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Evaluation for The Production Process of The Cover Plate Components Using Time Study Technique: A Case Study

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Abstract

Time study plays a crucial role in optimizing production efficiency and resource utilization in manufacturing processes. Time study helps to counter problems that occurred in the production industry such as uneven task distribution, bottlenecks, idle time, complexity, and time constraints. In this case study, a manufacturing company has been selected as a case study for time study which focused on packing department that produced cover plate component in order to identify the task time, normal time and standard time. There are 12 work elements that were identified in this case study and these work elements were grouped into 5 different workstations based on cycle time. As a result, among of 12 work elements, the first 7 work elements indicates that the processes did not show any delay, where the processes can be done in range of 12% to 31% faster than the expected standard time. Meanwhile the other 5 work elements indicates a delay in task completion, which is up to 43.63 seconds. In case of workstation analysis, workstation 1, 2 and 3 showcasing effective performance in terms of task completion, with 14.6% to 31.1% faster than the standard time. However, for workstation 4 and 5 were recorded a procrastinate process time about 8% and 11%, which can translated as 30.3 seconds and 77.7 seconds, respectively. As a conclusion, the analysis of manufacturing task efficiency identified elements H, I, J, K, and L as needing improvement. Conversely, elements A, B, C, D, E, F, and G are performing well. Workstations 4 and 5 are bottlenecks that hinder overall production efficiency. Addressing these bottlenecks is crucial for achieving optimal output.

1. Introduction

In the dynamic realm of manufacturing and production, optimizing efficiency and productivity is paramount. Time study, a systematic and scientific approach, plays a pivotal role in this pursuit. This methodological examination involves the careful analysis, measurement, and evaluation of every task within a production line, aiming to discern the most effective and efficient ways to carry out each operation. Time study serves as a cornerstone in the quest for operational excellence, providing invaluable insights into the utilization of resources, identification of bottlenecks, and enhancement of overall workflow [1]. Time study empowers organizations to make informed decisions about resource allocation, manpower utilization, and process optimization, ultimately contributing to increased output and reduced production costs [1].

The manufacturing factory encountered specific production line challenges that can have an impact on the quality, efficiency, and cost-effectiveness of its production processes. These challenges included issues with machine downtime, material shortages, and inconsistent product quality which necessitated a comprehensive review of the entire production setup from raw materials to finished goods. The production line faces challenges, including uneven workload distribution where some stations are overloaded while others are underutilized, lack of production process flexibility such as the inability to quickly adapt to changing product requirements or market demands, and staffing issues like skill shortages or high turnover rates [1,2].

Unequal distribution of time-intensive tasks at specific stations leads to work backlogs, which then result in delays and inefficiencies throughout the process. Inflexible and rigid processes, characterized by their resistance to change and lack of adaptability, often struggled to effectively respond to fluctuations in demand or unforeseen events. This inflexibility significantly contributed to operational difficulties, making it challenging for the organization to navigate unexpected disruptions. Moreover, these challenges could have a cascading effect on various aspects of the business operations and overall performance. For example, disruptions in the supply chain can lead to delays in production, impacting delivery schedules and ultimately customer satisfaction.

Staffing issues, including both a shortage and surplus of personnel at stations, continue to exacerbate production delays. This impacts the productivity of company's teams and has ripple effects on project timelines and delivery schedules. It is crucial to address these staffing challenges promptly to ensure smooth operations and meet client expectations. To address these challenges, the manufacturing factory carefully considered implementing time study techniques to improve efficiency and productivity [1,3,4]. This involves a careful examination of the production process, identifying potential bottlenecks, adjusting task sequences as needed, and ensuring that each station is equipped with the necessary resources for efficient and precise execution of tasks in order to enhance overall operational efficiency.

Therefore, the objectives of the research study are to identify the average task time, normal time, and standard time for each of the work elements of the production line, leading to analyse the cycle time and delay time of the production line. This research is focused on the production process of the packing department at the manufacturing factory.

2. Literature Review

2.1 Time Study

Time study entails a detailed examination of a specific operation, identifying its essential elements, establishing their sequence, and evaluating the necessary time for their efficient completion [1,2]. According to the International Labour Organization (ILO), time study is a work measurement technique that involves recording the times and rates of work for each element of a specific job carried out under specified conditions and analyzing the data to obtain the time necessary for carrying out the job at a defined level of performance [3,4].

2.2 Terminology and Terms Used in Time Study

There are a few key terminology and terms that are important to be familiar with in contemplation of understanding time study. The terms are as shown in Table 1 below [5,6]:

Table 1 *Terminology of time study [5,6]*

Terms	Definition
Task Time	Task Time is the rate at which products must be produced to meet customer demand.
Workstation	Workstation is a physical location on the production line where tasks are performed.
Task	Task is a specific activity that must be completed in the production process, such as assembling a component or inspecting a product.
Cycle Time	The duration required to finish a task, encompassing the processing period as well as any preparatory or transition time.
Efficiency	The percentage of time that a workstation is actively engaged in performing a task, as opposed to the total duration it is available.
Idle Time	The duration for which a workstation is not actively engaged in a task, encompassing both idle time and various other forms of non-productive time.
Balance Delay	The period when a workstation is not in use because there are no available tasks to be completed.

2.3 Techniques of Time Study

Time study is a crucial method in the field of industrial engineering and management science used to measure the time needed for completing a particular task. This process entails observing an experienced worker carry out the task and documenting the duration taken for each specific element of the work. There are four distinct techniques of time study, namely predetermined time standard systems, work sampling, standard data, and stopwatch time study [1,7,8].

