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Analysis of Lead Time Reduction in Pre-Delivery Installation Process of Excavator Units at PT. XYZ Assembly Plant

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Abstract

The Pre-Delivery Installation (PDI) Department of PT. XYZ is tasked with carrying out the installation process of imported heavy equipment attachment units, including one of the leading excavator units. Obstacles that arise can affect installation productivity. The gap between the actual installation results of 78 units and the company's target of 156 units requires a solution or resolution to improve the process that can be implemented. Therefore, it is necessary to investigate the wait time associated with decreased productivity, which is the longest component of the installation process. This work has a purpose to analyze lead time of the excavator attachment unit installation process. The method is applied with a time study approach referring to data sheets and observations, then processing lead time data using pie charts, Pareto diagrams, and fishbone diagrams. Furthermore, we review the planning calendar, realization, and improvement engineering. Reduction is carried out by providing additional work personnel and procuring sanding machine tools to reduce the installation and critical time of the planning calendar. The realization condition for 562 minutes with the implementation of improvement engineering is reduced to 318 minutes. Thus, it can speed up implementation time of the excavator attachment in unit installation process to 224 minutes or 44%.

Keywords: heavy equipment; productivity; pie chart; Pareto diagram; fishbone diagram.

1. Introduction

Heavy equipment is a crucial utility in large-scale construction projects [1]. Its use facilitates human work, enabling desired results to be achieved more easily and in a relatively short time [2]. The rapid development of the 4.0 construction industry requires smart construction, and the challenges faced are increasingly diverse and complex [3]. One significant challenge relates to increasing productivity, a challenge that arises with the increasing demand for infrastructure improvements. The use of heavy equipment construction technology provides opportunities for more efficient, intelligent, and interconnected work [4].

PT. XYZ, a Japanese-technology heavy equipment manufacturing company located in Jakarta, markets excavators and other products. Excavators are generally used for excavation, lifting, and moving materials such as soil, rock, and sand. This utility has a movable arm mounted on the front and a bucket attached to the end for digging. Plant Assembly is a division under the coordination of the Pre-Delivery Installation (PDI) Department of PT. XYZ. This department has the main task and function of carrying out attachment installation process for imported units. During the implementation of these activities, obstacles inevitably occur, which can affect decreased productivity [5]. To mitigate this, the company must implement improvement activities. Improvement activities are mandatory programs implemented by the management level in work units to improve performance [6]. This activity is carried out to investigate the root causes problems related to installation of the attachment unit, using a specific approach. Hence, suggestions and input can be provided for improving the work system to address the problems that occur [7]. The following are similar research activities that have been carried out by researchers to improve performance.

Masuti and Dabade [8] investigated manufacturing construction equipment where 12 booms were produced per day, while the actual customer demand was 15 booms per day. Lean implementation, by eliminating excess

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inventory and reducing total cycle time and setup time at various stations, was engineered and implemented. Machine breakdowns, inventory shortages, and equipment unavailability caused delays in meeting demand. Projection research outcome showed that implementing lean could shorten the time spent on value-added activities by 156 minutes, simultaneously reducing 430 minutes of non-value-added activities. This contributed to a total reduction in production lead time of 586 minutes.

Samad et al. [9] conducted reduction of manufacturing lead time by value stream mapping of a factory in Bangladesh. Adopting lean methodology comprehensively in the garment business is crucial for long-term sustainability in this highly competitive context. The objective of this activity was to identify waste and reduce production lead times by eliminating or reducing redundant tasks that lead to longer lead times, applying lean concepts. During the observation, a time study methodology was applied to collect data. The necessary information was gathered by observing the process and interacting with management elites. Next, a value stream mapping of the status was created. Waste causing longer lead times was ranked using an 80-20 rule diagram. Root cause analysis was then conducted to analyze undesirable time consumption. Lean improvement strategies such as kanban were chosen to reduce work-in-process (WIP). So does single minute exchange of break used to lessen changeover time, while total productive maintenance was applied to decrease machine breakdowns and minimize waste. Based on the improvement strategies, engineering projections of the value stream mapping showed an increase in improvements, with total manufacturing lead times reduced by 61.20%. The results of this activity yielded several recommendations for management of the selected RMG factory to minimize waste, increase efficiency, and reduce waste in operations.

Singh and Singh [10] applied lean manufacturing in automotive the manufacturing unit. The purpose of this activity is to implement lean manufacturing using value stream mapping (VSM) in a manufacturing organization (automotive suspension and fastener components). The design, methodology, and VSM approach are used in implementing lean stages in the U-bolt section. Projections have been prepared and then implemented. Furthermore, engineering has been carried out to compare current and future projections. The findings obtained were an 87.59% reduction in cycle time (C/T), a 76.47% reduction in WIP inventory, a 95.41% reduction in production lead time, a 66.08% increase in value-added ratio (VA), a 95.78% reduction in non-value-added time (NVA), a 57.14% reduction in the number of operators, and a 70.67% reduction in changeover time (C/O) for the u-bolt section. Engineering and VSM of the current condition and future projections have been obtained from observations, and an error of 5 seconds has been found.

The time study introduced by Taylor and the motion study further developed by Gilbreth are two distinct and separate concepts. Time study was initially used to determine standard time, while motion study was used to improve work methods. In the United States, Taylor (1856–1915) conducted time studies using stopwatches. In addition to studying work time, Taylor also contributed to the principles of scientific management, productivity, the study of tool life, tool grinders, slide rules, and the development of functional organizational models [11].

Based on three similar studies in this activity at PT. XYZ during the internship, investigative research was conducted at the longest process in the installation of excavator unit attachments. Attachment installation including the installation of boom, arm, and bucket components is a concern for observation. To reduce the lead time of attachment installation process, improvements need to be made that take the longest time. The purpose of this activity is to analyze the lead time in the installation process of excavator unit attachments in the PDI Department at PT. XYZ.

