

CHAPTER 2

LITERATURE REVIEW AND BASIC THEORY

2.1 Literature Review

A literature review is essential for gathering all relevant information related to the ongoing research. It involves analysing previous studies that address similar issues. This process helps in understanding various research approaches, insights, and solutions to challenges within a production system. The literature review contains the previous research which is related or similar with the problem related with inconsistent production capacity, overtime work, and efficiency in a production line.

This research adopts insights from several previous studies that addressed similar problem. Afifuddin (2019), Febriani et al. (2020), and Handayani & Hilmansyah (2022) utilized line balancing methods such as the Ranked Position Weight (RPW) and bicoplan approach to reduce cycle time, minimize delay, and enhance production flow. These studies demonstrated clear improvements in line efficiency and reduction in idle time, which directly relate to PT XYZ's challenge of inconsistent daily production and the reliance on Sunday overtime. Similarly, Tjioewinata & Saifuddin (2022) implemented a Region Approach for line balancing and successfully increased line efficiency from 76.03% to 95.14% while reducing balance delay, reinforcing the potential impact of optimizing workstation distribution an issue central to this research.

In terms of layout improvement and workflow optimization, Taufik & Maulana (2024) and Alzubi et al. (2019) focused on rearranging production facility layouts using simulation-based methods (ARC and VSM) to identify bottlenecks, improve material flow, and reduce lead times. These findings support the need to improve PT XYZ's layout and reduce unnecessary motion between workstations. Rauan et al. (2019) applied line balancing and the theoretical minimum method to reduce idle time in a coconut processing facility, which correlates with PT XYZ's goal to stabilize cycle times and reduce inefficiencies caused by unbalanced work distribution. Lastly, Ozgormus & Smith (2020) employed lean manufacturing principles to cut waste and increase productivity, offering further validation that efficiency-based methods are suitable for resolving time and resource losses in production systems like PT XYZ.

All the existing literature will serve as a foundation for formulating improvement strategies that can be implemented in PT XYZ. These references will directly influence the decision-

making variables selected in this study, based on methods that are proven effective and applicable. A detailed summary of these prior studies is presented in Table 2.1.



Table 2.1. Literature Review Summary

No	Researcher	Research Object	Research Purpose	Method	Result of Research
1	Ozgormus & Smith (2020)	Manufacturing Plants	Optimize manufacturing flow using lean principles	Lean Manufacturing	Increased productivity and reduced waste
2	Taufik & Maulana (2024)	Rama Teknik Company Production Layout	To optimize the production layout to improve production flow and reduce material handling costs	Activity Relationship Chart (ARC) method implemented through FlexSim simulation software	The simulation showed inefficiencies in the initial layout, leading to a new proposed layout design that improved production flow, reduced costs, and addressed production capacity issues.
3	Alzubi et al. (2019)	Facility Layout Design for Efficiency Improvement and cost reduction	Recognize and address the bottleneck caused by imbalances in the production line and extended lead times within the furniture manufacturing sector.	Application of VSM, Theory of Constraints (TOC), OEE, and ABC Analysis	Able to reduce the impact of the main bottleneck while mitigating the effects of secondary constraints.

Table 2.1. Continuation

No	Researcher	Research Object	Research Purpose	Method	Result of Research
4	Afifuddin (2019)	Line Balancing Implementation using Ranked Position Weight (RWP) Method	Focused on reduce the cycle time and reduce delay in workstations.	Application of Ranked Position Weight (RWP) Method	Achieved a cycle time of 10.88 seconds across five workstations, resulting in a 56.25% reduction in delay time compared to the initial condition.
5	Handayani & Hilmansyah (2022)	Production facility layout in UD. Barokah Lamongan	Improve the production efficiency	Applying line balancing and layout improvement to increase production efficiency using bicoplan	Based on the results obtained, snack production resulted in a moment reduction of 699,300 m/year and an improvement in material handling costs amounting to Rp. 278,635,896. Furthermore, the conducted research shows that the achieved production has exceeded the production target of UD. Barokah Lamongan.

