

Analysis Time Study and Takt Time in the Product Loading Process

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ABSTRACT

Objective: The purpose of this study is to determine the standard delivery process time and also determine the speed of workers. **Method:** The results of observations in this study will be processed using the time study method, which is a process used to determine how long it takes when carrying out a job or task with the aim of improving performance. This method will then be compared with the takt time method, which is a method of determining decisions regarding production capacity through the production system within a predetermined time. **Results:** The results used as the best time determination using the standard time of 47.01 minutes. Then, the takt time result of 21.6 minutes is used as a simulation of a more efficient roll loading process planning proposal. **Novelty:** This research highlights the problem of differences in roll loading process time between morning, afternoon, and night shifts, resulting in a 74.7% decrease in shipping capacity. The study introduces a comparison between time study and takt time methods to improve process efficiency and optimize shipping capacity.

INTRODUCTION

There are several constraints in loading goods activities, such as being influenced by workers, work methods, and equipment supporting the movement of goods [1]. The constraints in the workers can be identified as the number of workers being too few to complete the task, then there are also constraints regarding the working method caused by the shipping transportation service that cannot coordinate well with the warehouse team, and finally, there are constraints regarding the goods handling support equipment that is categorized as unfit for use [2].

The observation was conducted at a company involved in paper production, which produces several types and sizes of paper. This company has three production machines, where the finished products from two of the machines are stored in one warehouse called the old finished goods warehouse, and the finished products from the other machine are stored in a warehouse called the new finished goods warehouse. In the old finished goods warehouse, there was a lack of synchronization in the time required to process loading goods. This occurred during every work shift, where the loading goods process was very slow during the morning shift, while it was very fast during the afternoon and nite shifts. For example, a single loading process during the morning shift took an average of two hours with a tonnage of 40 tons, whereas during the afternoon and nite shifts, it took an average of one hour with the same tonnage. This caused a decrease in the daily shipping target from 750 tons/day to 560 tons/day. The causes of time differences in the loading process are delays in each step, such as delays in delivering the shipping order to the search team during the search process. During the unloading process, queues often occur because the material handling path is blocked by roll debris or other vehicles are passing

thru the path. During the physical inspection of the rolls, there is only one tool for smoothing the roll surface. Delays in fleet operations often occur during the unloading process.

The research aims to find the ideal time as a reference for creating good operational process standards, supporting time study methods, which essentially is an effort to determine the duration of work required by a worker to complete a task [3]. When work time is balanced, the available work facilities can function optimally. Conversely, if work time is less balanced at a workstation, it makes the work process less productive and can lead to bottleneck problems. The advantage of the time study method is that it produces the time for a job under specific conditions, where that time can be used to calculate productivity [4]. After obtaining the ideal time for the work process, it is then compared to the takt time method, which is the available time to produce goods or services, divided by the number of products or services needed by consumers during that period. There are advantages to using the takt time method, such as it can be used as a benchmark to determine how much time is needed to produce a product or complete a process [5]. The results of both methods are indeed similar, but not identical. In the time study method, the calculation process includes a component for allowances, resulting in standard time, while the takt time method accelerates the time it takes to produce goods or services. After that, the best time with the least risk was determined by comparing the two methods. To maximize the time plan, we are assisted by identifying the causes of delays using a fishbone diagram. The fishbone diagram, which is useful for identifying the root causes of problems in a complex process. This method has several branches in analyzing the problem, starting with finding evidence to be used as the cause and also a decrease in productivity or demand, which is interpreted as the effect. Then, from these causes, it is made specific enough as the causal factors, including management factors, manpower, machines, environment, methods, and measurement [6].

