CHAPTER 2
LITERATURE REVIEW

2.1. Literature Review

Research related to fulfilling customer orders has been carried out by many previous researchers using objects from various manufacturing companies, which operate in the fields of furniture, ceramics, musical instruments, metalwork, etc. These studies were carried out using various methods that provide solutions to the problems faced. As many as 10 previous studies have been collected which have a scope of discussion and conditions related to the current research can be seen in Table 2.1.

Research conducted by Sugarinda and Nurdiansyah (2020) at a piano manufacturing company that implements a make-to-order (MTO) system, it was explained that the smoothness of the production process will influence the fulfillment of demand within the specified time. They focus on analyzing the balance between actual production capacity and target production capacity in order to meet demand and achieve customer satisfaction. Direct observation and interviews are tools used to collect the primary data, and the Rough-Cut Capacity Planning method was used. With the same focus, namely increasing order fulfillment, research by Maria et al. (2019) which was carried out in the ceramic industry with a make-to-order and make-to-stock system using the DMAIC cycle method. This research reorganized the production planning process and increased the process efficiency, which is also supported with the Six-Sigma approach. In that research, observations and measurements were also conducted to obtain the expected data such as routing sheets, process time, and setup time.

The same DMAIC method is also applied in the research from Nandakumar et al. (2020) where they identified the root cause of the existence of bottlenecks while at the same time eliminating the waste to solve the problem. They used measurement and observation as their data collections method by recording the demand, inventory, and cycle time data at the food processing industry in India. The difference with Maria et al. (2019) is Nandakumar et al. (2020) research was also combined and supported with other methods in each of phases, such as SIPOC (Supplier, Input, Process, Output, Customer) for the define phase, VSM (Value Stream Map) for the measure phase, ANOVA for the analyze phase, and fishbone diagram and 5S for the improve phase. With these methods they have acquired details regarding the execution of the chosen action plan.

The bottleneck problem was also experienced by the research of Alzubi et al. (2019) where they first identified the value added and the non-value added, and found out that the total of the former is higher than the latter. Similar to Nandakumar et al. (2020), Alzubi et al. (2019) was concerned to use VSM but in more detail by visualizing the current state map and the future state map because they seek to find areas for improvement by providing methodical approach to improving and decreasing non-value-adding time. The data collection methods used by Alzubi et al. (2019) was quantitative method that involved understanding the state of work at the time and interviewing employees to collect data, as also applied by Sugarinda and Nurdiansyah (2020) and Ahmad et al. (2020). Later, an ABC study was carried out to identify which of the best-performing processes needed to be looked at for potential enhancements. Furthermore, it was also supported by the OEE which stands for Overall Equipment Effectiveness using the collected data, then the result was visualized by radar charts to graphically display the outcome as a comparison of multiple quantitative factors.

In the research held by Thakar (2023), the lean philosophy such as VSM 5S, and Kanban were used to analyze and keep track of all the relevant information regarding the production processes in order to increase productivity and maximize the amount of space used in the sofa manufacturing warehouse. This research also identified the bottleneck that occurs based on departments' output per hour. Like Alzubi et al. (2019), Thakar (2023) also presented the VSM current state map and future state map. Besides, it also provides some charts showing the distribution of the output and productivity in months.

Increasing the productivity can be achieved by eliminating the waste existed in the manufacturing company, as carried out in research by Suhardi et al. (2019) in Indonesian furniture industry. They also used measurement to obtain the cycle time and process flow data as the primary data. Stopwatch was used as this was the effective tool that can be used for measuring repetitive activities and rapid operator movement, and the data collection was done with 30 samples, which was also used by Ahmad et al. (2020). This research also utilized the VSM as their tool to determine and separate the value-added and the non-value-added activities, same as in the research of Alzubi et al. (2019). But the difference is Suhardi et al. (2019)

has further improvements that were done with two Kaizen' simple tools, i.e., 5W1H (What, Why, Where, Who, When, and How) techniques and ECRS (Eliminate, Combine, Rearrange, and Simplify) principles.

Almost similar tools with 5W1H but with the addition of 'how long', Dias et al. (2019) adopt the 5W2H technique when collecting the data using questionnaire. From all the literature reviewed, this is the only research that uses questionnaire as their data collection method. This paper also addressed the issues of waste in the order fulfillment process using different lean methodologies, such as SIPOC that also used by Nandakumar et al. (2020), VSM, production time data, and perceived waste mapping (PWM). This research results in a percentage of the value-added and the total number of work hours.

