CHAPTER 2
LITERATURE REVIEW AND THEORETICAL BASIS

2.1 Literature Review

Literature review is important to find out all information related to the project being conducted. The review is in the form of several previous studies related to the problem that being studied. Knowing and understanding how the project approaches, understands, and solves problems that arise in a production system. The keywords used in searching the literature include “Improving assembly line productivity.”

Hariyanto & Azwir (2021) conducted a study on a tire company. The problem found in the study was the imbalance of cycle time on the Assy Wheel line. Direct observation of the track was carried out to determine the nature of the process or work elements on the line. Time study can be used to record process time data for each work element which will later be used for data processing using line balancing. The division of work elements based on workload will be obtained and implemented on the Assy Wheel line.

Yetrina et al. (2023) conducted a study on a furniture company. The main problem found in the company was that an assembly line could not maintain the balance of the workstation. The solution provided was the use of the line balancing method used to determine the balance delay, smoothness index, and path efficiency which could then be used to compare the old and new paths which could then be determined whether the path would be repaired with a new path layout or not.

Table 2.1 Summary of literature review

Num.	Author	Problems	Objectives	Solutions	Methods	Results
1	Hariyanto and Azwir (2021)	*Workload imbalance between stations*	Obtaining an assembly line with evenly distributed workloads	Even out the workload for each workstation	Line balancing	Decrease in the smoothness index from 8.60 to 2.24
2	Fitri et.al. (2023)	Excessive number of workstations	Assembly line with higher line efficiency	Decrease balance delay and increase line efficiency	Ranked positional weight	Balance delay lowered from 33.3% to 20% and Line efficiency increased from 87.5% to 91.5%
3	Irsyad et.al. (2020)	The company seeks to reduce employee-related costs.	Reduced employment cost	Scheduling each employee based on the lowest wage.	Linear programming (Hungarian method)	Labor costs are reduced by ≤Rp20,000,000 because scheduling is arranged based on the lowest wage of each employee.

Table 2.1 Summary of literature review continuation

Num.	Author	Problems	Objectives	Solutions	Project Methods	Results
4	Silalahi et. al. (2023)	Scheduling issues for overtime schedules	Rearrange the overtime schedules	Determining employee overtime hours	Goal programming	Organized overtime schedules and allowances
5	Wibawa et al. (2014)	Employees do not have skill factors for workload calculation	Conducting skill factor measurement for each employee	Measuring employee performance using the Westinghouse method	Westinghouse	Six workers share the same workload across the assembly line
6	Parvez et al. (2017)	Uneven workload in the sewing production line that causes bottlenecks and low productivity.	Minimizing the number of workstations, cycle time, and evenly balance the workload in the assembly line	Redistributed tasks among workers to balance the workload.	Line balancing and time study	Production Output Increased from 227 pieces to 263 pieces along with the daily production from 1816 pieces/day to 2104 pieces/day

Table 2.1 Summary of literature review continuation

Num.	Author	Problems	Objectives	Solutions	Project Methods	Results
7	Yudisha (2021)	There is no clear standard working time for each process in the bottling production line.	Improve production efficiency with determining the standard working time	Measuring and determining the standard working time using the stopwatch time study method.	Standard time, stopwatch time study method	Standard time for operation successfully calculated 5.5 seconds.
8	Cevikcan et al. (2012)	Difficult to determine the correct worker tempo (skill factor) in time study and often inaccurate.	Develop a better method for determining worker tempo rating	Provide a continuous and more realistic performance evaluation	Westinghouse skill factor method	The system supports more accurate and systematic performance evaluation in time study
9	Yulvito et. al. (2020)	The optimal number of packer employees needed in the packing division is not yet known.	Determine the optimal number of workers	Conduct work measurement to determine standard working time	Work Sampling Method	Normal working time for packing process is 12.83 seconds, standard time is 15.10, and required number of workers is 1.31 workers per machine

Table 2.1 Summary of literature review continuation

Num.	Author	Problems	Objectives	Solutions	Project Methods	Results
10	Wardah et. al. (2017)	Imbalance between the number of workers and planting capacity	Determine the optimal number of workers needed for oil palm plantation	Conducted work sampling and productivity analysis to measure actual worker performance	Workload Analysis (WLA)	Optimal staffing for planting oil palm seedling is 8 workers
11	Basrati et. al. (2017)	How can CV. Y assign 8 employees to 8 clothing production tasks to achieve maximum production	determine the optimal allocation of employees to clothing production tasks and maximize the total number of clothing sets produced	Produces the assignment combination that maximizes production	Hungarian Method	Optimal assignment for clothing production