RESEARCH METHOD

Place and Time

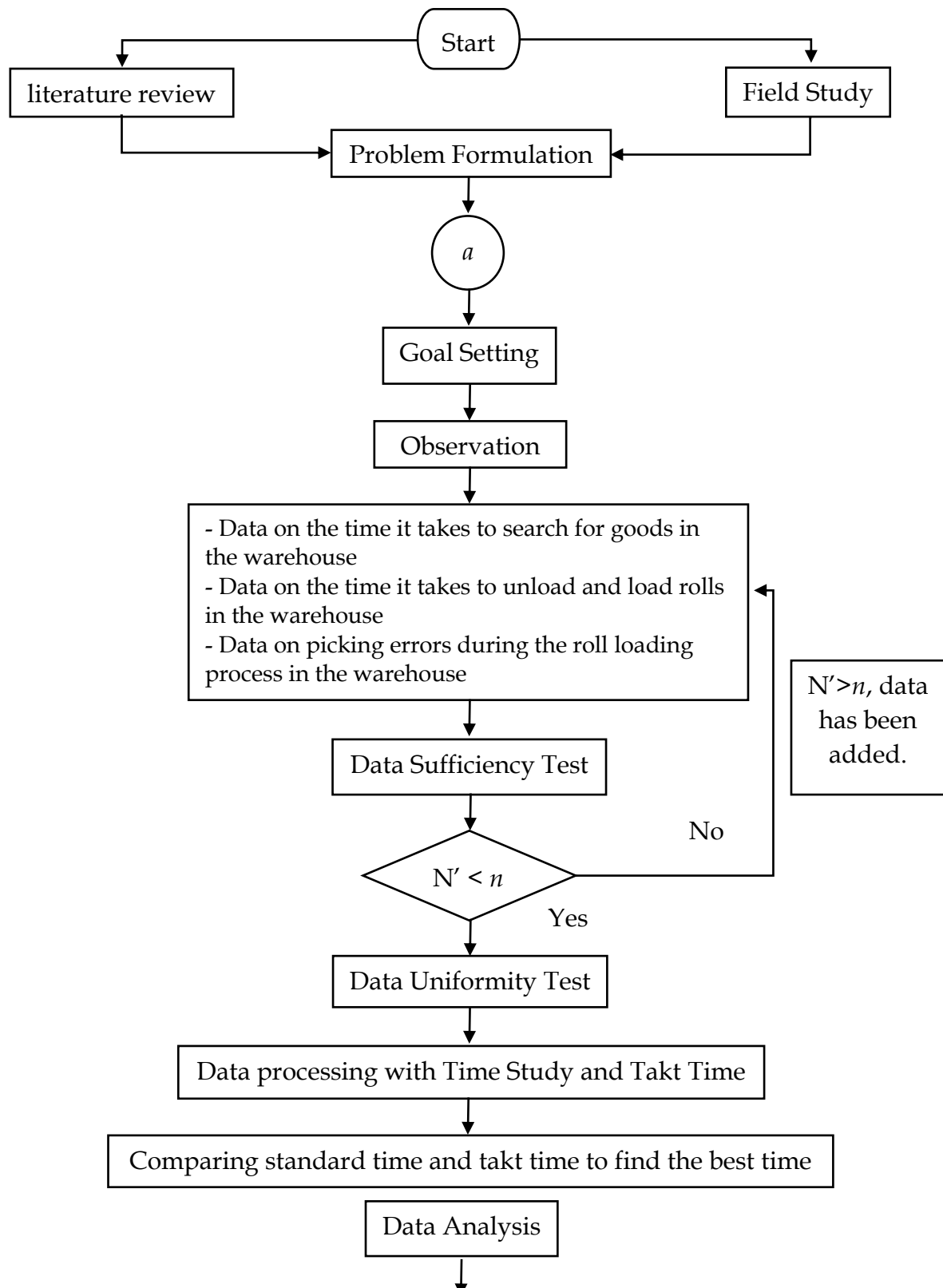
This research was conducted at a paper manufacturing company located in Pasuruan, East Java. The research process was carried out over 6 months, specifically from December 2022 to May 2023.

Data Collection

In obtaining data, several methods were used for direct data collection from the selected company, as follows: (1). Observation was conducted by observing the methods used by workers and operators in completing their job descriptions, and then recording the duration of time taken to complete the job descriptions using a stopwatch. The data obtained is in the form of time records from the roll search process, roll unloading, roll transfer to the transit area, roll checking before loading onto the fleet, and the process of loading rolls onto the fleet. (2) Interviews were conducted with the warehouse department heads regarding standard operating procedures (SOPs) and the layout of roll storage arrangements, and then with the coordinators of each process to identify the

causes of obstacles in completing their job descriptions. (3). Secondary data collection includes process operational standard flowcharts (SOPs), roll storage layout, and shipping order (kitir) report data. Primary data collection includes records of worker and operator time in completing job descriptions and work stretching.

Research Flowchart An explanation of the data identification process and the completion of this research is provided in the form of a flowchart, which can be seen in Figure 1.