In other side, Chara et al. (2020) and Silva et al. (2022) were implemented the lean manufacturing models, TPM (Total Productive Maintenance), SMED (Single Minute Exchange of Die), as well as 5S, for example, in order to reduce the causes of lateness in order fulfillment while at the same time increasing the order fulfillment rate in the manufacturing companies. Both included the quantitative calculation approach to obtain the model indicators. However, in Chara et al. (2020), it provides several scenarios to determine which categories are suitable for each indicator, which later proposed a model that increases the rate of order fulfillment. Meanwhile, in Silva et al. (2022), it presents the proposed layout with cell manufacturing that can reduce waste and increase the on-time order fulfillment.

Table 2.1. Summary of Literature Review

No.	References	Research Objective	Method	Tools	Solution / Improvement	Results
1	Maia et al. (2019)	Analyze and enhance the company order fulfilment process following the launch of a new product line	DMAIC cycle, Six-Sigma approach	Measurement, data collection, observation	Adapt each phase of the method until the process with analysis	There is a 31% reduction in the percentage of delayed orders
2	Suhardi et al. (2019)	Minimizing waste in furniture manufacturing process to increase productivity and speed up the production time	Value Stream Mapping (VSM), 5W1H, and ECRS	Observations, measurement	Provide the special tools for bigger potential in search item, and eye-catching tools to improve the working methods	There is a 4.79% reduction of lead time without the addition of workers, and the workers' workload can be balanced
3	Dias et al. (2019)	Identify and determine the activities that improve a metalwork company's fulfilment process	SIPOC, production time data analysis, VSM, Perceived waste mapping (PWM)	Data collection (questionnaire), 5W2H, observations	Use all the analysis method to obtain the information	Able to identify and estimate the right ratio of effective efficiency point

Table 2.1. Continuation

No.	References	Research Objective	Method	Tools	Solution / Improvement	Results
4	Alzubi et al. (2019)	Identify and utilize the bottleneck due to the suffers from an uneven production line and lengthy lead times in the furniture manufacturing industry	VSM, Theory of Constraints (TOC), OEE, and ABC Analysis	Interviews, observations, data collection, radar charts	Use the methods and running the simulation models	Capable of minimizing the impact of one primary bottleneck and neutralizing the influence of the other.
5	M., Sugarinda, and R., Nurdiansyah (2020)	To analyze and evaluate the production resources and facilities' capacity to satisfy customers and meet demand	Rough Cut Capacity Planning (RCCP)	Direct observations and interviews	Distribute the labor and increase the work hours	All the capacity deficiencies that exist can be overcome
6	Castro-Chara et al. (2020)	Determine and minimize the probable causes for order fulfillment obstacles in a small furniture manufacturing business	5-phase lean optimization model	Data collection, observations	Implement the proposed model	There is an improvement of order fulfillment from 12.5% to 60%
7	Ahmad et al. (2020)	To reduce cycle time to improve the company's operation value	Green lean	Interviews, observations (camera and stopwatch), data collection	Implement the green lean practices in the operation department	Able to reduce company's operation time and reduce all related wastes
8	Nandakumar et al. (2020)	Determine and remove any bottlenecks in the food processing company's production and packaging operations	DMAIC, SIPOC, VSM, ANOVA, and 5S	Observation, fishbone diagram, measurement	Modify the current 5S system to implement the selected solutions	Reduce the production fluctuations

Table 2.1. Continuation

No.	References	Research Objective	Method	Tools	Solution / Improvement	Results
9	Garrido-Silva et al. (2022)	To increase the order fulfilment rate	5S, Standardized Work (SW), SMED, TPM	Data collection, quantitative analysis, observations	Provide some scenarios with the proposed model to reduce waste and increase the on-time order fulfillment	Capable of achieving a 74.59% increase in order fulfillment rate
10	Thakar, G. (2023)	Increase productivity and maximize the amount of space used in the sofa manufacturing warehouse	Lean principle, VSM, 5S	Data collection	Implement the VSM, cellular layout, and Kanban system	There is a 95% improvement of productivity, 98% improvement of output, and 44% reduction of production cost
11	O., Silvia, and I., Ismianti (2022)	To optimizing the workstation and reducing the existing bottlenecks	Line balancing	Observation, interview, measurment	Conduct data processing such as sufficiency and uniformity of data, calculation of cycle time, normal time, and standard time	Resulting balanced track design, balance delay, and better efficiency
12	Purwanto, H., S., and Astuti., R., D.	To increase the line efficiency value in the packing process, as well as to increase the production productivity	Line balancing	Ranked Positional Weight	Calculation of weights and equal distribution of work elements	There is an increase in line efficiency value and the reduce in bottleneck