Table 2.1. Continuation

No	Researcher	Research Object	Research Purpose	Method	Result of Research
6	Tjioewinata & Saifuddin (2022)	Workstation efficiency and balance analysis in PT. XYZ	Increase line efficiency, balance in the workstation area	Using the line balancing – region approach	Based on the results obtained using the Region Approach method at PT. XYZ, the number of workstations before implementing line balancing was 7, which was reduced to 5 after implementation. This led to an increase in production capacity from 22 units per day to 25 units per day, along with a decrease in the balance delay percentage from 23.97% to 4.86%. Meanwhile, line efficiency improved from 76.03% to 95.14%, and the smoothness index decreased from 19.54% to 3.59%.
7	Febriani et al. (2020)	Workstation and line efficiency in door production process at CV Indah Jati Permana	Workstation and line efficiency in the production process	Using line balancing and ranked position weight	The results obtained from the study are: (1) a reduction in the number of workstations after implementing the line balancing method, (2) an increase in line efficiency by 99%, and (3) a lower smoothness index, indicating better line balance with minimal deviation between workstations.

Table 2.1. Continuation

No	Researcher	Research Object	Research Purpose	Method	Result of Research
8	Rauan et al. (2019)	Production facility layout improvement in PT Tropica Cocoprime Lelema	Improve the efficiency and reduce idle time in the workstation	Using line balancing and theoretical minimum method	Based on the research conducted, PT. Tropica Cocoprime achieved better efficiency, with worker idle time for a 120- minute cycle being lower than the maximum allowable time of 288 minutes.

2.2 Theoretical Background

This research is supported by the knowledge and competencies acquired through two core industrial engineering courses, which are Work System Analysis and Design (TIND26402) and Production Planning and Control System (TIND32502). In the Work System Analysis and Design course, the researcher learned about workload analysis techniques, time study methods, and the design of efficient work systems using tools such as right-left hand charts, two-hand process charts, and standard time calculations. These topics are directly relevant to identifying workload imbalances across workstations in the production line at PT XYZ, which is a key focus of this study. Meanwhile, the Production Planning and Control course provided a solid foundation in capacity planning, production scheduling, and production control techniques, including line balancing approaches suitable for production line conditions similar to those found in PT XYZ. The next part will discuss about the theoretical background that will support the research.

2.2.1 Workstation Layout

According to Ridwan et al. (2019), layouting refers to the arrangement of all physical facilities, including machines, production facilities, and workstations, within a company's production flow. Proper layout planning is crucial for ensuring a smooth production process. Layout design involves organizing workstations and equipment used by a company to manufacture its products. This process is essential for optimizing production activities by coordinating workers, production flow, and product output.

Layout plays a vital role in improving production efficiency, enabling companies to meet their output. A well-designed layout should help companies create an efficient working environment, allowing machines to produce outputs more quickly and with better quality. Layout design supports the production process for a company. Production processes involve methods used to enhance the functionality of raw materials by utilizing available facilities.

2.2.2 Line Balancing

Line balancing functions to distribute work assignments evenly across all workstations in a production line, aiming to improve production efficiency and minimize idle time. Accurate work time measurement is crucial for implementing the line balancing method, as each task within a company is interconnected. Therefore, optimizing completion time at each production station in PT XYZ is necessary to meet planned production capacity.

This can be achieved by adjusting and balancing inefficient workstations using the line balancing method (Tjioewinata & Saifuddin, 2022).

According to Trenggonowati & Febriana (2019), the goals of implementing line balancing are: (1) to evenly distribute work among workstations so that no single station is overloaded, (2) to minimize idle time at each workstation to ensure effective production, and (3) to improve efficiency in the production flow, enabling the company to meet its production capacity.

The line balancing method also requires the calculation of line efficiency, balance delay, workstation efficiency, and utilization as materials for further analysis. Line efficiency is a measure of line efficiency calculated by dividing the total time at the workstation (ST) by the product of the cycle time (the longest operation process time) and the number of workstations. Equation 2.1 represents the formula for calculating line efficiency (DwicaHyani & Muttaqin, 2020).

$$LE = \frac{\sum_{i=1}^n ST_i}{(n \times \text{cycle time})} \times 100\% \quad (2.1)$$

Balance delay is a measure of idle time or downtime that occurs due to imperfect allocation of operation processes across workstations. Equation 2.2 represents the formula for calculating balance delay (DwicaHyani & Muttaqin, 2020).

$$\text{Balance delay} = 100\% - LE \quad (2.2)$$

Workstation efficiency also needs to be calculated as a measure of the performance of the workstation against the established standard time. Equation 2.3 represents the formula for calculating workstation efficiency (DwicaHyani & Muttaqin, 2020).