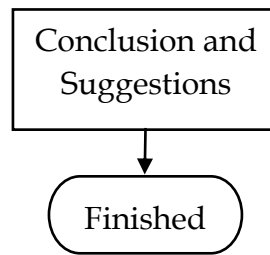


Figure 1. Research Flowchart.

The steps in the process are as follows: (1). Work time measurement, normal work standards will be used as an indicator of the time used by workers when performing their jobs [7]. Basically, every activity and time spent by workers must have an assessment or measurement of labor. From this assessment, information was obtained regarding the maximum and minimum achievements of a work plan, which can be used as a guideline for adjusting plans and controlling production at the company [8]. The data adequacy test is used as a tool to determine if N' is less than N (total observed data), indicating the data is valid. If N' is greater than N , the total observed data needs to be supplemented [9]. To conduct the data adequacy test, a confidence level must be established. To achieve ideal measurements, as many calculation attempts as possible need to be made in the hope that the results of these attempts will be definitive. However, this process is quite difficult to implement due to limitations in time, effort, and cost. Therefore, several attempts were made with the hope that the calculation results would be valid and reliable. The confidence level is a reflection of the uncertainty desired by the research. This uncertainty will indicate the maximum deviation from the actual research results, so it can be concluded that the confidence level is the percentage of a researcher's belief that the results meet the required level of accuracy [10]. The degree of accuracy is a measure of how close and correct the stated value is to the actual value, with a 95% confidence level and a 10% margin of error. These two factors provide an average tolerance for measurement results to deviate by 10% from the actual value, with a 95% probability of achieving this. In other words, if the calculation process yields an average measurement that deviates from the actual value by more than 10%, this is permissible with only a 5% probability (or 100%-95%) [11]. The calculation for the data adequacy test can be determined using the following formula:

$$N' = \left[\frac{K/s \sqrt{n \cdot \sum X^2 - (\sum X)^2}}{\sum X} \right]^2 \dots \dots \dots (1)$$

Source: [8]

Description:

n = Number of Observations

s = Degree of Accuracy

k = Confidence Level

= 1. For a 99% confidence level, the value of $k = 3$

= 2. For a 95% confidence level, the value of $k = 2$

= 3. For a 68% confidence level, the value of $k = 1$

(2). Data uniformity testing is used to determine the highest control indicator, called the Upper Control Limit (UCL), and the lowest control indicator, called the Lower Control Limit (LCL), where the demand data must always fall between these two limits [12]. Standard deviation is a statistical value used to determine the distribution of data in a sample, and is followed by measuring how close individual data points are to the sample mean [13]. The calculation of standard deviation and data sufficiency test can be determined using the following formula:

$$\sigma = \sqrt{\frac{(x_i - \bar{x})^2}{n-1}} \dots\dots\dots(2)$$

Source: [13]

$$BKA = \bar{x} + k.\sigma$$

$$BKB = \bar{x} - k.\sigma \dots\dots\dots(3)$$

Source: [12]

Description:

BKA = Upper Control Limit

BKB = Lower Control Limit

$\bar{x}$ = Mean of the observed data

X_i = Data

k = Confidence Level

σ = Standard Deviation

(3). Cycle time is the speed at which the production line performs production activities from raw material to finished product. In other words, cycle time is a real-time measurement of production time using a stopwatch. Cycle time can be calculated using the following formula [14]:

$$W_s = \frac{\sum x}{n} \dots\dots\dots(4)$$

Source: [14]

(4). Normal time is the measurement of worker activity with adjustments made for several factors [15]. Then, the work time measurements were compared with performance values including rhythm and speed, with the activities being carried out normally without pressure from the comparison itself. Performance rating has two methods that can be used: Westinghouse and Shumard [16]. The Shumard method is an assessment parameter based on job type, with each class having different weights. The parameters of the Shumard method are good, normal, fair, fair+, fair-, and so on. These parameters are agreed-upon evaluation guidelines according to the company. Conversely, the Shumard method provides a fairly clear explanation of each evaluation category, so it can be concluded that the evaluation from the Shumard method can be an objective reason [17]. Where the adjustment factor is at level 70 in the good class, the value obtained is 1.17. Normal time calculation can be determined using the formula:

$$\text{Normal time} = \text{cycle time} \times P \dots\dots\dots(4)$$

Source: [15]

Description:

P = Performance Rating

(5). Standard time is the amount of time an operator uses to produce each unit of various types of products [18]. In the process of calculating standard time, an allowance value is required. An allowance is the addition of duration to normal time so that workers can work as usual. The important role of an allowance is to provide time to meet personal interests and unavoidable fatigue [19]. Standard time can be calculated using the formula:

$$\text{standard time} = \text{normal time} \times \frac{100\%}{100\% - \text{Allowance}} \dots\dots\dots(5)$$

Source: [18]

(6). Takt time is a method that generates data on the speed of production within a single line, and this calculation influences the initial process, starting from raw materials until the goods enter the packaging process. The takt time calculation can be determined using the following formula [20]:

$$\text{Takt time} = \frac{\text{effective working time}}{\text{number of orders}} \dots\dots\dots(6)$$

Source: [20]

RESULTS AND DISCUSSION

A. Worker Time Data

Activities performed within the warehouse include the product search process, followed by unloading products from stacks and moving them to the transit area. After that, physical and label checks are performed on the products. Once the checks are passed, the goods are loaded onto the fleet using heavy lifting equipment (roll clamp). From all these processes, time records were obtained for each job description. The time records for activities performed in the warehouse are divided into 3 work shifts as shown in Table 1.

Table 1. Activity Time Records.

No	Roll Searching	Roll Unloading	Transfer to Transit Area	Roll Physical and Label Inspection	Roll Loading Process onto the Fleet
1	28,80	26,58	20,75	7,33	42,25
2	27,02	24,40	22,95	5,95	42,13
3	25,35	19,30	20,52	7,12	38,68
4	26,15	20,05	22,93	6,83	35,85
5	19,58	21,75	23,83	6,83	36,67
6	25,37	23,17	23,53	7,60	42,20
7	29,00	20,35	20,95	8,02	40,90

8	25,78	19,18	19,87	7,43	40,65
9	29,45	21,65	22,28	8,30	41,98
10	23,78	25,28	24,48	10,70	42,43
11	21,65	20,38	19,45	10,90	36,97
12	23,63	22,97	22,50	6,43	42,23
13	40,77	20,07	23,67	6,78	41,60
14	22,10	19,15	21,70	6,13	39,13
15	23,25	24,82	21,68	9,25	40,43

B. Teamwork Information

PT. XYZ has a work schedule that includes 3 work shifts: morning, afternoon, and nite. In the finished goods warehouse, there are 4 teams working according to the three-shift work schedule. These four teams consist of 1 shipping coordinator worker, 1 delivery order coordinator worker, 2 search process workers, 1 product storage coordinator worker, 3 heavy lifting equipment operators (roll clamp), and 1 product physical and label checking worker, with a total of 9 workers in each team.

C. Data Processing

Data processing began with a data sufficiency test, hoping that the data obtained would be sufficient for processing. Data processing was performed on each time record of the activity, but this study will include data processing related to the process of loading rolls onto the fleet. The results of data processing for the data sufficiency test process are shown in Table 2.

Table 2. Time Observer Data for the Roll Loading Process.

No	xi	xi - $\bar{x}$	(xi - $\bar{x}$) ²	(Σx) ²
1	42,25	1,98	3,90	1785,06
2	42,13	1,86	3,46	1775,22
3	38,68	-1,59	2,53	1496,40
4	35,85	-4,42	19,58	1285,22
No	xi	xi - $\bar{x}$	(xi - $\bar{x}$) ²	(Σx) ²
5	36,67	-3,61	13,02	1344,44
6	42,20	1,93	3,71	1780,84
7	40,90	0,63	0,39	1672,81
8	40,65	0,38	0,14	1652,42

9	41,98	1,71	2,92	1762,60
10	42,43	2,16	4,66	1800,59
11	36,97	-3,31	10,94	1366,53
12	42,23	1,96	3,84	1783,65
13	41,60	1,33	1,76	1730,56
14	39,13	-1,14	1,30	1531,42
15	40,43	0,16	0,03	1634,85
Total	604,12	0,00	72,17	24402,63

After calculations are performed as shown in Table 2, data sufficiency testing is then conducted to determine whether the data obtained is sufficient.

D. Data Sufficiency Test

The data sufficiency test is conducted with the expectation that the test result, N' , can have a value equal to N , which is the total of all data. During the testing process, there are several constant data points of 2 and a confidence level of 0.1. The following is an example calculation for the data sufficiency test:

$$N' = \left[\frac{K/s \sqrt{N \cdot \sum X^2 - (\sum X)^2}}{\sum X} \right]^2 \left[\frac{\frac{2}{0.1} \sqrt{15 (24402,63) - (364956,95)}}{604,12} \right]^2 = 4,75$$

Since $N' \leq N$, which is $5 \leq 15$, the data used is sufficient.