2.2. Theoretical Background

2.2.1. Time Study

Time study is a work measurement technique by collecting data based on the time needed to complete a job, generally used to measure work. This method is used to calculate the standard time value of a work (Pawiro, 2015). The main use of time study is to produce standard time for work under certain conditions, so that productivity can be calculated. Moreover, time study involves establishing a standard time by utilizing a time sample of an experienced worker's performance for a certain task.

Companies that implement time-based initiatives frequently reap numerous benefits from it. One of the most important things to consider when using a time study is opportunities to cut costs. Increasing productivity by determining and removing time that adds no value. Because there will be a shorter lead time overall, tasks that are still necessary will cost less. The task needs to be standardized in order to conduct an equitable and thorough time study. It is possible to improve process efficiency with a precise setting of standards time. In order to obtain accurate data, certain conditions must be satisfied before beginning a time study. An experienced station operator should be in charge, and they should be informed in advance of the study. It is important that the work is done at an average pace when measured (Gustafsson, 2019).

To be able to compare the best working time from existing working methods, standard time is needed as a reference for determining the best working method. standard time is obtained from measuring working time. Measuring working time can be done directly and indirectly. Direct measurement is when an observer directly measures or records the time required for an operator to carry out work. This measurement is usually done with a stopwatch or work sampling. Meanwhile, indirect measurement is when the observer does not always have to observe work directly because the previous documentation of the work exists. (Rahayu, 2014).

2.2.2. Data Uniformity Test

The data obtained from the measurements is then subjected to a uniformity test before being used to determine the standard time. Apart from data adequacy that must be met in implementing the time study, the data collected must also be uniform (Heldayani & Yuamita, 2022). To carry out data uniformity tests, the upper control limit (UCL) and lower control limit (LCL) are determined with a confidence level of 95% and an accuracy level of 5%. Data obtained from measurements are grouped into subgroups. (Putra & Jakaria, 2020).

$$\text{Number of subgroup } (k) = 1 + 3.3 \log n \tag{2.1}$$

Description:

n = Number of data

The upper control limit (UCL) and lower control limit (LCL) can be calculated using the following formula.

$$UCL = x + k.\sigma \tag{2.2}$$

$$LCL = x - k.\sigma \tag{2.3}$$

Description:

x = Average of data

k = A constant

σ = Standard deviation

Then, the standard deviation (σ) is calculated using the formula below.

$$\sigma = \sqrt{\frac{\sum (xi - \bar{x})^2}{n-1}} \tag{2.4}$$

Description:

xi = Data

$\bar{x}$ = Average of data

n = Number of data

2.2.3. Data Adequacy Test

The purpose of a data adequacy test is to determine whether the data collected has been properly representative of the population based on the outcome of a predetermined activity time (Lukodono & Ulfa, 2017). The level of confidence for this measurement is chosen first, and then the number of observations to be taken is then determined. In most work measuring tasks, a 95% confidence level and a 5% degree of accuracy are assumed. This indicates that a work element's measured time average will have a deviation greater than 5% in at least 95 out of 100 cases (Putra & Jakaria, 2020).

The number of measurements required can be calculated using the following formula.

$$N' = \left[\frac{K/S\sqrt{n \cdot \sum Xi^2 - (\sum Xi)^2}}{\sum Xi}\right]^2 \quad (2.5)$$

Description:

N' = number of samples required

n = number of data

K = confidence level

S = degree of accuracy

2.2.4. Adjustment and Allowance

a. Adjustment

The adjustment is a factor that is used to give workers the opportunity to do things other than their main task, so that complete working time can be obtained and can represent the observed work system. Westinghouse is one of the common rating systems that is used for adjustments, where there are four factors in assessing the operator's performance, which are skill, effort, conditions, and consistency (Hartanti, 2016). Thus, in this research, the Westinghouse method is used. There are also six classes of each the factors in Westinghouse method.