2. Experimental Methods

Research activities at PT. XYZ during internship, the Company has a policy in which interns participate in a development program involving case studies with an improvement approach [12]. This is available as a means of practice and competency improvement [13]. Furthermore, regarding the challenges of technical problems in increasing the productivity of joint industrial activities, historical activity data is collected referring to the logbook available in the relevant section as previous research. Time measurements are carried out directly when the research is achieved. Time data collected at one time according to the due date given by the Company's management during the research period. Time data is validated by reporting results of the research time that has

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been carried out for further improvements to reduce the pre-delivery process of excavator unit installation. The implementation methods for solving them are presented in Figure 1.

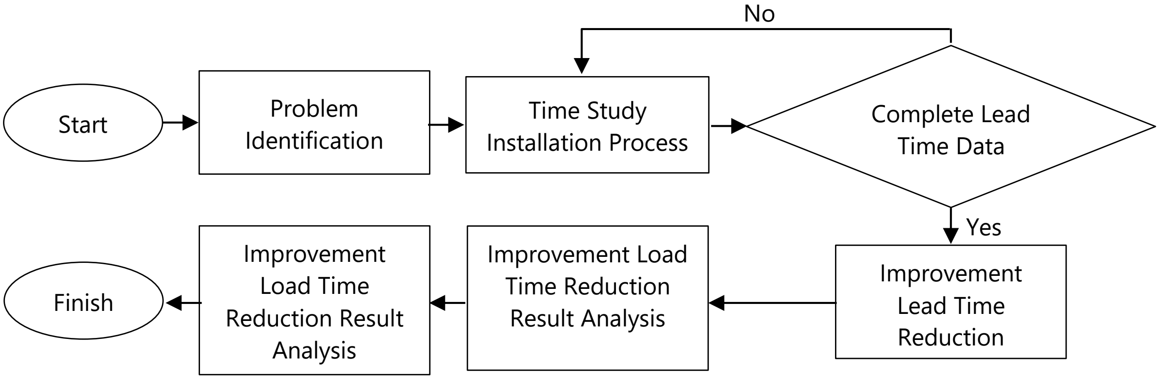

Figure 1. Research flow diagram

2.1. Problem Identification

Problem identification is the first crucial step in time study. When a researcher identifies a phenomenon with potential for research, the next step is to urgently identify the problem within the observed phenomenon. The assembly plant is a continuation of other plants within the company, including the foundry, fabrication, and hydraulic plants. The assembly plant's primary task and function is to assemble products that pass through the previous plant into finished goods. Furthermore, under coordination of the assembly plant is the PDI division. There is a close link between the assembly plant and the installation and modification process of imported units. This process involves a series of steps necessary to adjust imported units to meet the standards and requirements ordered by customers.

Table 1. Attachment installation process

Unit	Boom	Arm	Bucket	Grapple	C/W	C-Frame	Blade	Ripper	Scarifier	Painting	Mnt	Komtrax	Fuel Guide	CR
PC200-10M0CE KS	☑ China	☑ China	✓ SAS		☑ China									
PC210-10M0 BKC	☑ Thailand	☑ Thailand	✓ SAS		☑ Thailand							✓ PDW		
PC210-10M0 KSC	☑ China	☑ China	✓ SAS		☑ China							✓ PDW		
PC300-8M0	☑ Thailand	✓ KMI	✓ KMI		☑ Thailand									
PC300-8M2										✓ Timag				
PC350LC-8M2										✓ Timag				
PC500LC-10R	✓ Japan	✓ Japan	✓ Fab. Cib		✓ Ondo									
PC70-8 KSC												✓ PDW		
PC71-7	☑ India	☑ India	☑ India		☑ India							✓ PDW		
PC45MR-3										✓ Timag				
PC55MR-3														
D85ESS-2A						☑ Japan	☑ Japan							
D31EX-22						☑ Japan	☑ Japan							
D31PX-22						☑ Japan	☑ Japan							
D39EX-22						☑ Japan	☑ Japan							
D39PX-22						☑ Japan	☑ Japan							
D65E-12						☑ Japan	☑ Japan			✓ Timag			✓ PDW	✓
D65P-12						☑ Japan	☑ Japan			✓ Timag			✓ PDW	✓
GD535-5							☑ Japan	☑ Japan	☑ Japan	✓ Timag				
HB365-1	✓ Fab. Cil	✓ KMI	✓		✓ Japan									
HB365LC-1	✓ Fab. Cil	✓ KMI	✓		✓ Japan									
WA150-6			☑ Japan							✓ Timag				
WA200-6			☑ Japan											
WA320-6			☑ Japan											
WA380-6			☑ Japan											
WA480-6			✓ Fab. Cib											
WA500-6R			✓ Fab. Cib											
WB93R-5E0										✓ Timag				
HD785-7										✓ Timag				
MH875										✓ Timag				

☑ : Process by maker
✓ : Process by KI

The assembly plant consists of various divisions, including the large machine division, the medium machine division, and the PDI division. The PDI division plays a crucial role in the installation process of imported unit attachments. This process is a crucial stage in which imported units are installed and prepared before being

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shipped to various locations. The PDI serves as a liaison between the assembly of attachments to various units and the final preparation before the product reaches the customer.

The installation process is not only carried out by PT. XYZ, but there are several external partners, including PT. TXV and PT. WPB, who support PT. XYZ's manufacturing performance. PT. TXV is responsible for carrying out the paint coating process and installing labels for imported units. Meanwhile, PT. WPB is responsible for conducting surveys of imported units, installing Komtrax or remote monitoring equipment provided by the company, and also refueling imported units [14].