Parves et al. (2017) investigates the application of line balancing through the work-sharing method to improve productivity in a garment sewing assembly line. The authors explain that an unbalanced production line creates bottlenecks, increases work-in-process (WIP), extends production cycle time, and lowers overall manufacturing efficiency. The primary objective of the research is to reduce bottlenecks, optimize workload distribution, and improve line efficiency without adding extra manpower

Basrati et al. (2013) compares the Hungarian Method and the Penalty Method for solving assignment problems in a garment manufacturing company, CV. Surya Pelangi. The assignment problem focuses on allocating employees to specific jobs according to their skills to maximize production output and improve operational efficiency. The authors emphasize that selecting the appropriate assignment method is important because different workers possess different productivity levels for different tasks.

Irsyad et al. (2020) conducted project on a company with problems with unstable employee scheduling. The linear programming method was used to find a solution by maximizing profits by minimizing the costs used.

A study by Parvez et al. (2017) explored how line balancing techniques, particularly the work-sharing method, can boost productivity in apparel manufacturing. They defined line balancing as the strategic allocation of tasks to workstations on an assembly line to reduce bottlenecks, cycle time, idle time, and uneven workloads. The authors contended that unbalanced lines lead to an increase in work-in-progress (WIP), longer production cycles, and higher overall costs.

2.2 Basic Theory

The courses used as a theoretical basis are Analysis and Design of Work Systems course (STIN28402), Operational Research (STIN26403), and Operational Research 2 (STIN35503).

2.2.1 Westinghouse Method

Westinghouse Method is a job evaluation technique used to assess employee performance based on four key factors: skill (quality), effort (quantity), responsibility (reliability), and working conditions (cooperation). Keyser et al. (2025) stated that this method was developed by the Westinghouse Electric Corporation as a systematic approach to evaluate productivity and efficiency in

industrial settings. Evaluations are typically conducted by supervisors or evaluators who are familiar with the employees' performance over time. Each factor is rated individually using a specific scale, often ranging from -2 to +2, to capture both strengths and weaknesses. The scores are not based on isolated incidents but rather on consistent patterns of behaviour and output. Once each factor is scored, the ratings are multiplied by predetermined weights that reflect their relative importance. The weighted scores are then summed to produce a total performance score. This comprehensive score provides a basis for identifying top performers and those in need of improvement. It also supports decisions regarding promotions, training needs, and potential disciplinary actions. By offering a structured evaluation process, the Westinghouse Method aims to ensure fairness and objectivity in performance management. Westinghouse table can be seen in Appendix 50.

Each of the four factors in the Westinghouse Method is clearly defined to ensure consistent application. Skill (quality) refers to the accuracy and thoroughness of an employee's work, as well as their ability to meet quality standards. Effort (quantity) measures the amount of work completed within a given time frame. Responsibility (reliability) evaluates dependability, punctuality, and adherence to rules and schedules. Working conditions (cooperation) reflect the employee's attitude toward teamwork, willingness to assist others, and ability to work harmoniously within a group. Evaluators use their professional judgment to assign scores to each factor, guided by specific criteria and examples.

$$\text{Rating Factor} = \text{Skill} + \text{Effort} + \text{Environment} + \text{Consistency} \quad (2.1)$$

$$\text{Skill factor} = 100\% \,.\, (1 + \text{Rating Factor}) \quad (2.2)$$

The method emphasizes behavioural and performance trends, rather than one-time accomplishments or failures. When applied correctly, it provides a balanced view of both technical and interpersonal aspects of performance. One of its strengths is the ease of use and its focus on critical performance dimensions. However, its effectiveness largely depends on the evaluator's objectivity and familiarity with each employee. Without proper training, there's a risk of bias, which can undermine the fairness the method aims to achieve. The skill factor calculation is then used to calculate normal time and standard time. The following is the formula for calculating normal and standard time.

$$\text{Normal time} = \text{Observe time} \,.\, \text{Skill factor} \tag{2.3}$$

$$\text{Standard Time} = \text{Normal time} \,.\, (1 + \text{allowance\%}) \tag{2.4}$$

This calculation is used to calculate the normal time and standard time for each employee to determine the employee's ability to carry out each assigned process.

