E-ISSN 2503 - 1430

Journal of Industrial Engineering Management
(JIEM Volume 9. No.2 Tahun 2024)

# REDUCTION OF SETUP TIME IN THE DISASSEMBLY PROCESS WITH A SINGLE MINUTE EXCHANGE OF DIES (SMED) APPROACH AND FUZZY FAILURE MODE AND EFFECT ANALYSIS (FMEA)

**Syifa Allyssa[1], Muqimuddin[2], Faishal Arham Pratikno[3]**
[12]Departement of Industrial Engineering, Institut Teknologi Kalimantan
[3]Departement of Logistic Engineering, Institut Teknologi Kalimantan
Jl. Soekarno-Hatta Km. 15, Karang Joang, Balikpapan, Kalimantan Timur, 76127
E-mail: 12201067@student.itk.ac.id[1] , muqimuddin@lecturer.itk.ac.id[2],
faishal.arham@lecturer.itk.ac.id[3]

**Article history :**
Submitted April 23, 2024
Revised June 18, 2024
Accepted August 5, 2024
Available online August 20, 2024

## ABSTRACT

PT XYZ, a company specializing in heavy equipment component remanufacture, is committed to ensuring that its processes run quickly and efficiently. However, from 2022 to 2023, the disassembly engine process exceeded the average processing time. Observations revealed that 24% of the time was categorized as waste setup time, necessitating a more objective reduction. This research aims to determine the actual total setup time, internal and external activities, and time reduction using the SMED and Fuzzy FMEA methods. The disassembly process includes the main disassembly, sub disassembly 1, and sub disassembly 2. Single Minute Exchange of Dies (SMED) is employed to identify and reduce setup time by distinguishing between internal and external activities. Additionally, this research integrates the SMED method with Fuzzy Failure Mode and Effect Analysis (FMEA) to identify potential risks in setup activities and determine which internal activities can be modified. Changes to external activities will be analyzed using the 5-Why's method to identify root causes and find solutions. Observations revealed that the average disassembly engine setup time was 20 hours and 12 minutes, consisting of 25 internal activities and 56 external activities. The SMED method resulted in an 18% reduction in setup time, and when combined with the Fuzzy FMEA method, the reduction reached 59%, equivalent to 8 hours and 17 minutes.

Keywords: reduction time, setup time, disassembly, SMED, Fuzzy FMEA.

**Published By:**
Fakultas Teknologi Industri
Universitas Muslim Indonesia
**Address :**
Jl. Urip Sumoharjo Km. 5 (Kampus II UMI)
Makassar Sulawesi Selatan.
**Email :**
Jiem@umi.ac.id
**Phone :**
+6281341717729
+6281247526640


DOI : http://dx.doi.org/10.33536/jiem.v4i1.262

# 1. INTRODUCTION

The main aspect of business processes, particularly in the fields of manufacturing and remanufacturing, lies in the production segment. Production is closely related to how resources, as inputs, can produce a product that becomes an output through a process with minimal costs (Rambe and Syahputra, 2017). Inputs in the production process can include labor or human resources, capital, information, expertise, machinery, and raw materials or material, while the outputs produced can be in the form of physical goods or services(Zainul, 2019). Every company strives to increase high production to gain as much profit as possible. The profits obtained are achieved by improving the quality of the products produced and minimizing the necessary operating costs, thus requiring a system to achieve these objectives (Pristianingrum, 2017). Each company has its own strategic system to achieve its profit targets and meet customer needs and desires.

PT XYZ is a manufacturing company that focuses on repairing heavy equipment components. As a company operating in the manufacturing field, PT XYZ strives maximally to repair as many tools as possible according to the company's capabilities. One effort made is to maximize the completion time of heavy equipment components in a short period so that the turnover of incoming heavy equipment components will be higher. However, in reality, the repair process of heavy equipment experiences a longer processing time, particularly in the disassembly section. The disassembly process becomes the foundation for proceeding to the next assembly stage, so if there is inefficiency in the process, it can cause delays in the work and impact the overall completion time or lead time. Lead time has a varied meaning that depends on each industry. In the manufacturing industry, lead time refers to the amount of time needed to process a part or product during the production process (Tambun *et al.*, 2019). Therefore, this becomes the basis for research to reduce the time in the disassembly process.