Based on Table 1, excavator unit is the unit that most often undergoes attachment installation processes, thus providing a strong reason to be able to identify problems that exist in the attachment installation process. A process flow map is a map that describes all activities, both productive activities (operation and inspection) and non-productive (transportation, waiting, and storage), where the activities involved in the work implementation process are described in detail from start to finish. Attachment installation on an excavator unit is the process of installing modified components, such as the boom, arm, bucket, and counterweight. The excavator has been upgraded from the previous unit, where the fuel consumption has been modified for a longer period use. In completing installation stage of the imported unit, there is a process flow that explains the stages that must be passed for the success of activities within the division. The processes completed are as shown in Figure 2.

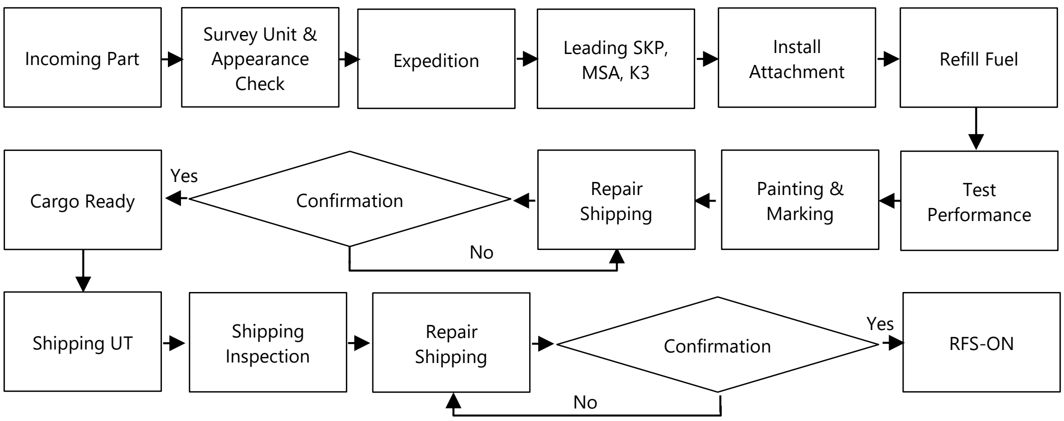

Figure 2. Pre-delivery division installation activity

a. Incoming Port

Imported units from abroad arrive in Indonesia and are then installed by PT. XYZ.

b. Unit Survey and Appearance Check

This stage involves inspecting the physical condition and appearance of the new unit. This activity takes place at the port and is carried out by PT. WPB.

c. Expedition

This stage involves shipping the unit from the port to the yard within PT. XYZ's premises by the Marketing and Support representative in Indonesia.

d. Loading SKP, MSA, and KI

Units shipped from the port are then placed in various yards adjacent to PT. XYZ's premises. These yards include the SKP yard, MSA yard, and PT. XYZ's yard. This stage is performed by PT. WPB.

e. Install Attachment

Install Attachment is the installation of additional component attachments, a key step in the PDI division's activities. This stage takes place at the assembly plant and is done by PT. WPB.

f. Fuel Refill

Fuel refilling is performed after the unit installation process. The unit is filled to ensure the fueled unit is ready for shipment. This activity is finished by PT. WPB.

g. Performance Test

After the unit is refueled, a performance test is performed on the unit. This aims to determine the unit's condition and ensure there are no defects once it reaches the customer. This stage is accomplished by the PT. XYZ inspection team.

h. Painting + Marking

The next process involves painting and labeling the unit. This process allows for repainting damaged body parts and affixing the company's identity to the unit. This process is completed by PT. TXV.

i. Shipping Inspection

This stage involves the PT. XYZ inspection team conducting a pre-shipment inspection to guarantee the unit's condition.

j. Repair Shipping

This stage is carried out by PT. TXV and PT. WPB. At this stage, the inspected unit undergoes repairs to ensure it is ready for shipping, should any damage occur during the previous stage.

k. Confirmation

This stage confirms the unit's condition and ensures it is ready for shipping. This stage is performed by the PT. XYZ inspection team.

l. Cargo Ready

After confirmation, the unit is then assigned a status indicating it is ready for shipping. This stage is done by the PT. XYZ inspection team.

m. UVW Shipping

The next stage is delivering to the yard owned by PT. UVW.

n. Repair Shipping

After shipping, the unit that has arrived at PT. UVW undergoes repairs for any damage sustained during shipping. This activity is conducted by PT. TXV and PT. WPB.

o. Confirmation

After repairs are completed, the repair results are inspected by PT. XYZ. This aims to ensure the unit is free from damage from start to finish.

p. Ready For Sales (RFS) and Delivery Note (DN)

After all stages are completed, the RFS and DN sections provide a status statement indicating the item's readiness for sale and its inclusion on the delivery note in the sales transaction.

The installation process includes the installation of the boom, arm, bucket, and counterweight (Figure 3). The boom is a component that connects the cabin to the arm, its function is to allow the arm to reach further areas and work optimally when picking, compacting, and digging material. The arm is a component that connects the boom and bucket, its function is quite important, namely allowing the bucket to reach distant areas and moving more flexibly. The bucket is the main component on the excavator which is shaped like a basket equipped with

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teeth or forks at the end. The counterweight has functions to maintain the balance of the excavator while operating.