E. Data Uniformity Test

The data uniformity test process begins by finding the standard deviation, which is used to validate the distribution of data within the sample, with the aim of determining the distance between individuals and the sample mean. Here is the calculation for standard deviation, BKA, and BKM:

$$\bar{x} = \frac{\sum xi}{n} = \frac{604,12}{15} = 40,27$$

$$\sigma = \sqrt{\frac{\sum (xi - \bar{x})^2}{n-1}} = \sqrt{\frac{72,17}{14}} = 2,19$$

$$BKA = \bar{x} + k(\sigma) = 40,27 + 2(2,19) = 44,66$$

$$BKB = \bar{x} - k(\sigma) = 40,27 - 2(2,19) = 35,89$$

After obtaining the results of BKA and BKB, an analysis was performed using the aid of a control chart for the process of loading rolls onto the fleet, as shown in Figure 2.

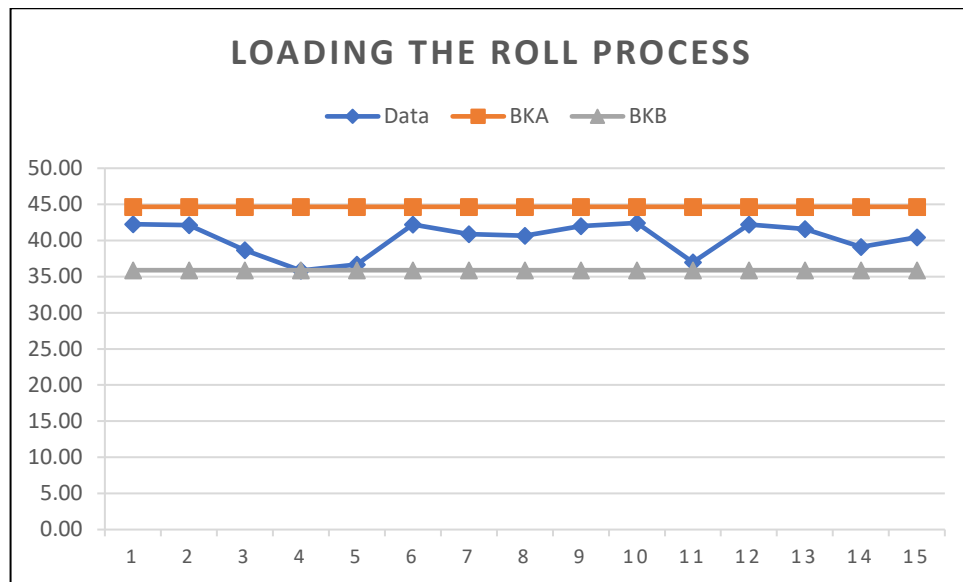


Figure 2. Roll Loading Control Chart.

The results from the control chart graph on the data uniformity test indicate the presence of extreme data points, such as in data points 4, 5, 11, and 14. This indicates that the process is accelerating.

F. Cycle Time

Cycle time calculation is the result of the total activity time divided by the number of data points in a single observation. Here is the calculation for cycle time:

$$W_s = \frac{\sum x}{n} = \frac{604,12}{15} = 40,27 \text{ menit}$$

G. Normal Time

Calculating normal time requires an assessment of a worker's personality, work behavior, and work results, and then a decision is made based on these assessments regarding new steps aimed at setting labor standards [21]. Here is the calculation for normal time:

$$\text{Normal time} = \text{cycle time} \times P = 40,27 \times 1,17 = 46,99 \text{ menit}$$

H. Standard Time

The calculation of standard time is based on the multiplication of normal time by the percentage of allowance. Table 3 shows the allowance data obtained:

Table 3. Slack Factor.