2.2.2 Test of Uniformity and Adequacy

Douglas (2009) stated that uniformity test is a statistical method used to evaluate whether data is uniformly distributed throughout the measured data. Applied in simulations to ensure that each value that exist in a data group is spread without bias. According to Banfai et al. (2007) crucial step in production system standardization and evaluation involves ensuring strong statistical validity through data uniformity and data adequacy tests. These tests do not analyse individual raw observations but instead employ the Aggregate Method. Collected data first went through grouping into small units referred to as subgroups. The subgroup structure depends on the sample size (n), which in the context of production floor performance rating consists of three independent observations provided by three different assessors for each evaluated employee or process. Each subgroup contains a sample size of three (n = 3). This data aggregation structure provides the foundation for measuring within-subgroup variability and overall system stability before decision-making and generalization.

The first stage of the statistical analysis performs the Data Uniformity Test using a pair of variable control charts, namely the Range Chart (R-chart) and the Mean Chart (X-bar chart). The X-chart will determine whether field data variation originates solely from random natural factors (common causes) or results from extreme disturbances caused by procedural errors (assignable causes). The evaluation begins with the Range Chart (R-chart) to examine the consistency of variability within each subgroup. The control limits for the R-chart follow the product of the average range ($\bar{R}$) and the statistical constants listed in the Control Chart Factors Table. For a subgroup size of three, the upper control limit uses the constant D_4 equals to 2.574, while the lower control limit uses the constant D_3 equals to 0.

$$UCL = D_4\bar{R} \tag{2.5}$$

$$UCL = D_3\bar{R} \tag{2.6}$$

Where:

UCL = Upper control limit

D_3,D_4 = Constant

$\bar{R}$ = Mean range

The X-chart monitors process accuracy by evaluating mean value consistency against the overall average. The formula for constructing the control limits as follows:

$$UCL = \bar{\bar{x}} + A_2\bar{R} \quad (2.7)$$

$$LCL = \bar{\bar{x}} - A_2\bar{R} \quad (2.8)$$

Where:

UCL = Upper control limit

LCL = Lower control limit

$\bar{\bar{x}}$ = Grand mean

A_2 = Constant (subgroup n=3, A_2 = 1.023)

$\bar{R}$ = Mean of Range

The data qualify as uniform when the mean of the variable falls between the Upper Control Limit (UCL) and the Lower Control Limit (LCL).

The data adequacy test determines whether the collected data sufficiently represent the sample. The following formula calculates the required number of observations (N') to evaluate whether the collected data provide adequate representation.

$$N' = \left(\frac{k \cdot \sigma_{\bar{X}}}{s \cdot \bar{\bar{X}}}\right)^2 \quad (2.9)$$

2.2.3 Hungarian Method (Linear Programming)

Linear programming is a mathematical technique used to solve optimization problems, where the main objective is to find the maximum or minimum value of a linear function known as the objective function Hillier (2000). These problems are solved by considering various constraints, which are also expressed as linear equations or inequalities. Study that has been conducted by Basriati & Lestari

(2017) shows that linear programming is widely applied in fields such as economics, management, engineering, and operations to support optimal decision-making when resources are limited and must be allocated effectively among different alternatives. This approach is designed to provide the best possible solution from a set of options by determining the values of decision variables that yield the most optimal outcome in line with the desired objective. Linear programming is a planning process that involves allocating scarce resources among several competing activities in a mathematically structured way, with the goal of achieving the best possible result based on the constructed linear model.

Silalahi et al. (2023) stated that several key components must be considered in linear programming, including the decision variables, which represent the elements whose values are to be determined; the objective function, which is a linear function to be maximized or minimized; and the constraints, which impose limitations on the values of the decision variables to ensure that the solution remains feasible. For instance, in the context of production optimization, the objective function may involve maximizing profit or minimizing cost, while the constraints may consist of production capacity, labour, raw materials, and time. Linear programming also relies on several important assumptions: linearity, meaning that both the objective function and the constraints must be expressed in linear form such as additivity, which implies that the effect of each variable is independent and additive divisibility, which allows decision variables to take fractional values; and determinism, which assumes that all model parameters are known with certainty and without randomness. These assumptions are essential to ensure that the linear model can be applied correctly and that the solutions obtained are both valid and reliable.