2.3.1 Predetermined Time Standard Systems

These processes entail decomposing tasks into small, fundamental movements and allocating a set amount of time to each movement. The combined standard times for the different movements are then calculated to establish the overall standard time for the task. Well-known predefined systems include Methods-Time Measurement (MTM) [9], Maynard Operation Sequence Technique (MOST) [10] and Modular Arrangements of Predetermined Time Standards (MODAPTS) [11–13].

2.3.2 Work Sampling

Work sampling is a method of research where employees are observed at irregular intervals, and their tasks are recorded. The collected data can be converted into percentages to show how their time is distributed among various activities. This approach involves intermittent and random observations over a period of time, providing an economical way to analyze and estimate the distribution of work time across different tasks [1,3,8]. Work sampling consists of four sub-techniques for determining standard time: elemental sampling studies, performance sampling studies, time standard development studies and process effectiveness studies.

2.3.3 Standard Data

The standard data method involves establishing and using fixed time standards for specific work elements or movements within a given task or process. This approach relies on historical observations, time and motion studies, as well as expert evaluations to determine the expected time required for routine tasks in typical working conditions. These predefined standards are developed through insights gathered from various sources and can be classified into different levels of detail such as motion, element, and task. Motion standard data, although widely applicable, requires more development time compared to element or task standard data. Element standard data is more broadly applicable and allows for a quicker development process than motion data. Various methods including general approach, tabular data, and nomograms and plots approaches are used in developing these standards [1,3,8].

2.3.4 Stopwatch Time Study

The stopwatch time study method is a conventional and widely used technique in time study and industrial engineering for assessing the duration of a worker's performance in a specific task. This method employs a stopwatch to document the time taken for each element of a job or task, aiming to establish the standard time required for that activity. The standard time serves as a foundation for establishing performance benchmarks, workload distribution, and resource management [14–16]

2.4 Standard Time

Standard time denotes the time needed for an adequately skilled operator, working at a standard pace, to execute a defined task following a specified method. This duration encompasses suitable allowances to enable the individual to recuperate from fatigue, and when deemed necessary, an extra allowance to account for unforeseen elements that might arise but have not been previously observed [1,2,15,17]. Standard time can be calculated by using the formula Eq. (1) below [18–20].

$$Standard\ Time = \frac{Normal\ Time}{(1 - Allowance)} \tag{1}$$

2.4.1 Normal Time

Normal time is a term used to represent the time required for a qualified and trained worker to perform a specific task or work element at a standard pace, without considering any allowances. It is an essential component in the calculation of standard time, providing a baseline for evaluating work performance. Normal time is also a fundamental building block for standard time. It represents the theoretical or ideal time required to perform a task under normal working conditions and at a standard pace. Normal time can be calculated by using formula Eqs. (2) and (3) as shown below [1,3,19,20].

$$Normal\ Time = Average\ Observed\ Time \times Performance\ Rating \tag{2}$$

$$Average\ Observed\ Time = \frac{Sum\ of\ the\ times\ recorded\ to\ perform\ task}{Number\ of\ observations} \tag{3}$$

2.4.2 Cycle Time

Cycle time pertains to the total time required to complete one cycle of a particular operation or production process. This metric is fundamental for assessing and measuring the effectiveness and output of a production system, especially in contexts involving repetitive processes or tasks within manufacturing or service domains. Cycle time can be calculated by using formula Eq. (4) shown below [19–21]

$$Cycle\ Time = \frac{Production\ time\ per\ day}{Number\ of\ units\ required\ per\ day} \tag{4}$$

2.5 Performance Rating

During time study, the assessment of a worker's performance in relation to predetermined standards while observing and measuring work activities is known as performance rating. This plays a crucial role in time study and industrial engineering by providing a numerical measure of how efficiently a worker completes a task compared to the expected pace. Typically presented as a percentage or ratio, the performance rating indicates an individual's effectiveness relative to the established standard. Additionally, this process involves the evaluation of observed operators' performance against normal standards by time study engineers, resulting in the determination of a factor called the rating factor [22–24]. Various evaluation systems are available for assessing the performance of operators on a given job or task. These include speed rating, synthetic rating, objective rating, and the Westinghouse system.

2.5.1 Speed Rating

Speed assessment involves assessing how quickly or slowly a worker completes a specific task in relation to the established benchmark. It measures the pace at which work is completed compared to the expected speed, quantified as a percentage with 100% representing the standard pace [25].

2.5.2 Synthetic Rating

The time study observer documents the precise time necessary for each element within this system. This method strives to provide an evaluation that is not affected by subjective opinions, accomplished by using established time values to evaluate an operator's efficiency. The synthetic rating process determines a performance coefficient for typical work cycle elements by comparing recorded times for actual tasks with times calculated from fundamental motion data [3].

2.5.3 Objective Rating

M.E. Mundel introduced a rating system that considers the pace at which an operator completes a task and the complexity of the job. This system evaluates movement speed and job difficulty separately, then combines these assessments to determine an overall value. The speed rating is determined as mentioned earlier, while assessing job difficulty involves choosing adjustment factors based on characteristics such as amount of body used, foot pedals, bimanualness, eye-hand coordination, handling or sensory requirements and weight handled, or resistance encountered [25].

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2.5.4 The Westinghouse System

The Westinghouse system is a technique developed by the Westinghouse Electric Corporation to evaluate and rate the efficiency of workers. The Westinghouse System offered a comprehensive assessment of a worker's performance. Rather than concentrating solely on quantitative measures such as speed or output, it considers both quantitative and qualitative aspects. This method considers four factors to assess operator performance: skill, effort, conditions, and consistency [3,26,27]. The equivalent percentage value for each factor class is provided in Table 2 below.