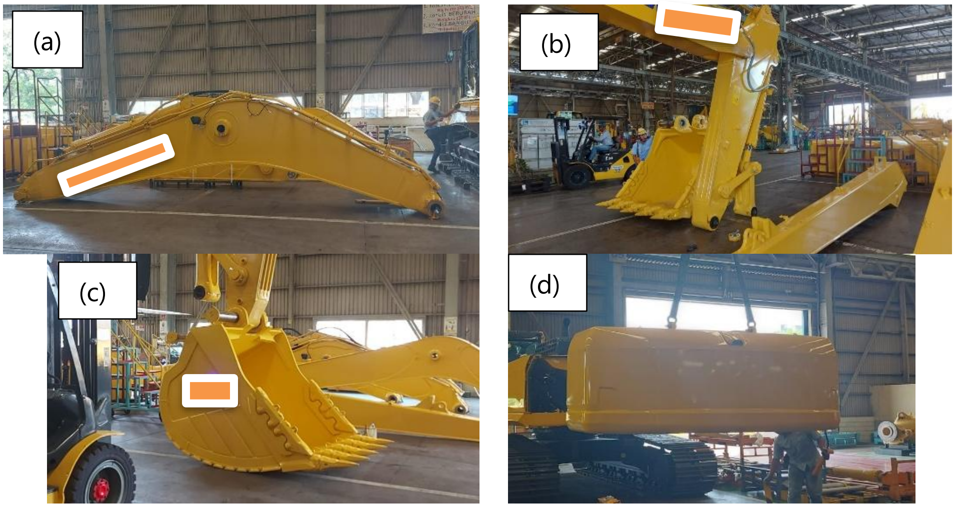

Figure 3. Excavator parts (a) Boom, (b) Arm, (c) Bucket, and (d) Counterweight

The installation of imported excavator attachments at the assembly plant underwent various processes until the unit was considered complete. Observations of the processes at the installation station identified several steps requiring accelerated processing times. Some attachment installations did not align with the planned production calendar for excavator attachments. Therefore, time study was required to determine the time required to complete these processes.

2.2. Installation Process Time Study

A time study is a labor productivity measurement technique that involves establishing time standards for a task or job. This method involves direct observation of work activities, measuring the time required for each step, and analyzing factors that can affect the speed and efficiency of task execution. Data processing utilizes data input and generates useful information to accelerate the planned schedule and prevent production from falling behind schedule.

The time study data recording and process analysis were carried out simultaneously, beginning with direct observation of each excavator assembly process at the worksite. Then, each stage was calculated for its processing time, including both waiting time and processing time. However, in accordance with the standard time study implementation stages at the PT. XYZ uses five process factors as categories to analyze the attachment installation steps, including:

a. Assembling

This process involves installing components into the unit being assembled, including the installation of connecting elements such as bolts and nuts. This activity can be categorized as adding value to the unit being assembled.

b. Preparation

This process includes preparing tools, equipment, and materials, as well as installing auxiliary equipment into the unit before completing the next action or process. Please note that this step does not add value to the unit being assembled (non-value added).

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c. Moving & Carrying

This process involves the operator moving from one location to another, either carrying or without tools or objects in their hands.

d. Checking

This process involves inspecting components that have been assembled into the unit, including adjustments to optimize component function.

e. Others

These are other processes performed by operators outside of the unit assembly activity, such as sitting, discussing, removing and putting on gloves, taking notes, and so on.

2.3. Data Processing

Data processing is based on the planned installation calendar for imported excavator units, compared to actual implementation conditions and shown in Figure 4. It clearly shows that the installation of the excavator attachment unit has been delayed compared to the previously established planning calendar. It indicates certain obstacles or challenges in the installation process. The delay significantly impacts the overall process and schedule, necessitating an evaluation and review to identify the causes of delay and formulate appropriate corrective measures.

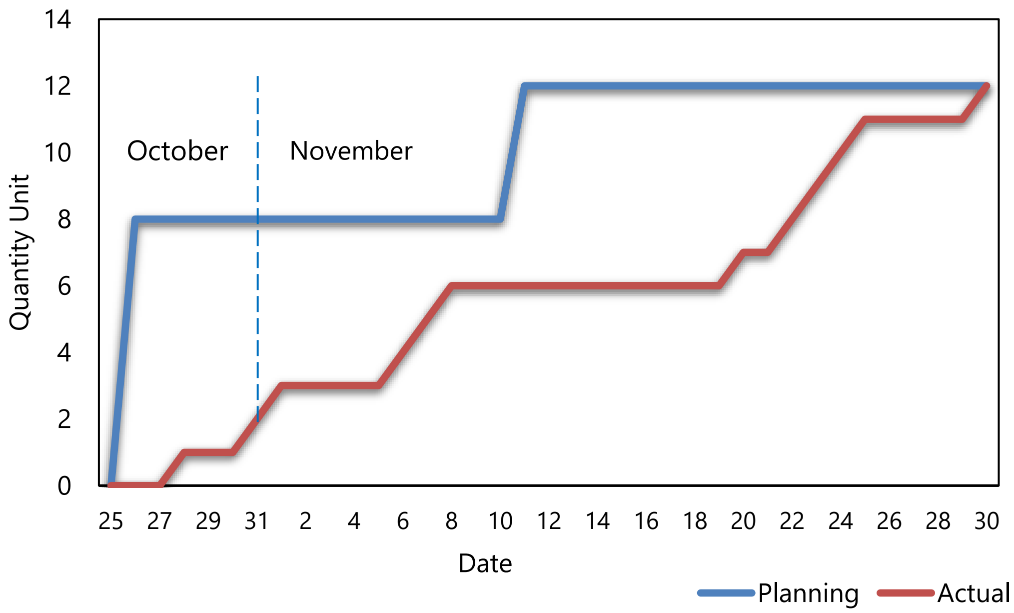

Figure 4. Comparison between planning activity and realization activity

3. Results and Discussion

The time study was conducted carefully by reviewing the installation data sheet. Then we confirmed with the relevant installation unit and validated the information's accuracy. The following are the time study results, as shown in Table 2.