Allowance Factor	Minutes	Percentage
Toilet Trip	1	0,2%
Urination	2	0,5%
Defecation	5	1,2%
Stretching	3	0,7%
Working Posture	1	0,2%

Unavoidable Delays	6	1,5%
Allowance Factor	Minutes	Percentage
Total	18	4,3%

The overall result for the allowance factor is 18 minutes or 4.3%. The higher the percentage for the allowance factor, the more the need for fatigue allowance, personal allowance, and allowance to eliminate fatigue itself can be met, resulting in productive time. Conversely, a decrease in the percentage for the allowance factor leads to a shortage of productive time within the available time for workers and can also trigger accidents.

$$\text{Standard Time} = \text{Waktu normal} \times \frac{100\%}{100\% - \text{Allowance}} = 46,99 \times \frac{100\%}{100\% - 4,3} = 47.01 \text{ minutes}$$

After obtaining the cycle time, normal time, and standard time, the analysis can proceed with the help of a process control chart like the one in Figure 3, which shows the loading of the roll.

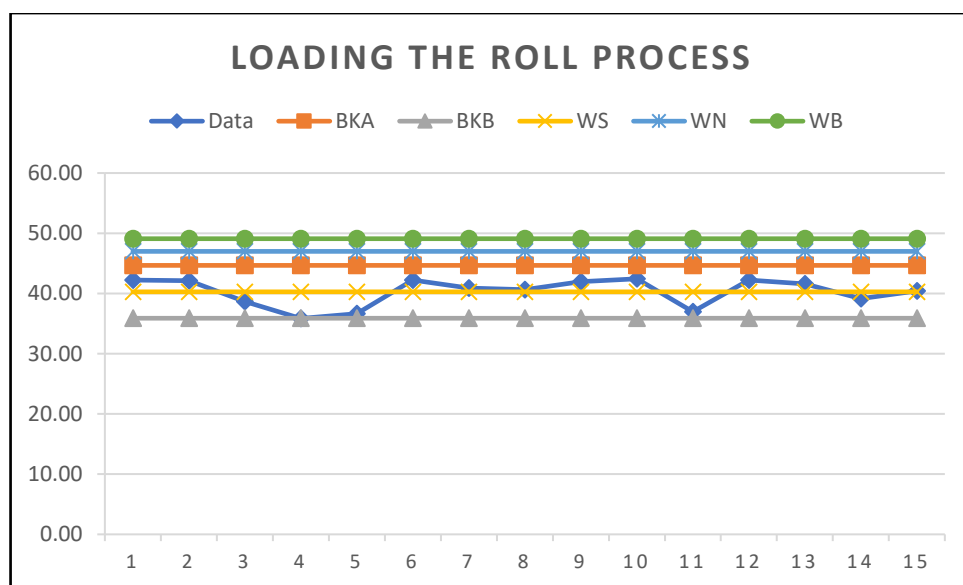


Figure 3. Roll Loading Control Chart.

From the process control chart for roll loading, it is known that the research data is still far from approaching the standard time and normal time parameters. This indicates that the actual work process is quite fast, but this acceleration is unstable and the differences between data are significant. This makes it difficult for the fleet coordinator to plan the roll loading process.

I. Takt Time

The calculation in the takt time method serves to identify several pieces of information, such as the benchmark for the average time needed to complete a task in order to meet consumer demand. The output of this comparison provides detailed information about the level of efficiency and wasteful activities occurring

within the unit. Furthermore, there are other results, including information about the minimum number of workers or resources used in the process, which can be used to plan the number of workers or resources needed to achieve optimal goals [22]. Table 4 provides the total supporting factors for calculating takt time.

Table 4. Demand.

Type	Total	Units
Cycle time	7136	Seconds
Number of Days	24	Day
Demand	18000	Ton
Working Hours	6	Hour
Work Effectiveness	75	Percentage

It is known that the working hours for one shift are 8 hours, from 08:00 to 16:00, shift 2 is from 16:00 to 24:00, and shift 3 is from 24:00 to 08:00. Based on the observation results, the effective working hours are 6 hours out of 8 hours. 1 hour is for rest time, and 1 hour is for workers to recover from fatigue. The loading process takes 3 shifts with a working hour effectiveness of 75%. Working hour effectiveness is calculated by dividing effective working hours by total working hours. The factor influencing effectiveness is time management, where someone will be more effective in their work if they have time management skills.

Working Hours = Working Hours $\times$ 3600 $\times$ % Work Effectiveness = $6 \times 3600 \times \frac{75}{100} = 16200$ seconds.