Table 2 *Components of the Westinghouse rating system [3]*

Skills Ratings			Effort Ratings		
+0.15	A1	Superskill	+0.13	A1	Excessive
+0.13	A2	Superskill	+0.12	A2	Excessive
+0.11	B1	Excellent	+0.10	B1	Excellent
+0.08	B2	Excellent	+0.08	B2	Excellent
+0.06	C1	Good	+0.05	C1	Good
+0.03	C2	Good	+0.02	C2	Good
0.00	D	Average	0.00	D	Average
−0.05	E1	Fair	−0.04	E1	Fair
−0.10	E2	Fair	−0.08	E2	Fair
−0.16	F1	Poor	−0.12	F1	Poor
−0.22	F2	Poor	−0.17	F2	Poor
Condition Ratings			**Consistency Ratings**		
+0.06	A	Ideal	+0.04	A	Perfect
+0.04	B	Excellent	+0.03	B	Excellent
+0.02	C	Good	+0.01	C	Good
0.00	D	Average	0.00	D	Average
−0.03	E	Fair	−0.02	E	Fair
−0.07	F	Poor	−0.04	F	Poor

2.6 Allowances

Allowances involve adjustments made to the observed time. These allowances are incorporated by adding them to the observed time to accommodate factors that may impact a worker's performance but are beyond their control. Allowances are allocated to three components of the study which are the overall cycle time, machine time and manual effort time. Allowances can be categorized into 2 main types: constant allowance and variable allowance [1,3,28–33].

2.6.1 Constant Allowance

The constant allowance, also referred to as the basic allowance, covers personal needs and fundamental fatigue allowances [1,3]. These factors are added to the observed time in a time study to account for individual requirements and the essential impact of fatigue on a worker's productivity. Personal needs refer to the time needed for activities like drinking water, using the restroom, or attending to personal matters. Fatigue allowances, on the other hand, account for the gradual decline in a worker's physical and mental capabilities over the course of a shift due to the cumulative effects of physical and mental exertion [30].

2.6.2 Variable Allowance

Variable allowance, also referred to as a contingency allowance, is an extra amount of time added to the standard time in time study [1,3]. It considers unpredictable or fluctuating factors that can impact a worker's productivity. The purpose of a variable allowance is to introduce adaptability into the standard time by accommodating changing conditions from one work cycle to another. This ensures that the standard time offers a practical estimate of the required task duration under varying circumstances. Several factors contribute to variable allowances, including abnormal posture, muscular effort, environmental conditions such as noise and illumination levels, visual and mental strain, monotony, and tediousness [30].

3. Methodology

3.1 Identification of Workstations

The initial stage of addressing this case study entails identifying workstations within the production line, a crucial step for optimizing efficiency and productivity. Fig. 1 provides a visual representation of the sequential flow within the packing department of the manufacturing factory's production line.

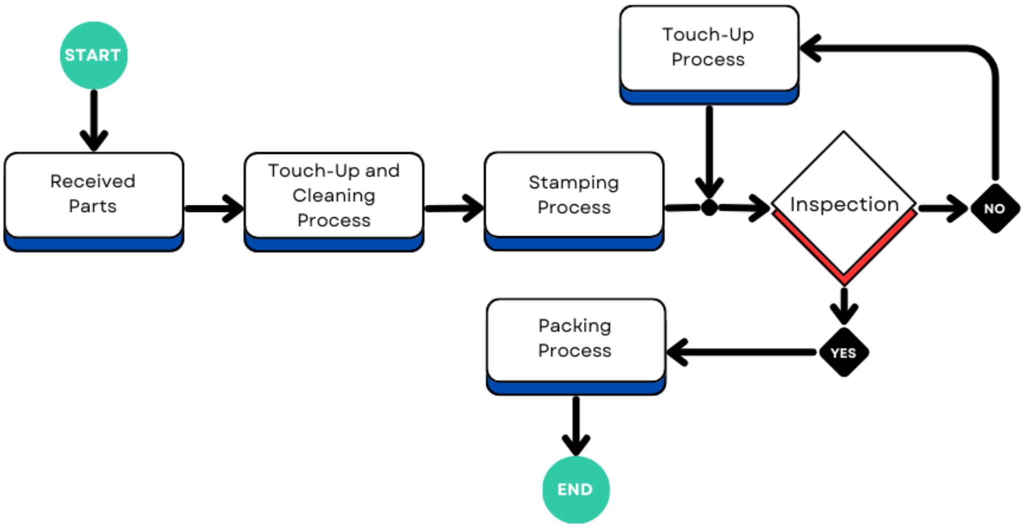

Fig. 1 *Flow process of the production line*

3.2 Selection of Parameters and Methods

Parameters play a pivotal role as benchmarks and references in addressing this research problem within the manufacturing factory. The initial phase involves identifying these parameters as foundational criteria for the subsequent steps. Examples of parameters pertinent to time study are cycle time, task times and idle times are intrinsically linked to time measurements. Once identified, these parameters guide the selection of an appropriate methodology to address this research problem. In this context, time study is recognized as the most suitable method, establishing it as the method of choice for resolving the challenges outlined in this case study.