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Table 2. Results of the excavator unit installation time study

No.	Activity components	Information	Duration (minutes)
1	Preparation	Cleaning the station	11
2	Preparation	Preparing tools and attachments	8
3	Moving and carrying	Removing anti-rust lubricant	3
4	Preparation	Removing rust from the arm cylinder	20
5	Preparation	Removing rust from the arm cylinder	6
6	Preparation	Removing rust from the cylinder pin	22
7	Preparation	Removing rust from the cylinder pin	7
8	Preparation	Removing rust from the boom pin	14
9	Preparation	Removing rust from the boom pin	6
10	Moving and carrying	Removing bolts	3
11	Assembling	Installing the grip	7
12	Assembling	Installing the lights on the boom	4
13	Assembling	Installing two boom cylinders	13
14	Others	Coffee Break	10
15	Moving and carrying	Relocating the unit	6
16	Assembling	Installing the boom center pin	21
17	Moving and carrying	Removing the housing	3
18	Assembling	Installing the cylinder housing	19
19	Assembling	Installing the grease tube	5
20	Assembling	Installing the step	8
21	Moving and carrying	Removing the crane	4
22	Preparation	Installing the crane sling hook to the boom	6
23	Others	Removing the housing oil	11
24	Assembling	Removing the boom from the unit	20
25	Assembling	Installing the boom cylinder	14
26	Others	Lunch break	60
27	Preparation	Refilling grease	6
28	Assembling	Installing the arm pin	19
29	Moving and carrying	Removing the boom hose from the arm	3
30	Assembling	Installing the boom hose on the arm	34
31	Moving and carrying	Removing the crane	5
32	Assembling	Installing the arm	27
33	Others	Coffee Break	10
34	Moving and carrying	Removing the impact machine	2
35	Moving and carrying	Removing the crane	5
36	Preparation	Installing the crane sling hook to the boom counterweight	7
37	Assembling	Installing the counterweight	43
38	Moving and carrying	Relocating the impact machine	3
39	Moving and carrying	Relocating the unit	4
40	Assembling	Installing the bucket pin	13
41	Preparation	Lubricating the grease bucket	5
42	Preparation	Filter replacement	14
43	Assembling	Installing the mirror	11
44	Preparation	Filling the grease bucket	4
45	Preparation	Filling the arm and boom cylinders with grease	11
46	Preparation	Filling the hydraulic oil	14
47	Checking	Unit flushing	11

From the time study data, the total time for each activity component can be calculated, along with the length of the implementation process. The following is a summary of the implementation time calculations, shown in Table 3.

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Table 3. Duration of excavator unit installation activities

Activity components	Duration (minutes)
Assembling	258
Preparation	161
Others	91
Moving & carrying	41
Checking	11
Total	562

The time study recapitulation shows that the entire attachment unit installation process took a total of 562 minutes, or the equivalent of 9 hours and 22 minutes. This result indicates a significant amount of time required to resolve issues within this installation component. This time calculation is crucial for evaluating process efficiency, identifying potential points for improvement, and planning productivity improvement strategies at the Plant Assembly. To facilitate observation of installation time in each process within the overall attachment installation process, the data in Table 3 is presented in the form of a pie chart, as shown in Figure 5.

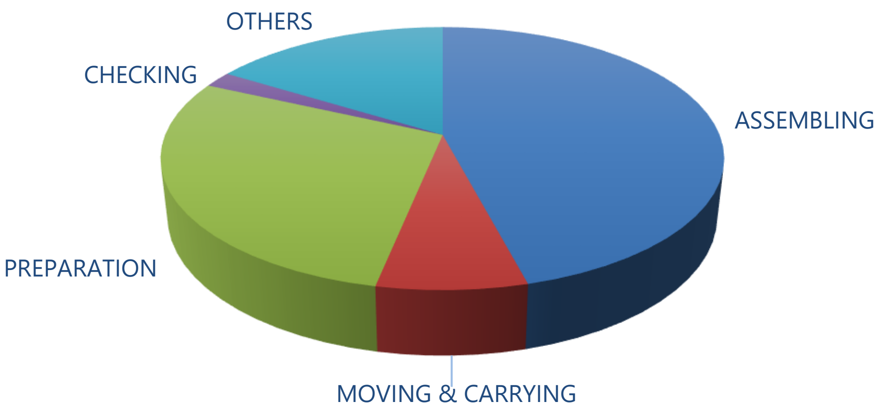

Figure 5. Installation attachment pie diagram of excavator unit

The excavator attachment installation process component, through a time study, revealed that the installation time took longer than the company's target. Inspections were conducted at each stage. Obstacles or challenges that occurred required solutions or resolutions to improve the process, because these obstacles created a gap between the actual results of 78 units and the desired plan of 156 units as shown in Figure 6. Solutions can be defined as concrete methods or actions designed to provide adequate solutions or responses to certain obstacles. Engineering is a method that involves numerical elements.

The results were then observed and analyzed to understand the system's characteristics. Obstacles to the installation process and root causes were identified step by step using several problem-solving methods, including a sequential approach using a Pareto diagram. A Pareto diagram provides a bar graph visualization that depicts problems based on the frequency of occurrence. The order is applied from the most frequent obstacle to the least frequent. In this context, a Pareto diagram provides an overview of the actions or events most frequently performed by operators across all process categories. The following is a summary of the input data into the Pareto diagram, shown in Figure 7.