The disassembly process at PT XYZ consists of three main parts: main disassembly, sub 1 disassembly, and sub 2 disassembly. Based on observations of the main disassembly process, it was found that the setup time is carried out by mechanics. Generally, the setup process includes material preparation, preparation of supporting tools, machine and environment condition adjustments, sample taking and testing, checking, etc (Nurrizky *et al.*, 2021). According to observations, the main disassembly takes 3.5 days to complete. Compared to the company's standards, this observation exceeds the standard by 30%. The high disassembly time can be influenced by the setup time, which based on observations, accounts for 24% of the total working hours. According to (Wibowo and Pramudika, 2023) in the concept of lean manufacturing, setup activities are considered a form of waste. The setup process not only extends production time but also negatively impacts product quality and customer satisfaction (Yazıcı, Gökler and Boran, 2020).

The SMED (Single Minute Exchange of Die) method is the main method commonly used to reduce equipment and machine setup time. Imperfections in the SMED method can be addressed by analyzing internal activities based on problem analysis using a combination of Fuzzy methods and Failure Mode and Effect Analysis (FMEA) to optimize the reduction of setup time in the production process (Yazıcı, Gökler and Boran, 2020) Therefore, this research aims to determine the setup time in the disassembly process, identify internal and external activities, and reduce setup time using SMED and Fuzzy FMEA. The results of this research are limited to providing theoretical improvement proposals, assuming that the setup activities categorized as external activities can be eliminated in the time calculation using the Single Minute Exchange of Dies (SMED) and Fuzzy Failure Mode and Effect Analysis (FMEA) methods, considering the time change becomes shorter.

# 2. METHODS

The SMED (Single Minute Exchange of Die) method is a component of lean production aimed at minimizing setup time. Setup time is a form of waste in the lean concept that must be eliminated because it does not add value (non-value added) to the product and can lead to inefficient processes (Purnomo *et al.*, 2021). The implementation of SMED is developed through four stages:

1. Identification: In the initial stage, setup activities for the observed object are identified.
2. Separation: Internal and external activities are separated. Internal activities are those setup activities that can only be performed when the equipment or machine is stopped or the setup process is carried out when the equipment is not operating, while external activities are setup activities performed while the equipment or machine is still operating.
3. Convert: In this stage, efforts are made to convert internal activities into external activities by considering substitution, elimination, and combination (Mestanza *et al.*, 2023)
4. Standardize: In the final stage, the implementation of SMED is verified through clear guidelines that provide considerations for maintaining changes in the long term.

Based on research by (Mughitsa *et al.*, 2023), it is evident that the implementation of Single Minute Exchange of Dies (SMED) has successfully accelerated setup times across various manufacturing sectors, including communication companies, the automotive industry, the food sector, shoe factories, and more. The results of this implementation not only include faster setup times but also increased productivity, cost reduction, and waste reduction (Jacob *et al.*, 2023).

Fuzzy FMEA (Failure Mode and Effect Analysis) is an improvement over the traditional FMEA method commonly used to convert objective problems into the fuzzy concept of FMEA. FMEA measurement uses the risk index parameters of FMEA, which are severity, occurrence, and detection, which will be transformed into fuzzy with appropriate membership functions (Setiawan, Yanto and Yasdomi, 2018). Using FMEA sometimes results in the assessment of causes that are not very significant, but by using fuzzy FMEA analysis, those causes become very important. This occurs because fuzzy logic, related to the understanding of the issue, can be elevated to complex problems, characterized by inaccurate and subjective information, resulting in a more accurate risk analysis (Godina, Silva and Espadinha-Cruz, 2021). The management of fuzzy is carried out using Matlab software with a fuzzy logic system as follows as *Figure 1* . Matlab provides a toolbox to facilitate the creation of fuzzy systems with several graphical user interfaces (GUI) (Kaafi, 2017).

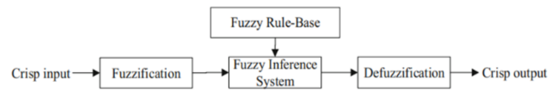


Figure 1. The Fuzzy Logic System

The crisp input value is the average result from 3 respondents for each parameter. The crisp value will be converted into linguistic parameters as shown in the Table 1.

*Table 1. Linguistik Term for Input*

| Linguistic Term (Input) | Range |
|---|---|
| High | (0; 0; 5) |
| Medium | (5; 5; 10) |
| Low | (5; 10; 10) |

In the fuzzification process, which converts crisp values from the questionnaire results into linguistic terms, membership functions are required. The parameters used for input are high, medium, and low, while the parameters for output are very high, high, medium, low, and very low. The membership function used is the triangular membership type (a; b; c), which is determined by three different parameters: the lower limit 'a', the middle value 'b', and the upper limit 'c'. The fuzzy output parameters used are as follows (Karatop *et al.*, 2021).