$$\text{Workstation Efficiency} = \frac{\text{standard time}}{\text{actual time}} \times 100\% \quad (2.3)$$

The Smoothness Index (SI) needs to be calculated to show the relative smoothness of the results from line balancing. The Smoothness Index has units of time. Equation 2.4 represents the formula for calculating the Smoothness Index (DwicaHyani & Muttaqin, 2020).

$$SI = \sqrt{\sum_{n=1}^K ((ST)_{max} - (ST)_n)^2} \quad (2.4)$$

2.2.3 Solution Selection Matrix Method

The Solution Selection Matrix Method is a systematic approach used to evaluate and select the best alternative solution from several available options based on multiple criteria. This method is particularly valuable when dealing with complex decision-making problems, where multiple alternatives need to be evaluated in terms of their effectiveness, feasibility, and alignment with desired outcomes.

In the context of complex manufacturing problems, a similar method is applied in matrix completion approach, which also involves evaluating several possible solutions to a problem using optimization techniques. The method emphasized the importance of comparing solutions based on efficiency, accuracy, and computation time, similar to how the Solution Selection Matrix evaluates alternatives based on defined criteria. This comparison framework is useful for problems where several solutions might seem viable, but a systematic approach is needed to identify the best one based on specific performance metrics (Sun et al., 2025).

2.2.4 Uniformity Test

Good data is consistent data. To check if the data is consistent, a test of data uniformity needs to be conducted. Consistent data means that all data collected fall within the upper control limit (UCL) and lower control limit (LCL). The test of data uniformity begins by grouping the data into subgroups and calculating the average of each subgroup. Then, the standard deviation of the subgroups should be calculated to determine the upper control limit (UCL) and lower control limit (LCL) (Siswanto et al., 2021).

$$\sigma = \sqrt{\frac{\sum (x_i - \bar{x})^2}{N-1}} \quad (2.5)$$

The formula of UCL and LCL is stated as follows.

$$UCL = \bar{X} + k\sigma_{\bar{x}}$$

$$LCL = \bar{X} - k\sigma_{\bar{x}} \quad (2.6)$$

Description:

x_i = the value of x in i

$\bar{x}$ = the average of x data

σ = Standard deviation

k = confidence level

2.2.5 Adequacy Test

Data is considered adequate if the theoretical data count from the data adequacy test is smaller than the actual observed data count collected in the field ($N' < N$). Below is the formula for calculating the data adequacy test (Siswanto et al., 2021).

$$N' = \left[\frac{k/s \sqrt{N \sum x_i^2 - (\sum x_i)^2}}{\sum x_i} \right]^2 \quad (2.7)$$

Description:

N' = data adequacy test

k = confidence level

s = precision level

x_i = i-th data point

Confidence level and precision must be determined when conducting research. Precision is set to limit the maximum percentage of deviation from the actual measurement data. The confidence level is then set as the degree of certainty the researcher has regarding the measurement results in relation to the established precision criteria. For example, a researcher may set the precision level at 5% and the confidence level at 95%. This means that the average measurement results allowed by the researcher can deviate by up to 5% from the actual average, and the probability of successfully meeting the 5% condition is 95%. Below are the values of K for different confidence levels:

If s = 99%, then K = 3.

If s = 95%, then K = 2.

If s = 90%, then K = 1.65.

2.2.6 Standard Time

Cycle time must be calculated first before calculating standard time. The time or duration of a process from start to finish at a workstation is referred to as cycle time. Cycle time is taken during data collection in the field (Widagdo, 2020). The average cycle time is calculated using the formula in equation 2.8.

$$W_s = \frac{\sum X_i}{N} \quad (2.8)$$

Next, normal time can be calculated after obtaining the average cycle time. Normal time also considers an adjustment factor (p) derived from the researcher's assessment of the worker's performance. Normal time is the cycle time with the added consideration of the adjustment factor. The formula to calculate normal time is shown in equation 2.9 (Widagdo, 2020).

$$W_n = W_s \times p \quad (2.9)$$

Then, the calculation of standard time involves the normal time that was previously calculated along with the allowance factor. Therefore, standard time can be considered the total work time that accounts for both the adjustment factor and the allowance factor (a), making it the overall time for a process. The formula to calculate standard time is shown in equation 2.10 (Widagdo, 2020).

$$W_b = W_n (1+a) \quad (2.10)$$