3.3 Data Collection

Observation methods are employed to document the actual operation time of the production line. This recorded operation time is subsequently utilized in calculating the standard time and cycle time, a pivotal factor in determining the maximum allowable operation time for each work element and workstation within the production line to enhance overall efficiency. The collection of time data for individual workstations involves the use of a stopwatch. The time is measured on 10 occasions for each work elements and the average time is then computed.

3.3.1 Tasks and Work Elements

Table 3 shows task and work elements for the cover plate. Each of the work elements has its own precedence, which refers to the order or sequence in which tasks need to be performed before proceeding to the next task.

3.3.2 Performance Rating of Operators

Performance rating is a measure that reflects the efficiency or productivity of a worker in completing a task. To assess the performance rating of operators, observations are conducted on operators completing tasks, and a comparison is made with the Westinghouse rating system. Table 4 below shows the performance rating of the operators for each of processes after assessment. In instances where a task requires the involvement of 2 operators, the factors are determined by finding the average between the 2 operators involved. Referring to Table 4 below, it is evident that each of the operators undertakes distinct tasks based on their skills. Consequently, the completion time for work elements is contingent upon the performance rating of the operators.

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Table 3 *Task and work elements for cover plate*

Work Element	Work Element Description	Precedence	No. of Operators
A	Move part from waiting bay to touch up and cleaning workstation	-	1
B	Touch up and cleaning process	A	1
C	Checked and move part to waiting bay	B	1
D	Settings and stamping process	C	1
E	Move part to quality check workstation	D	1
F	Settings and final inspection process	E	2
G	Move part to waiting bay	F	1
H	Move part to packing workstation	G	1
I	Wrapping process	H	2
J	Move part to waiting bay	I	1
K	Settings of packing	J	2
L	Packing process	K	2

Table 4 *Performance rating of the operators based on processes*

Factor	Operator 1	Operator 2	Operator 3	Operator 4
Work Element	A, B, C	D	E, F, G	H, I, J, K, L
Skill	+0.06	+0.06	0.00	−0.16
Effort	+0.08	+0.05	0.00	−0.04
Conditions	0.00	0.00	0.00	0.00
Consistency	+0.03	+0.01	0.00	−0.02
Algebraic Sum	+0.17	+0.12	0.00	−0.22
Performance Rating	1.17	1.12	1.00	0.78

3.3.3 Allowances

Allowances refer to additional time allowances or adjustments made to the standard time to account for factors that are not directly related to the actual work being performed. This also takes into consideration various factors that could potentially slow down the production process. In essence, these measures offer a buffer for operators, allowing them to maintain a normal pace of a regular workflow without experiencing excessive stress or fatigue. Table 5 below shows related allowances for the packing department.

3.4 Data Analysis

Normal time and standard time are computed to find the most optimal solution for enhancing the production line. The work elements are separated into 5 workstations. The design and organization of workstations play a crucial role in optimizing workflow, productivity, and the overall efficiency of work processes within the packing department. These workstations are primarily based on the cycle time.

After recording average task times for individual work elements, Eqs. (1) and (2) provide a framework for calculating both normal time and standard time. These equations are crucial for determining the expected time required to complete a task efficiently. The following section presents a sample calculation and analysis of normal and standard times for work element A, illustrating the practical application of these equations.

$$\text{Normal time} \quad = 8.26 \times 1.17 = 9.66\ sec$$

$$\text{Standard time} \quad = \frac{9.66}{(1 - 0.12)} = 10.98\ sec$$

Table 5 *Allowances for each work elements*

Work Element	Work Element Description	Total Allowances (%)
A	Move part from waiting bay to touch up and cleaning workstation	12
B	Touch up and cleaning process	15
C	Checked and move part to waiting bay	12
D	Settings and stamping process	15
E	Move part to quality check workstation	12
F	Settings and final inspection process	14
G	Move part to waiting bay	12
H	Move part to packing workstation	12
I	Wrapping process	16
J	Move part to waiting bay	12
K	Settings of packing	11
L	Packing process	14

4. Results and Discussion

4.1 Average Task Time

Task time denotes the duration required for the completion of a specific task or operation within the manufacturing or production process. Finding the average task time is important as it serves as a key metric in understanding and improving the efficiency of the production line.

4.1.1 Average Task Time for Work Elements

Work elements denote a particular and discernible task or activity that plays a role in the broader manufacturing or production procedure. Table 6 below shows the average task time for each of the work elements. From the table, it can be observed that each of the work elements exhibit significant variations in the time required for completion. Minimum average task time observed are at work element A, C, E, G, H and J. The minimum time taken to complete the task is in margin between 8.26 sec to 38.36 sec. Among the 6 work elements, work element A which is moving part from waiting bay to touch up and cleaning workstation, demonstrating the shortest average task time to complete the task with only 8.26 sec.

Table 6 *Average task time for work elements*

Work Element	Work Element Description	Average Task Time (sec)
A	Move part from waiting bay to touch up and cleaning workstation	8.26
B	Touch up and cleaning process	91.15
C	Checked and move part to waiting bay	9.12
D	Settings and stamping process	171.57
E	Move part to quality check workstation	9.73
F	Settings and final inspection process	102.92
G	Move part to waiting bay	10.35
H	Move part to packing workstation	14.91
I	Wrapping process	338.92
J	Move part to waiting bay	38.36
K	Settings of packing	275.22
L	Packing process	469.08

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However, there are notable spikes in the processes of work elements I, K and L, with work element I require 338.92 sec for completion, followed by work element K at 275.22 sec and lastly work element L at 469.08 sec. Particularly, work element L, which is packing process consumes the most time (469.08 sec) to complete compared to the other 2 work elements. Work element L is also registering as the longest average task time duration across all work elements in the production line. Conversely, work element B, D and F exhibit average task time falling within the range between the minimum and maximum average task time groups, with durations ranging from 91.15 sec to 102.92 sec.