SKILL			EFFORT		
+0.15	A1	Superskill	+0.13	A1	Superskill
+0.13	A2		+0.13	A2	
+0.11	B1	Excellent	+0.1	B1	Excellent
+0.08	B2		+0.08	B2	
+0.06	C1	Good	+0.05	C1	Good
+0.03	C2		+0.02	C2	
0	D	Average	0	D	Average
-0.05	E1	Fair	-0.04	E1	Fair
-0.1	E2		-0.8	E2	
-0.16	F1	Poor	-0.12	F1	Poor
-0.22	F2		-0.17	F2	
CONDITION			**CONSISTENCY**		
+0.06	A	Ideal	+0.04	A	Ideal
+0.04	B	Excellent	+0.03	B	Excellent
+0.02			+0.01		
0	C	Good	0	C	Good
-0.03	D	Average	-0.02	D	Average
-0.03	E	Fair	-0.04	E	Fair
-0.07	F	Poor	-0.07	F	Poor

Figure 2.1. Westinghouse' Adjustment Factor

b. Allowance

Besides adjustment, allowance needs to be considered for the time study. Allowance is a factor that is needed by workers during measurement, because it is impossible for a person to work all day without interruption, so time for personal needs, time to eliminate fatigue, as well as unexpected obstacles in doing a job are needed. These three things are actually needed by workers, but are not observed, measured, recorded, or calculated (Hartanti, 2016).

FACTOR	JOB EXAMPLE	ALLOWANCE (%)		
		LOAD EQUIVALENT (kg)	MALE	FEMALE
A. Energy Expanded				
1. Negligible	Working at a table, sitting	No load	0.0 - 6.0	0.0 - 6.0
2. Very light	Working at a table, standing	0.00 - 2.25	6.0 - 7.5	6.0 - 7.5
3. Light	Shoveling, light	2.25 - 9.00	7.5 - 12.0	7.5 - 16.0
4. Medium	Mattock	9.00 - 18.00	12.0 - 19.0	16.0 - 30.0
5. Heavy	Swinging a heavy hammer	19.00 - 27.00	19.0 - 30.0	
6. Very heavy	Shouldering a burden	27.00 - 50.00	30.0 - 50.0	
7. Extremely heavy	Carrying heavy sacks	>50.00		
B. Work Posture				
1. Sitting	Work while sitting, light		0.0 - 1.0	
2. Standing on two legs	Erect, supported by two legs		1.0 - 2.5	
3. Standing on one leg	One foot works the controller		2.5 - 4.0	
4. Lying down	On the side, back, or front of the body		2.5 - 4.0	
5. Bending over	The body is bent forward, resting on two legs		4.0 - 10.0	
C. Work Movement				
1. Normal	Free swing of the hammer			
2. Quite limited	Limited swing of the hammer			
3. Difficult	Carrying heavy loads with one			
4. In limited limbs	Work with your hands above your head			
5. All limbs are limited	Working in narrow mining tunnels			

Figure 2.2. Allowances Factor (1)

FACTOR	JOB EXAMPLE	ALLOWANCE (%)		
		LOAD EQUIVALENT (kg)	MALE	FEMALE
D. Eye Fatigue		**Lighting**		
		Good	**Bad**	
1. Intermittent vision	Bring measuring tools	0.0 - 6.0	0.0 - 6.0	
2. Almost continuous vision	Thorough work	6.0 - 7.5	6.0 - 7.5	
3. Continuous vision with changing focus	Check for defects in the fabric	7.5 - 12.0	7.5 - 16.0	
4. Continuous vision with fixed focus	Very thorough inspection	19.0 - 30.0	16.0 - 30.0	
E. Working Place Temperature Condition	**Temperature (celcius)**	**Normal humidity**	**Excess humidity**	
1. Frozen	0 - 13	>10	>12	
2. Low	13 - 22	10 - 5	12 - 5	
3. Moderate	22 - 28	5 - 0	8 - 0	
4. Normal	28 - 38	0 - 5	0 - 8	
5. High	> 38	5 - 40	8 - 100	
6. Very high		>40	>100	
F. Atmospheric Conditions				
1. Good	Well-ventilated room, fresh air		0	
2. Fair	Ventilation is not good, there are odors		0 - 5	
3. Poor	The presence of toxic or non-toxic dust but a lot		5 - 10	
4. Bad	there are dangerous odors so respirator must be used		10 - 20	