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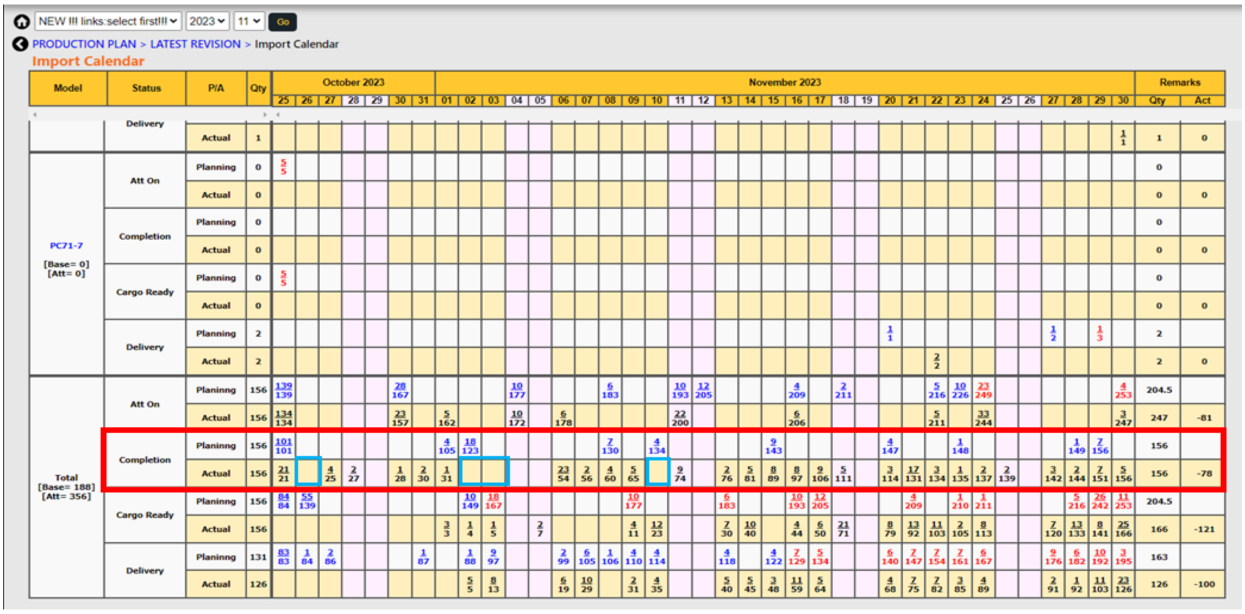

Figure 6. Comparison of plan and actual realization

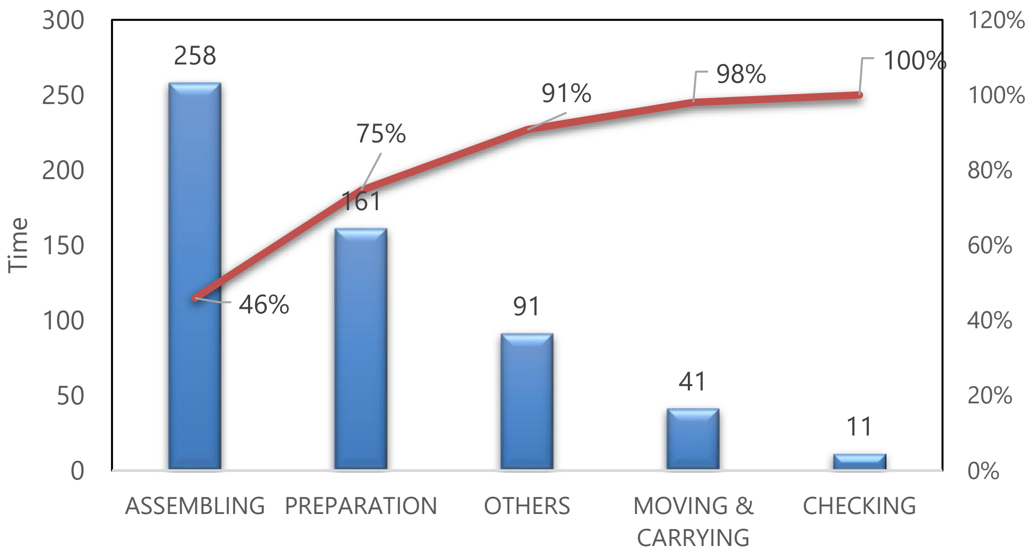

Figure 7. Pareto diagram: duration of the excavator unit installation attachment process

Based on the diagram, of all the installation activities, the most time-consuming process is assembly, followed by the preparation process. The assembly process takes a long time because the counterweight installation must be carried out in stages. Furthermore, the alignment of the two sides of the body is required, which is done repeatedly by one operator. Meanwhile the other operator installs bolts on the bottom of the counterweight using an impact wrench.

After the Pareto diagram is compiled, the next step is to construct a fishbone diagram, also known as a fishbone diagram [15], [16]. This is an effective analytical method or tool for identifying and investigating the root cause of a problem. This approach allows teams or individuals to systematically detail the factors that may contribute to an issue or obstacle. The following is a fishbone diagram applied to advanced processing, shown in Figure 8.

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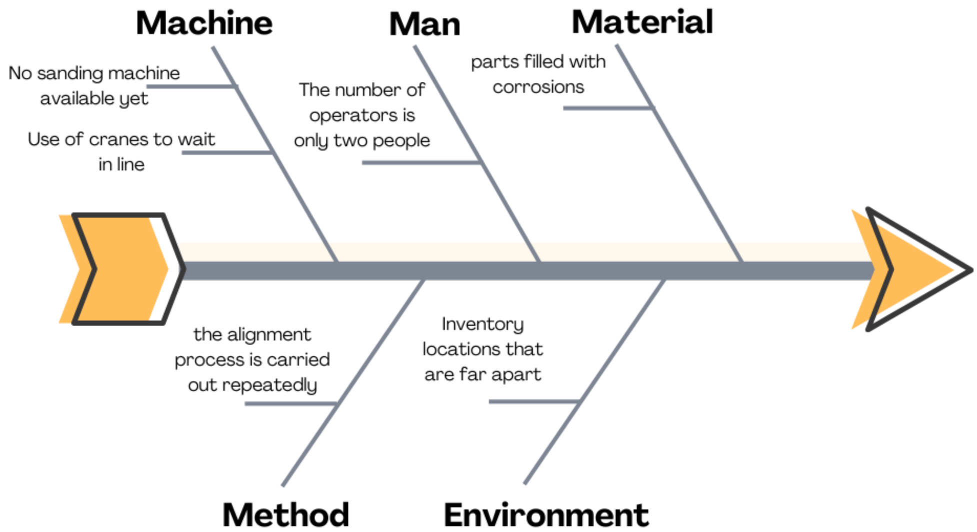

Figure 8. Installation attachment fishbone diagram of excavator unit

After conducting observations and receiving input from operators, the researcher obtained a clear picture of the various factors that were the main causes of the long installation time. Visual analysis of the images revealed several factors that could be identified as contributing to the prolonged installation time. The preparation phase, based on field observations, as shown in Figure 9, revealed that the pin and hole corrosion cleaning process took too long. This was because the cleaning was performed by only one worker and still using manual abrasive sanding without the aid of a sanding machine [17].