4.1.2 Average Task Time for Workstations

Workstation is a designated space where a particular task or a set of tasks is carried out as part of the manufacturing process. Table 7 below shows the total average time for workstations. The work elements for workstations are classified based on the cycle time. The objective is to cluster interconnected work elements in a manner that maximizes workflow, reduces idle time, and guarantees efficient operation of each workstation within the designated cycle time.

Table 7 *Average task time for work elements*

Workstation	Work Element	Total Average Task Time (sec)
1	A, B, C	108.53
2	D	171.57
3	E, F, G	123.00
4	H, I, J	392.19
5	K, L	744.30

The cycle time for the production line is 186 sec/unit. From the cycle time, the work elements are classified into 5 different workstations as shown in Table 7. From the table, total average task time for workstations 1, 2 and 3 are within the cycle time. In addition, workstations 1, 2 and 3 exhibit a similar trend within margin ranging from 108.53 sec to 171.57 sec. However, for workstation 4 and 5, the total average task time exceed the cycle time, indicating that tasks are taking longer than the allotted cycle time. Workstation 4 experience a sudden increase with 392.19 sec. The time continues to increase for workstation 5, reaching 744.30 sec. This conclude that workstation 4 exceed the cycle time by 206.19 sec while workstation 5 exceed it by 558.30 sec more than allotted cycle time. Notably, the time exceeding for workstation 5 is 352.11 sec more than workstation 4. This indicated that workstation 5 has the longest total average task time among the workstations.

4.2 Normal Time and Standard Time

Normal time and standard time are vital as it serves as foundations for establishing realistic performance expectations and enhancing overall efficiency in industrial processes.

Table 8 *Normal time and standard time for work elements*

Work Element	Work Element Description	Normal Time (sec)	Standard Time (sec)
A	Move part from waiting bay to touch up and cleaning workstation	9.66	10.98
B	Touch up and cleaning process	106.65	125.47
C	Checked and move part to waiting bay	10.67	12.13
D	Settings and stamping process	192.16	226.07
E	Move part to quality check workstation	9.73	11.05
F	Settings and final inspection process	102.92	119.68
G	Move part to waiting bay	10.35	11.77
H	Move part to packing workstation	11.63	13.21
I	Wrapping process	264.35	314.71
J	Move part to waiting bay	29.92	34.00
K	Settings of packing	214.67	241.20
L	Packing process	365.88	425.45

4.2.1 Normal Time and Standard Time for Work Elements

Average task time is used as reference in calculating normal and standard time as it is a quantitative measure that reflects the central tendency of the observed task times. Table 8 presents a comprehensive dataset of normal time and standard time data for each of the work elements, gathered through meticulous calculation.

4.2.2 Normal Time and Standard Time for Workstations

After obtaining standard time and normal time for work elements, the times for workstations can be computed based on data in Table 8 above. Table 9 below presents normal and standard time for workstations.

Table 9 *Normal and standard time for workstations*

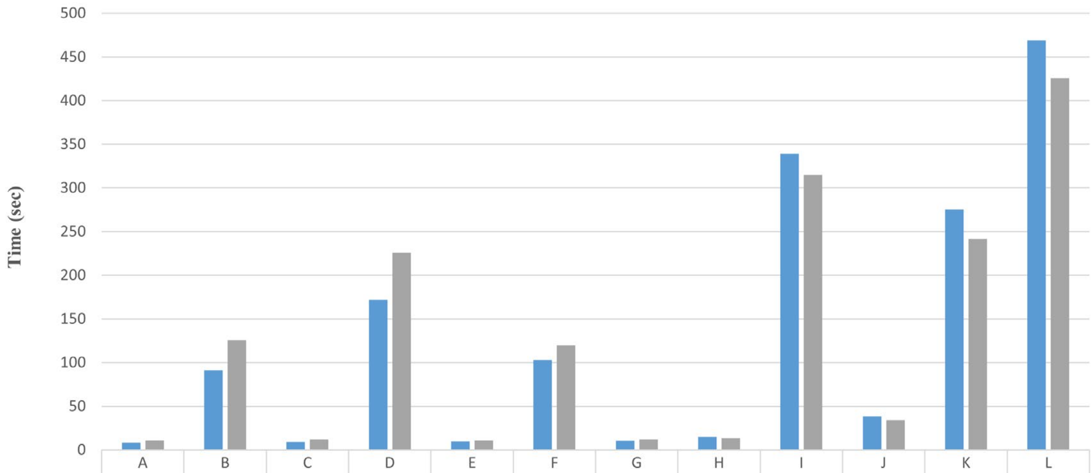
Workstation	Work Element	Total Normal Time (sec)	Total Standard Time (sec)
1	A, B, C	126.98	148.58
2	D	192.16	226.07
3	E, F, G	123.00	142.50
4	H, I, J	305.90	361.92
5	K, L	580.55	666.65

4.3 Standard Operating Procedures (SOP)

Standard Operating Procedures (SOPs) are defined as documented instructions and guidelines that delineate the standardized methods and procedures for executing specific tasks or operations. In this section, a comparison between average task time and standard time is conducted to assess the efficiency of work processes and the performance of operators. This comparison offers insights into how effectively tasks are being executed in relation to standards. The comparisons are conducted in 2 categories: work elements and workstations.