Application of linear programming in employee scheduling is widely used in managerial decision-making. Study conducted by Basriati & Lestari (2017) proved this method systematically creates work schedules that account for several critical factors, such as employee availability, the required number of workers per shift, restrictions on working hours, and mandatory rest periods in compliance with labour regulations. By using this technique, companies can optimize workforce allocation, thereby minimizing operational costs including overtime wages while maintaining productivity and employee satisfaction through fair and efficient schedules. Moreover, this model enables the automation of complex scheduling processes, replacing manual methods that are prone to errors and inefficiencies, and providing clarity and flexibility in human resource decision-making within the

organization. The use of applications such as Excel and Python can be used to make this method easier to work on.

2.2.4 Time Study

Groover (2014) stated that time study is a fundamental technique within work measurement that is used to determine the standard time required to complete a specific task. This method involves observing, recording, and analysing the time taken to perform each element of work in a production process. Additionally, the study that has been conducted by Mariawati (2019) shows the primary objective of time study is to establish a reliable time standard that can be utilized for production planning, capacity determination, and performance evaluation.

Cycle time refers to the amount of time required to complete one cycle of operation or to produce one unit of output. Cycle time is obtained from time study measurements and serves as a key parameter in evaluating production capacity. A shorter cycle time indicates a higher potential output within a given period.

$$\text{Cycle time} = \frac{\text{Observed time}}{\text{Number of unit produced}} \tag{2.10}$$

Normal time is obtained from the average cycle time normalized by the worker's skill factor (work pace).

$$\text{Normal time} = \text{Cycle time} \times \text{skill factor} \tag{2.11}$$

Hence, the calculation for standard time can be seen as follows.

$$\text{Standard time} = \text{Normal time} \times (1 + \text{allowance\%}) \tag{2.12}$$

Where:

Allowance% = company use 7% for allowance

In production planning, cycle time analysis is applied to estimate the number of units that can be produced within a specific duration, such as per hour or per shift. The relationship between available working time and cycle time can be expressed using the following equation.

$$\text{Output} = \frac{\text{Effective working time}}{\text{Cycle time}} \tag{2.13}$$

Where:

Output = number of units produced

Effective Working Time = total available working time excluding breaks

Cycle Time = time required to produce one unit

If the production rate is expressed in units per hour, the total output per shift can be calculated as.

$$\text{Output per shift} = \text{Output per hour} \cdot \text{Working Hour per shift} \quad (2.14)$$

In practical industrial applications, production output is influenced not only by cycle time but also by efficiency and allowance factors. The calculation can be extended as follows.

2.2.5 Cost-Benefit Analysis

According to Boardman et al. (2018) in Cost-Benefit Analysis: Concepts and Practice, the Benefit–Cost Ratio (BCR) represents one of the primary indicators in Cost–Benefit Analysis for evaluating the economic feasibility of a project, policy, or solution implementation. According to Department of Financial Administration of Australia (2006) BCR refers to an index that compares the present value of total expected benefits with the present value of total costs incurred throughout the project's economic life. The fundamental principle of BCR can be found in Valacich & George (2017) book, the principle stated that BCR incorporates the time value of money by discounting all projected future benefits and costs to the base year (year 0) using an appropriate discount rate. This approach provides management with a clear rating of the relative efficiency of the proposed investment costs. Benefit–Cost Ratio (BCR) can be expressed as follows:

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}} \quad (2.15)$$

Where:

B_t = Total estimated benefits or cost savings in year t

C_t = Total initial investment and system operational costs in year t

i = Applied discount rate (%)

t = Analysis period

n = Economic life of the project or the analysis time horizon.

According to the Monthgomery, (2021)Cost–Benefit Analysis framework, the final Benefit–Cost Ratio (BCR) provides the primary basis for determining the economic feasibility of the proposed solution. If BCR>1, The proposed solution qualifies as

economically feasible. The present value of the expected benefits or cost savings exceeds the present value of the investment costs, indicating that the implementation generates economic value for the company. If BCR<1, The proposed solution does not qualify as economically feasible. The present value of the expected benefits remains lower than the present value of the investment costs, indicating that the implementation may result in financial losses for the company.

2.3 Standards and Codes of Ethics

Based on the laws and regulations of the Republic of Indonesia, several standards and ethical guidelines provide the foundation and limitations for this study, including the following:

a. Data collection proceeded under the supervision of a Human Resources staff member to ensure data validity.
b. The Westinghouse table model served as a guide for applying the Westinghouse rating system