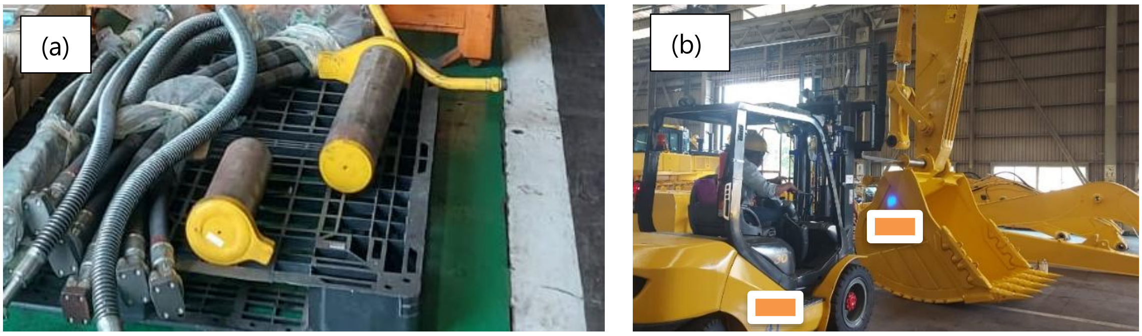

Figure 9. Findings on the length of the sanding process (a) Pin and (b) Removing pin

After each pin and hole had been cleaned of corrosion, the installation process proceeded. If the installed pins were not properly cleaned the corrosion, the installation process tended to be lengthy. The installation of the center pins also took a long time because the pin holes in each mechanical component were difficult to pin, requiring the assistance of a forklift for pushing. The design process solution required an engineering phase, where the engineering aimed to create a predictive picture of efforts to accelerate the installation. In this context, engineering became a highly effective tool for detailing the predicted acceleration of the installation process and comparing it to the previously prepared planning calendar.

Efforts to reduce the time required to clean corrosion on pins and holes using a sander [18]. Accelerating this process with proper methods can significantly impact the installation of all other components. The sander required is shown in Figure 10.

Konversi Energi dan Manufaktur
P-ISSN : 2339-2029
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Jurnal Konversi Energi dan Manufaktur
Volume 11 Number 1 – January 2026 Page 37-52
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Figure 10. Sanding machine tube sander type

Corrosion removal on pins and holes can be performed using a tube sander. This process is quicker and results in a smoother surface, accelerating subsequent assembly processes [19]. When facing situations where labor shortages are a problem, the solution is to increase the number of personnel. Increasing the number of personnel can have a positive impact, particularly in improving time efficiency during the attachment installation process. Several significant benefits are anticipated from the addition of personnel, such as optimized productivity, reduced processing time, increased precision and quality, reduced individual workload, flexibility in task management, and meeting company needs.

Adjusting working conditions and the assigned workload is a consideration when increasing the number of personnel to accelerate the excavator attachment installation process. Applying mathematical calculations using the work output projection approach can determine the number of additional personnel needed to meet predetermined targets. The work output approach is a formulaic calculation that considers the results of workload identification from the work output of each position level. Applying this approach requires the following information:

a. The form of work output and its units.
b. The total workload resulting from the work output target to be achieved.
c. Average competency standards for achieving work results.

Work output of each position can be determined by the formula below:

$$\frac{\sum \text{Work Load}}{\text{Average ability standard}} \times 1 \text{ person} \qquad (1)$$

After understanding the formula used, a standard unit of average capacity is then provided, where at the PDI station the installation process is generally able to complete one unit per day with a workforce of 2 (two) personnel. Next, a projected work achievement target is given, where the workload is applied, namely 1.5 units per day, or three units in two days. It can be formulated as follows.

$$\frac{1{,}5 \text{ unit}}{1 \text{ unit}} \times 2 \text{ people} = 3 \text{ people} \qquad (2)$$

Based on the calculation formulation, the number of work personnel needed to complete the excavator unit attachment installation process is three. The addition of one work personnel to complete the work target can be met, for a projection of three units per two days. Engineering the implementation of the installation process is finished after obtaining engineering data. It was processing to evaluate the engineering projections previously explained in the attachment installation process. Engineering is considered as a tool to project and analyze the impact of the proposed improvements. The engineering time for the improvement process is shown in Table 4.

Konversi Energi dan Manufaktur

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Volume 11 Number 1 – January 2026 Page 37-52
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Table 4. Work duration improvement for the time study installation attachment of the excavator unit

No.	Activity component	Information	Duration (minutes)
1	Preparation	Cleaning the station	5
2	Preparation	Preparing tools and attachments	3
3	Moving and carrying	Removing anti-rust lubricant	3
4	Preparation	Removing rust from the arm cylinder	6
5	Preparation	Removing rust from the arm cylinder	4
6	Preparation	Removing rust from the cylinder pin	4
7	Preparation	Removing rust from the cylinder pin	3
8	Preparation	Removing rust from the boom pin	4
9	Preparation	Removing rust from the boom pin	3
10	Moving and carrying	Removing bolts	3
11	Assembling	Installing the grip	4
12	Assembling	Installing the lights on the boom	4
13	Assembling	Installing two boom cylinders	4
14	Others	Coffee break	10
15	Moving and carrying	Relocating the unit	6
16	Assembling	Installing the boom center pin	8
17	Moving and carrying	Removing the housing	3
18	Assembling	Installing the cylinder housing	8
19	Assembling	Installing the grease tube	5
20	Assembling	Installing the step	4
21	Moving and carrying	Removing the crane	4
22	Preparation	Installing the crane sling hook to the boom	5
23	Others	Removing the housing oil	11
24	Assembling	Removing the boom from the unit	10
25	Assembling	Installing the boom cylinder	6
26	Others	Lunch break	60
27	Preparation	Refilling grease	6
28	Assembling	Installing the arm pin	9
29	Moving and carrying	Removing the boom hose from the arm	3
30	Assembling	Installing the boom hose on the arm	4
31	Moving and carrying	Removing the crane	5
32	Assembling	Installing the arm	8
33	Others	Coffee break	10
34	Moving and carrying	Removing the impact machine	2
35	Moving and carrying	Removing the crane	5
36	Preparation	Installing the crane sling hook to the boom counterweight	6
37	Assembling	Installing the counterweight	14
38	Moving and carrying	Relocating the impact machine	3
39	Moving and carrying	Relocating the unit	4
40	Assembling	Installing the bucket pin	5
41	Preparation	Lubricating the grease bucket	5
42	Preparation	Filter replacement	6
43	Assembling	Installing the mirror	5
44	Preparation	Filling the grease bucket	4
45	Preparation	Filling the arm and boom cylinders with grease	5
46	Preparation	Filling the hydraulic oil	13
47	Checking	Unit flushing	6