4.3.1 SOP by Work Elements

Fig. 2 below shows a comparison of graph between task time and standard time, where the x-axis of graph represents work elements while the y-axis of graph betokens for time (sec). Analyzing the data on Table 6 and Table 8, it is evident that work element A, B, C, D, E, F and G demonstrate task time lower than the corresponding standard time. This suggests that these tasks are being executed more swiftly or efficiently than the standard expectations.



	A	B	C	D	E	F	G	H	I	J	K	L
Average Task Time	8.26	91.15	9.12	171.57	9.73	102.92	10.35	14.91	338.92	38.36	275.22	469.08
Standard Time	10.98	125.47	12.13	226.07	11.05	119.68	11.77	13.21	314.71	34	241.2	425.45

Fig. 2 *Comparison graph for work elements*

In particular, work element E and G shows tasks completed 1.32 sec and 1.42 sec faster than the standard time, with percentage difference of 12.70% and 12.84%, respectively. Work elements A and C also exhibit slightly faster performance and task completion times compared to E and G, with work element A being 2.72 sec faster and work element C done 3.01 sec faster than the standard time. Both work elements A and C have almost identical percentage differences, standing at 28.27% and 28.33%, respectively. However, work elements B, D, and F display significant differences in time, ranging from 16.76 sec to 54.50 sec, indicating that these tasks are completed much faster than work elements A, C, E, and G. This distinction is visually evident in Fig. 2, where a noticeable gap exists between task time and standard time for work elements B, D, and F.

On the other hand, work elements H and J demonstrate task times exceeding the standard time, indicating that these tasks are performed more slower than the expected standards. Work elements H, I, and J are executed 1.7 sec, 24.21 sec, and 4.36 sec slower than standard time, with percentage differences ranging from 7.41% to 12.09%. Fig. 2 depicts a slight gap between task time and standard time for work element I, where the task time exceeds the standard time. Work elements K and L exhibit substantial differences in time, with tasks taking 34.02 sec and 43.63 sec longer than the standard time. Work element L has the slowest task completion time, indicating the longest duration to among all tasks. This substantial difference is clearly illustrated in Fig. 2, where task time and standard time bar shows the largest gap for work element L compared to work element K.

4.3.2 SOP by Workstations

Observing Fig. 3, tasks at workstations 1,2 and 3 are performed faster than the expected standards. Workstation 2 achieves the fastest task completion, finishing tasks 54.50 sec ahead of the standard time, resulting in a percentage difference of 27.41%. This substantial difference is clearly illustrated in Fig. 3, where a noticeable gap exists between task time and standard time, indicating that task time did not exceed the standard time. Next followed by workstation 1 and 3, where tasks are completed 40.05 sec and 19.5 sec faster than the standard time, with 31.15% and 14.69% percentage difference, respectively.

However, workstation 5 shows a significant disparity between task time and standard time. Task at workstation 5 take 77.65 sec longer than the standard time, resulting in a percentage difference of 11.0%. This significant variance is also apparent in Fig. 3, where a substantial gap exists between the task time and standard time, indicating that task time exceeds the expected completion time. Similarly, workstation 4 completes tasks 30.27 sec longer than the standard time, with a percentage difference of 8.03%. A slight, notable gap is visible in the task time and standard time, where the task time bar is higher than the standard time. This also signifies that task time for workstation 4 surpasses the expected standard, represented by the standard time.

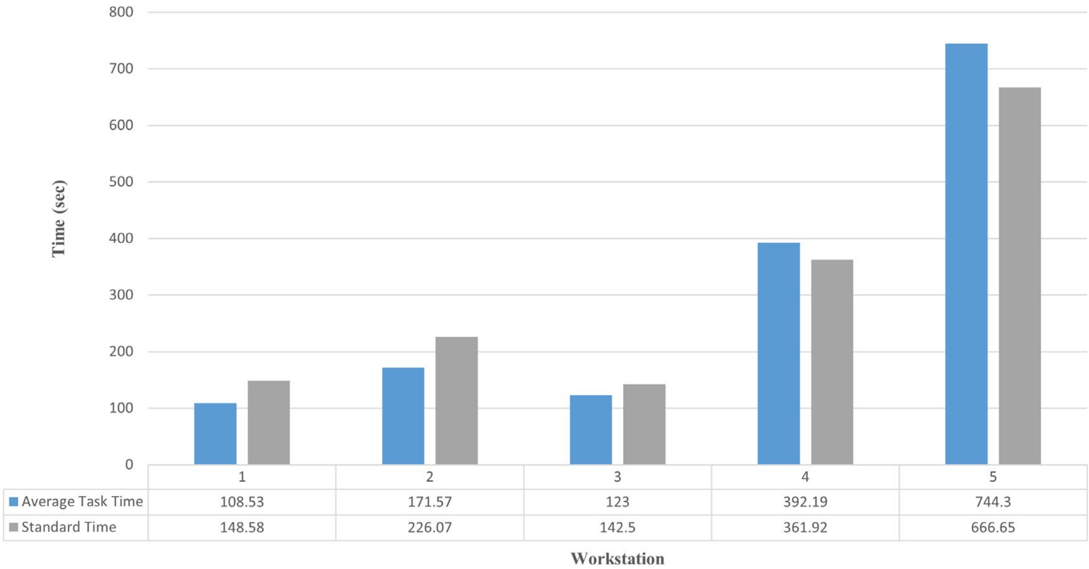


Fig. 3 *Comparison graph for workstations*

4.4 Summarization of Results and Analysis

4.4.1 Work Elements

From Fig. 2, work element I, K and L demonstrate the most time taken to complete the tasks. The average task time for work element I, K and L also exceeded the expected standard time. This indicated a potential bottleneck for these processes. Work element L consistently takes the longest time to complete compared to the other work elements. This extended duration for the packing process was attributed to factors such as complexity of packaging, variability in product sizes and shapes, and customization requirement. Since the packing process relies heavily on manual labor, it is inherently slower than most of the automated packing processes. Manual packing can be more time-consuming, especially if it involves intricate tasks or if the workforce is not optimized. This is the major reason behind this bottleneck for optimizing overall production efficiency. The workforce is also operating at a level of efficiency that is below the established standard. Factors such as skill levels, training, and motivation also contributed to a slower pace of work.