Thus, the required ton to be achieved per day = $\frac{\text{total demand}}{\text{Number of Days}} = \frac{18000}{24} = 750$ ton/day

$Takt\ time = \frac{\text{Effective Working Time}}{\text{Number of Orders}} = \frac{16200}{750} = 21,6$ minutes

J. Analysis and Discussion

The process of loading goods involves moving them from one place to another with great care to avoid errors in processing. At the finished goods warehouse at PT. XYZ, the process of moving goods includes searching for the goods (rolls), then unloading them from the storage stacks, followed by checking the physical condition of the goods and their labels. The goods are then moved to the transit area for weighing, cleaning the outer surface of the rolls, and wrapping the rolls in plastic to protect their surface during loading or unloading from transportation vehicles. After the rolls have been physically checked and match the kitir (customer order), they are loaded onto the transportation vehicles and neatly arranged.

From all these processes, time records were obtained for each one. Based on these time records, the difference between the morning, afternoon, and nite shifts was calculated. Therefore, an analysis was conducted using the time study and takt time

methods. The results of the analysis using the time study method are shown in Table 5.

Table 5. Time Study Calculation Results.

Jobdesc	BKA	BKB	WS	WN	WB
Roll Searching	35,79	17,77	26,78	31,24	31,26
Roll Unloading	26,68	17,20	21,94	25,60	25,61
Roll Transfer to Transit Area	25,03	19,11	22,07	25,75	25,76
Pre-Loading Inspection	10,83	4,89	7,86	9,17	9,18
Roll Loading Process	44,66	35,89	40,27	46,99	47,01

From the results of the time study calculations, there are BKA and BKB which function as upper and lower parameters, then there is cycle time which is the average time to complete an activity, then normal time becomes a parameter using a combination of performance ratings that results in the time to complete the work under normal conditions, and finally, standard time is a parameter that has the best results in the current work system.

The result of the takt time calculation is 21.6 minutes, a value based on the average time needed to perform the work in order to meet consumer demand. The solution to increase productivity in the process of loading goods at the finished goods warehouse is to add workers and material handling to manually performed processes such as roll searching, roll unloading, and roll loading. This should be balanced with a systematic arrangement or layout of the rolls to make it easier for workers to find and unload them. Additionally, the work environment can be further optimized in terms of lighting, limiting roll stacks to provide workers with a clear line of sight, and creating a more effective loading area for all types of material handling to maximize the potential of each tool.

Analysis of process inhibitors frequently reveals shortcomings that hinder work. There are three areas of focus: the search process, the unloading of rolls assisted by a roll clamp machine, and the loading of rolls onto the fleet. In the process of analyzing the causes of obstacles, direct observation and time calculation were conducted, supplemented by interviews with material handling operators. The questions covered maintenance schedules, maintenance process execution, and factors hindering the material handling operators' job duties. The results of the interview were used to create a fishbone diagram to provide a visual and facilitate the identification process. Fishbone or Ishikawa can be said to be an approach process that has its own structure in analytical activities specific to problem causes, intentionality, and manipulation [23]. The following

are the causes of obstacles in the process of loading the roll, as shown in the fishbone diagram in Figure 4.