Figure 2.3. Allowances Factor (2)

FACTOR	JOB EXAMPLE	ALLOWANCE (%)		
		LOAD EQUIVALENT (kg)	MALE	FEMALE
G. Good Environmental				
1. Clean, healthy. Bright with low noise			0	
2. Repetitive work cycle between 5-10 seconds			0 - 1	
3. Repetitive work cycle between 0-5 seconds			1 - 3	
4. Very noisy			0 - 5	
5. If influencing factors can reduce quality			0 - 5	
6. Floor vibrations can be felt			5 - 10	
7. Extraordinary circumstances (noise, cleanliness, etc.)			5 - 10	
Inevitable allowance			5	
Personal needs allowance for male			0 - 2.5	
Personal needs allowance for female			2 - 5	

Figure 2.4. Allowances Factor (3)

2.2.5. Cycle Time, Normal Time, and Standard Time

Cycle time is the period of time required to complete a task or activity in its entirety. This includes all steps or requirements from start to finish. In a manufacturing or production context, cycle time includes all the steps or activities required to produce a product or service. This is important in measuring operational efficiency, planning production, and identifying areas that can be improved to increase productivity. (Taifa & Vhora, 2019).

Normal time in a production system refers to the estimated time required to complete a task or process under normal conditions, without any specials disruptions or obstacles. This concept can help in several things such as production planning, resource allocation, and efficient scheduling of activities (Garetti & Taisch, 2012). The cycle time is multiplied by the adjustment factor (p) in normal time calculations. Since the adjustment factor calculation under normal circumstances has a value of 1, the p value is added to the total factor value obtained using the Westinghouse method for conditions based on existing factors (Sutalaksana, 2006). The normal time calculation formula is as follows.

$$\text{Normal time} = \text{Cycle time} \times p \tag{2.6}$$

Standard time in a production system refers to the time that should be required to complete a process if it is carried out with specifired performance standards efficiently and optimally. This concept is often used in operations and production management to measure actual performance, identify potential improvements, and evaluate operating efficiency (Pekkaya & Uzsoy, 2013). Normal time and the value of the allowance factor (a) are used to calculate standard time. The formula to determine standard time is as follows.

$$\text{Standard time} = \text{Normal time} \times \left(\frac{100\%}{100\% - a}\right) \tag{2.7}$$

2.2.6. Line Balancing

Line balancing is a solution used to increase line efficiency value so that productivity can be increased. Line balancing balances assignment loads from production lines to workstations, to minimize the number of workstations and minimize idle time (Angga & Junaidi, 2017). Generally, a balanced line will maximize the line efficiency (LE) value and minimize the balance delay. For this reason, there are also calculations of LE, balance delay, station efficiency, and smoothness index. In the line balancing process, a precedence diagram is needed to map the work sequence and relationships between work operations. The following is the calculation formula for line efficiency.

$$LE = \frac{\sum_{i=1}^{n} ST_i}{(n \text{ x cycle time})} \text{ x } 100\% \quad (2.8)$$

Balance delay is a measure of the idle time contained in the production path with the available time. Balance delay arises due to imperfect allocation of operational processes within workstations (Dwicahyani & Mutaqqin, 2020). The balance delay calculation is 100% minus the value of LE.

$$\text{Balance delay} = 100\% - LE \quad (2.9)$$

Smoothness index (SI) shows the relative smoothness of the line balancing results. The closer the smoothness index value is to zero, the more balanced a line can be (Sitorus et al., 2020).

$$\text{Smoothness index} = \sqrt{\sum_{n=1}^{k}((ST)_{max} - (ST)_n)^2} \quad (2.10)$$

In line balancing calculations, the method commonly used to optimize production line efficiency values is Ranked Positional Weight (RPW). This method calculates the weight of each machine and operator in the system. The weights are then sorted from largest to smallest (Purwanto & Astuti, 2019).

2.2.7. Critical Path Method (CPM)

In Critical Path Method (CPM), the term critical path is known, which aims to identify activities that have a high level of sensitivity to delays in implementation, so that the level of priority in organizing production can be determined (Subaderi & Purnamayudhia, 2021). This method can contain information regarding activities carried out before or after, and the duration of the activity.