Work element A, C, E, G, H and J displaying the least average task time and did not exceeding the standard time. This suggests that these tasks are relatively straightforward, less time-consuming, and easy to complete. Even though these work elements exhibit the shortest completion times, it is evident that there is still room for improvement, as indicated by the significant percentage difference between average task time, normal time and standard time.

4.4.2 Workstations

From Fig. 3, workstations 4 and 5 emerge as potential bottlenecks, with the total average task time exceeding the cycle time and standard time significantly. This indicates significant operational challenges that need to be addressed and require immediate attention and improvement. The fact that workstations 4 and 5 exceed both the cycle time and standard time suggests the presence of severe bottlenecks. Workstation 5 continuously showcasing the most pronounced inefficiency compared to the other workstations. There are several factors that contribute to this inefficiency, and the most obvious one is insufficient staffing levels or lack of skilled personnel. Performance rating of workers for workstation 4 and 5 is 78%, which means that operators are working 22% slower than normal. This indication shows that operators take longer time to complete the tasks than expected standard.

Workstation 4 and 5 also showcasing a consistent and significant deviation. This suggests potential inefficiencies in the work processes at the workstation. The inefficiencies identified at the workstations may have a cascading effect on the overall production line. Addressing these issues promptly is crucial to maintaining a smooth and streamlined workflow throughout the packing department. As for workstation 1, 2 and 3, the total average task time did not exceed both cycle time and standard time. This shows that these workstations are operating efficiently and contributing to the overall process without causing delays. Even though these workstations did not exceed cycle time and standard time, it still showcases that there is still room for improvement that needed to take to decrease the big percentage difference between total average task time, normal time and standard time. Considering a large percentage difference between normal time and standard time suggests that the actual performance, as represented by the average task time, deviates significantly from the established standard time. This gap may indicate a difference in efficiency or productivity. Factors contributing to the difference could include variations in worker skill levels, changes in equipment, modifications to work processes, or other environmental factors.

4.4.3 Overall Results for Work Elements and Workstations

The analysis of production processes allows for a comprehensive understanding of task durations, worker activity patterns, and potential areas for process improvement. Table 10 below shows delay time for work elements, Table 11 shows total delay time for workstations.

Table 10 *Delay time and analysis for work elements*

Work Element	Work Element Description	Delay Time (sec)	Analysis
A	Move part from waiting bay to touch up and cleaning workstation	-2.72	Fast
B	Touch up and cleaning process	-34.32	Fast
C	Checked and move part to waiting bay	-3.01	Fast
D	Settings and stamping process	-54.50	Fast
E	Move part to quality check workstation	-1.32	Fast
F	Settings and final inspection process	-16.76	Fast
G	Move part to waiting bay	-1.42	Fast
H	Move part to packing workstation	1.70	Slow
I	Wrapping process	24.21	Slow
J	Move part to waiting bay	4.36	Slow
K	Settings of packing	34.02	Slow
L	Packing process	43.63	Slow

Table 11 *Analysis and delay time for workstations*

Workstation	Work Element	Cycle Time	Total Delay Time (sec)
1	A, B, C	Within	-40.05
2	D	Within	-54.50
3	E, F, G	Within	-19.50
4	H, I, J	Exceed	30.27
5	K, L	Exceed	77.65

Analysis of work element completion times revealed minimal delays for work elements A through G, ranging from -2.72 sec to -1.42 sec. This signifies efficient execution and a positive contribution to the overall cycle time. The negative values indicate that these work elements are completed marginally faster than planned cycle time. Conversely, elements H through L exhibited significant delays, ranging from 1.70 sec to 43.63 sec. This suggests inefficiencies within these tasks, leading to a negative impact on the overall production rate.

As for workstations, an examination of total delay times across workstations revealed that workstations 1, 2, and 3 operate within their designated cycle times, exhibiting delays ranging from -40.05 sec to -19.50 sec. This suggests the workstations function relatively efficiently. The negative delay values indicate the presence of buffer time within these workstations, allowing for task completion ahead of schedule. In contrast, workstations 4 and 5 displayed total delay times exceeding their respective cycle times by 30.27 sec and 77.65 sec, respectively. This signifies the presence of critical bottlenecks within these workstations, hindering the overall production flow.