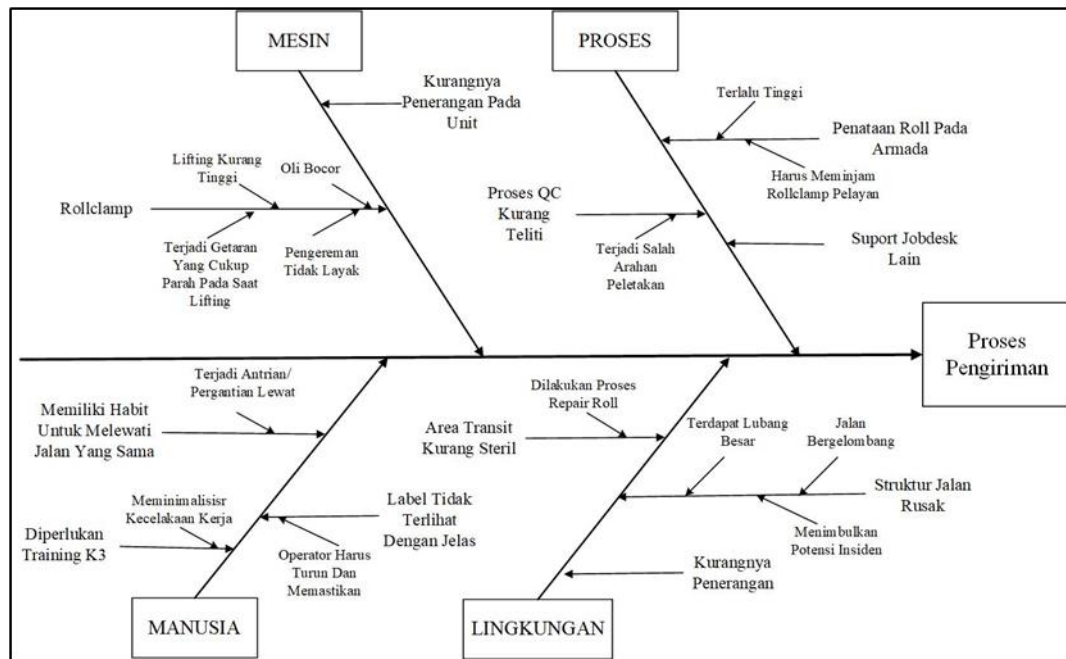


Figure 4. Fishbone Diagram.

There are several factors that hinder the loading process; these factors are interconnected and create a rather complex problem, which requires improvement or updates to each of them. As with the machine factor, where the use of machinery in the process is based on material handling, the type of material handling is 3-ton capacity with a maximum lifting height of 3 meters. Meanwhile, one roll has an average height of 2 meters, and the warehouse storage system is stacking with a maximum of 3 rolls. Therefore, material handling must lower 2 rolls simultaneously with a load exceeding 3 tons, which can trigger workplace accidents. Then, maintenance schedules are often delayed, which leads to oil leaks and brake pads wearing out quickly. On the material handling line, the main lights from the material handling system itself are still relied upon due to insufficient lighting, but no spotlights have been added.

The process factor experienced delays due to insufficient physical condition checks, leading to rework such as flipping or rolling the rolls to cut off damaged or dirty sections. Furthermore, there was frequent miscommunication between the arrangement coordinator on the fleet and the material handling operators because there were no communication aids (handy talkies) available, and the environment was quite noisy due to material handling and production machinery. And very often, the material handling process involves loading rolls that are difficult to move for the waste cleaning process, which should have a separate unit to perform that task.

Regarding the environmental factors where material handling is carried out, it can be categorized as having poor lighting, both from spotlights to illuminate the path and minimal natural sunlight ventilation. Not only is the lighting of the track conditions, the

repair roll area, and the loading dock lacking, but the road construction is also uneven and even potholed, which is quite dangerous considering the transfer process relies solely on special roll clamps from material handling equipment that has no safety features.

Human factors present obstacles where operators have a habit of taking the same route, even tho that route has obstacles such as lane narrowing due to the roll unloading process or other vehicles passing thru it. Other workers disregard the presence of other vehicles crossing the material handling lane, citing the existence of two material handling lanes. Then, the label itself is quite small, and given the warehouse's environmental conditions, which have many shortcomings, the small size of the labels causes operators to have to get off the unit to check them.

Of all these factors, they have a rather complex relationship, making warehouse facility upgrades or improvements the key to reducing delays caused by these factors.

CONCLUSION

Fundamental Finding : From the calculation results using the time study method, the roll search process took 31.26 minutes, roll unloading took 25.61 minutes, roll transfer to the transit area took 25.76 minutes, pre-loading inspection took 9.18 minutes, and the roll loading process took 47.01 minutes. Meanwhile, the takt time method yielded a value of 21.6 minutes. These results show that the two methods, time study and takt time, serve different functions. The best time to carry out the process can be determined using standard time, while the time study results can be used as a comparison or simulation for planning a more efficient roll loading process. **Implication :** The findings from this study suggest that using the time study method can provide valuable insights into the current process duration for each stage of roll handling. This method can be used to identify areas for improvement and serve as a benchmark for more efficient planning. Meanwhile, the takt time method offers a practical approach for determining production capacity within a predetermined time, which could be beneficial for optimizing the roll loading process and improving overall efficiency in the warehouse operations. **Limitation :** This research does not discuss the costs of creating good working hours or the process of improving or updating facilities. Therefore, the financial and infrastructural aspects, which could potentially influence the effectiveness of the proposed improvements, have not been considered in this study. **Future Research :** Future research can be developed by studying ergonomic theory to ensure that the results of time formulation can be realized accurately and systematically. Additionally, further studies could explore the impact of updating facilities and improving working conditions on the overall efficiency of the roll loading process, as well as the associated costs of implementing these improvements.

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