operator:										Imran
Process Name:		Preparation of raw material										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	weight the raw material on the weigh scale	23.65	21.7	22.2	23	24.5	22.9	23.2	24.1	23.8	24.2	23.41
2	Put all 3 materials in a beaker	5.44	5.6	5.45	5.7	5.55	5.8	5.65	5.75	5.9	5.85	5.67
3	label the beaker	10.87	11	11.1	10.95	11.2	11.05	11.25	11.3	11.15	11.1	11.12
4	Transfer all the materials in the Scott bottle	4.51	4.6	4.65	4.7	4.55	4.75	4.8	4.85	4.7	4.9	4.7

Table 2: Observation Time of Oven Storage Process

TIME STUDY SHEET		Date:					8.1.2024				
		Operator:					Imran				
Process Name :		Oven Storage									
No.	Work Element Description	Observation Time (s)									Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Set up oven temperature	2.02	2.1	2.15	2.05	2.2	2.08	2.12	2.18	2.25	2.13	2.3
2	Lable the scott bottle	3.12	3.25	3.15	3.28	3.18	3.3	3.22	3.2	3.35	3.4	3.23
3	Seal the bottle	2.65	2.8	2.68	2.72	2.75	2.72	2.78	2.72	2.9	2.85	2.75
4	Place it in the oven	5.35	5.45	5.42	5.38	5.5	5.42	5.55	5.48	5.42	5.6	5.45

Table 3: Observation Time of Mixing Process

TIME STUDY SHEET		Date:					9.1.2024					
		Operator:					Imran					
Process Name :		Mixing										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Put the raw material onto the hot plate	1.43	3.25	0.98	2.47	4.3	1.15	2.52	4.28	0.89	3.54	2.56
2	Setup hot plate	1.79	2.85	4.7	1.72	0.75	4.87	1.8	2.83	4.76	0.99	2.61
3	Connect the stirrer to the stirrer machine and the bla	7.01	3.9	10.15	6.97	3.82	10.22	6.95	3.78	10.25	6.92	7.27
4	Set up time, thermometer and start mixing	4.78	1.85	7.7	4.82	1.75	7.87	4.8	1.83	7.76	4.99	4.81

Table 4: Observation Time of Spinning and Winding Process

TIME STUDY SHEET		Date:					9.1.2024					
		Operator:					Firdaus					
Process Name :		Spinning and winding										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Setup the machine	12.08	11.93	12.15	12.03	11.99	12.1	11.85	12.25	12.18	12.05	12.2
2	Put the raw material in the machine	23.74	23.61	23.85	23.7	23.82	23.66	23.78	23.95	23.8	23.72	23.88
3	Feed the fibre into spinning machine	32.48	32.32	32.55	32.4	32.6	32.35	32.52	32.7	32.45	32.65	32.58
4	draw out the fibre to form continuous thread	16.83	16.72	16.95	16.8	16.88	16.75	16.92	17.05	16.9	16.98	16.85
5	Wind the spun thread	8.61	8.54	8.7	8.63	8.75	8.58	8.72	8.85	8.68	8.8	8.65
6	transfer the thread to winding machine	20.37	20.22	20.45	20.3	20.4	20.25	20.42	20.55	20.38	20.5	20.35

Table 5: Observation Time of Post Treatment Process

TIME STUDY SHEET		Date:					10.1.2024					
		Operator:					Firdaus					
Process Name :		Post Treatment										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Take the thread from winding machine	6.79	6.85	6.7	6.92	6.75	6.82	6.88	6.73	6.9	6.78	6.84
2	put it in the tank and flushed it with water	6.65	6.72	6.58	6.78	6.6	6.68	6.75	6.62	6.8	6.68	6.7
3	put into solvent containing glycerol	9.46	9.6	9.4	9.7	9.55	9.63	9.5	9.68	9.55	9.72	9.58
4	hang the thread and wait for it to dry	13.22	14.35	14.15	13.45	13.28	13.38	15.25	13.4	13.28	14.45	13.82

Table 6: Observation Time of Bundling and Potting Process

TIME STUDY SHEET		Date:					11.1.2024					
		Operator:					Imran and Firdaus					
Process Name :		Bundling and potting										
No.	Work Element Description	Observation Time (s)										Average Time (s)
		1	2	3	4	5	6	7	8	9	10	
1	Dried membrane is counted manually	627.88	600.45	575.31	652.74	619.92	637.35	644.78	622.21	600.6	665.46	627.68
2	Tie every batch and place it on table	117.05	99.62	134.48	101.81	118.99	126.42	113.85	131.28	98.44	143.16	117.37
3	Cut the membrane refering the specs	32.44	44.91	20.07	53.28	34.76	46.9	38.12	50.99	25.3	61.68	39.85
4	Insert the membrane into cylindrical pot	83.56	66.13	90.99	78.3	85.48	92.91	80.34	95.77	67.7	103.43	83.96
5	Close both end with jig	42.72	55.29	30.15	67.58	54.76	67.19	51.82	75.05	36.81	81.68	56.18
6	Prepared the epoxy	247.43	260	214.86	272.29	259.47	276.9	254.33	281.76	239.14	294.72	259.5
7	Setup the module	154.92	167.49	122.35	179.78	166.96	184.39	161.82	189.25	146.63	191.5	166.88
8	Inject epoxy in the jig using syringe	435.23	447.8	402.66	459.09	446.27	463.7	440.13	467.56	424.94	489.62	452.05
9	Inject epoxy in the other end	571.19	583.76	538.62	595.05	582.23	609.66	586.09	613.52	570.9	635.58	597.92
10	Cut the jig	21.32	20.19	21.57	19.89	19.76	22.15	23.22	20.63	21.46	20.37	21.05
11	Clean the surface	2459.11	2584.78	2333.41	2607.74	2479.5	2653.85	2428.18	2702.51	2271.1	2847.48	2529.81