5. Conclusion

In conclusion, time study constitutes a methodical strategy for comprehending and improving work processes. Its significance lies in its capacity to boost workplace efficiency, allocate resources effectively, measure performance, foster continuous improvement, and play a pivotal role in informed decision-making across diverse industrial and business environments. A time study of cover plate components revealed potential workflow improvements. Tasks A, B, C, D, E, F, and G are efficient, but elements H, I, J, K, and L require focus. Workstations 4 and 5 are critical bottlenecks hindering production efficiency. Addressing these bottlenecks is essential to maximize output.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Mohd Hazrein Jamaludin, Aida Husna Ahmad, Saliza Azlina Osman, Shahrul Azmir Osman;* ***data collection:*** *Mohd Hazrein Jamaludin;* ***analysis and interpretation of results*** *Mohd Hazrein Jamaludin, Aida Husna Ahmad;* ***draft manuscript preparation:*** *Mohd Hazrein Jamaludin, Aida Husna Ahmad, Saliza Azlina Osman, Shahrul Azmir Osman. All authors reviewed the results and approved the final version of the manuscript.*

References

[1] Meyers, F. E. (2002). *Motion and Time Study for Lean Manufacturing*.
[2] Lovelady, M., Tramel, N., Funderburk, T., Hossain, M. S. J., and Sapkota, N. *"Motion and Time Study for Increasing Efficiency, Productivity, and Safety for an Unloading Facility".*
[3] A. Freivalds and B. W. Niebel. (2009). *Methods, Standards, and Work Design.*
[4] Studynka, B. A., & Aryanny, E. (2024). Improvement Productivity Menggunakan Metode Time Motion Study Pada Area Dissolving Soy PT XNX. Venus: Jurnal Publikasi Rumpun Ilmu Teknik, 2(1), 99-108.
[5] Pachghare, V., and Dalu, R. S. (2014). Assembly Line Balancing–A Review. *International Journal of Science and Research, 3(3),* 807–811.
[6] Vílchez-Torres, M. K., Cáceres-Pérez, S. M., & Castro-Pérez, D. J. (2021). A Stopwatch Time Study for an Underground Mining Extraction. *Dyna*, *88(218),* 152-158.
[7] Budiman, I., Sembiring, A. C., Tampubolon, J., Wahyuni, D., & Dharmala, A. (2019). Improving effectiveness and efficiency of assembly line with a stopwatch time study and balancing activity elements. Journal of Physics: Conference Series, 1230, 012041. doi:10.1088/1742-6596/1230/1/012041.

[8] Puvanasvaran, A. P., Mei, C. Z., & Alagendran, V. A. (2013). Overall equipment efficiency improvement using time study in an aerospace industry. Procedia Engineering, 68, 271-277.
[9] Aft, L. S. (2000). *Work Measurement and Methods Improvement* (Vol. 9). John Wiley & Sons.
[10] Machado, R. H. C., Helleno, A. L., de Oliveira, M. C., Santos, M. S. C. D., & Dias, R. M. D. C. (2019). Analysis of the Influence of Standard Time Variability on the Reliability of the Simulation of Assembly Operations in Manufacturing Systems. *Human Factors*, *61(4),* 627-641.
[11] Marasabessy, U. R., Astrides, E., Ahistasari, A., Wahyudien, M. A. N., & Rachmadhani, M. M. (2023). Analysis of Work Measurement Using the Stopwatch Time Study Method at PTEA. Journal of Industrial System Engineering and Management, 2(1), 23-31.
[12] Lukodono, R. P., & Ulfa, S. K. (2018). Determination of standard time in packaging processing using stopwatch time study to find output standard. JEMIS (Journal of Engineering & Management in Industrial System), 5(2), 87-94.
[13] Taifa, I., & Vhora, T. (2019). Cycle Time Reduction for Productivity Improvement in the Manufacturing Industry. *Journal of Industrial Engineering and Management Studies, 6(2),* 147-164.
[14] López, J., Franco, C., Martínez, I., Dueñas, R., García, M., Lastra, S., & Ponce, M. (2019, November). Simultaneous Non-Intrusive Monitoring of Environmental Parameters for Standard Time Synchronization as Part of the Westinghouse System of Rating in the Industrial Sector. In 2019 *International Conference on Mechatronics, Electronics and Automotive Engineering (ICMEAE)* (pp. 87-90). IEEE.
[15] Cevikcan, E., & Kilic, H. S. (2016). Tempo Rating Approach using Fuzzy Rule Based System and Westinghouse Method for the Assessment of Normal Time. *International Journal of Industrial Engineering*, *23(1).*
[16] Yovi, E. Y., Prasetiana, D., & Nirmalasari, N. A. (2021). Work Measurement Study on Motor-Manual Pine Tapping Operation: The Application of the Concept of Lean Manufacturing and Allowances*. Indonesian Journal of Forestry Research*, *8(1),* 111-125.
[17] D. K. Adhwarjee. (2013). Establishment of Standard Time in Different Sections/ Departments of a Large Heavy Engineering Industry.
[18] Barnes, R. M. (1991). *Motion and Time Study: Design and Measurement of Work*. John Wiley & Sons.
[19] El Mouayni, I., Etienne, A., Lux, A., Siadat, A., & Dantan, J. Y. (2020). A Simulation-Based Approach for Time Allowances Assessment during Production System Design with Consideration of Worker's Fatigue, Learning and Reliability. *Computers & Industrial Engineering,* 139, 105650.
[20] Shukla, H. M., Ganvir, K. D., Joshi, M. P., & Gupta, I. (2023, July). Revamping Machining Operator Allowances through Standard Time Estimation using MOST Technique. In *2023 14th International Conference on Computing Communication and Networking Technologies (ICCCNT)* (pp. 1-6). IEEE.
[21] Ferreira García, K. Y., de la Riva Rodriguez, J., Sánchez Leal, J., Reyes-Martínez, R. M., & Prieto, A. W. (2019). Determination of Allowance Time by Work Sampling and Heart Rate in Manufacturing Plant in Juárez México. *Journal of Engineering*, 2019.