Based on the proposed engineering calculations, the total time for each activity component can be calculated. The following is a summary of the proposed engineering calculations, shown in Table 5.

Konversi Energi dan Manufaktur

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Jurnal Konversi Energi dan Manufaktur
Volume 11 Number 1 – January 2026 Page 37-52
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Table 5. Recapitulation of proposed improvements

Activity components	Duration (minutes)
Assembling	98
Preparation	82
Others	91
Moving & carrying	41
Checking	6
Total	318

The total time for the installation activity components after the engineering improvements resulted in a reduced lead time of 318 minutes, or 5 hours and 18 minutes, for the excavator unit attachment installation process. This reduction could be achieved by adding additional personnel and procuring a sanding machine, thereby accelerating the installation process. Based on the planned, realized, and total engineering calendars for the excavator unit installation, there are gaps in the installation process at the PDI station. These gaps can be filled by implementing the engineering results and relocating the accelerated installation schedule, as shown in Figure 11.

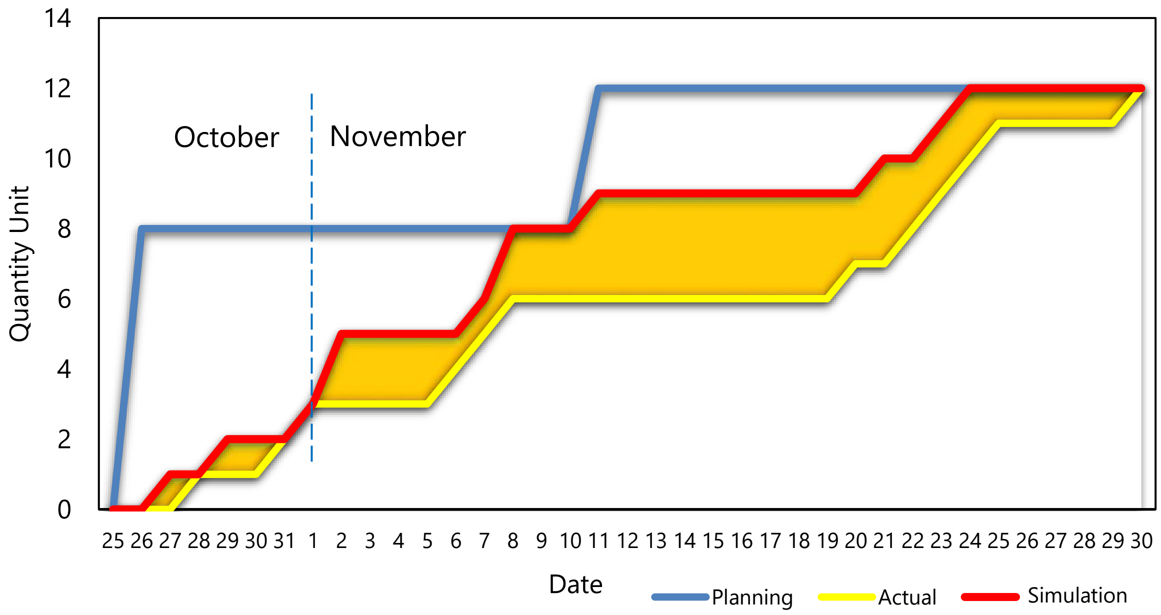

Figure 11. Duration improvement for attachment installation process of excavator unit

Based on the evaluation of the engineering results, on October 24, the previously prepared planning calendar can be implemented faster than stated in the actual data. In this case, follow-up is needed to implement engineering solutions so that the planning schedule can be implemented according to the predetermined targets. The successful adaptation of this solution is expected to make a positive contribution to the achievement of previously set planning objectives. The addition of personnel is something that must be considered to realize activities where employee qualifications and wages are included in the budget plan so that in the budget implementation year, additional personnel selection activities and wage payments can be accommodated [20]. The identification data required 562 minutes to be installed. The proposed improvement program could reduce the installation time to 318 minutes, saving the company 44%. This reduction effort, of course, would require additional personnel, additional equipment, and consumables, which must be considered.

Konversi Energi dan Manufaktur

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4. Conclusion

Based on the analysis results of the excavator unit attachment installation process in the PDI division at PT. XYZ, it can be concluded that the installation process takes a long time and the implementation does not match the predetermined planning calendar, so it needs an acceleration increase to avoid overdue according to the planning calendar. Reducing the installation process time by providing additional work personnel and procuring a sanding machine can reduce the installation process time. Therefore, it approaches the initial plan, which was 562 minutes implementation of the engineering decreasing to 318 minutes. The addition of personnel and the procurement of a sanding machine is predicted to save time for implementing excavator unit attachment installation process for only 224 minutes or saving 44% of consuming time.

5. Acknowledgments

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