*Table 2. Linguistic Term for Output*

| Linguistic Term (Output) | Range Score |
|---|---|
| Very High | (0; 0; 2.5) |
| High | (0; 2.5; 5) |
| Medium | (2.5; 5; 7.5) |
| Low | (5; 7.5; 10) |
| Very Low | (7.5; 10; 10) |

Based on the input and output parameters mentioned above, rules will be created to connect these parameters. The rules are developed based on discussions with local experts. In this study, given that there are 3 input parameters, there are 3^3 = 27 rules as follows.

*Table 3. Rules Fuzzy FMEA*

| No | Parameter | | | *Output* |
|---|---|---|---|---|
| | *Severity* | *Occurance* | *Detection* | |
| 1 | Low | Low | Low | Very Low |
| 2 | Low | Low | Medium | Very Low |
| 3 | Low | Low | High | Low |
| . | . | . | . | . |

| No | Parameter | | | Output |
|---|---|---|---|---|
| | *Severity* | *Occurance* | *Detection* | |
| . | . | . | . | . |
| . | . | . | . | . |
| 25 | High | High | Low | High |
| 26 | High | High | Medium | Very High |
| 27 | High | High | High | Very High |

*Table 4. Severity Criteria*

| Impact | Severity Criteria (S) | Rating |
|---|---|---|
| Hazardous | If not performed, it can halt the operation of the production system. | 10 |
| Serious | If not performed according to regulations, it can produce products that endanger consumers. | 9 |
| Extreme | If not performed, it can disrupt the smooth operation of the production system, and the product cannot be operated or is highly unsatisfactory. | 8 |
| Major | If not performed, it can slightly disrupt the smooth operation of the production system, and the product's performance is not perfect but still functional, or the product's outcome is not entirely satisfactory but still acceptable to consumers. | 7 |
| Significant | If not performed, the product's performance declines because some specific functions may not operate. | 6 |
| Moderate | If not performed, the performance of the production system or the production outcome decreases but can still be repaired. | 5 |
| Low | If not performed, the performance of the production system or the production outcome decreases but does not require repair. | 4 |
| Minor | If not performed, it has a small impact on the production system or product outcome, with some consumer complaints. | 3 |
| Very Minor | If not performed, it has a very small impact on the production system or product outcome. | 2 |
| No Impact | If not performed, it has no impact on the production system or product outcome. | 1 |

*Table 5. Occurance Criteria*

| Risk Occurrence Probability | Likelihood of Risk Occurrence | Rating |
|---|---|---|
| Very high and extreme; failure is almost unavoidable | 50 out of 100 | 10 |
| Very high; failure is related to previously failed processes | 20 out of 100 | 9 |
| High; failure occurs repeatedly | 10 out of 100 | 8 |
| Relatively high | 7 out of 100 | 7 |
| Moderately high | 5 out of 100 | 6 |
| Moderate | 4 out of 100 | 5 |
| Relatively low | 3 out of 100 | 4 |
| Low | 2 out of 100 | 3 |
| Very low | 1.5 out of 100 | 2 |
| Almost impossible | 1 out of 100 | 1 |

*Table 6. Detection Criteria*

| Detection Probability | Current Control | Rating |
|---|---|---|
| Almost impossible | No control to detect potential issues | 10 |
| Very low | Very few controls to detect potential issues | 9 |
| Low | Few controls to detect potential issues | 8 |
| Very low | Controls exist but have very low ability to detect potential issues | 7 |
| Low | Controls exist but have low ability to detect potential issues | 6 |
| Moderate | Controls exist with moderate/fair | 5 |

| Detection Probability | Current Control | Rating |
|---|---|---|
| | ability to detect potential issues | |
| Relatively high | Controls exist with relatively high ability to detect potential issues | 4 |
| High | Controls exist with high ability to detect potential issues | 3 |
| Very high | Controls exist with very high ability to detect potential issues | 2 |
| Almost certain | Controls almost certainly can detect potential issues | 1 |

External activities are then analyzed using the 5 Why Analysis method, an effective technique for finding the root cause of a problem. This analysis process is conducted by identifying an issue or undesired outcome, which prompts the question 'Why did this happen?' and is continued with each subsequent answer until the root cause is reached (Braglia, Frosolini and Gallo, 2016).

## 3. FINDINGS AND DISCUSSION

### 3.1. Current Condition of the Disassembly Process

The engine disassembly process has an average completion time of 6 days. This process is carried out in 3 parts: main disassembly, sub disassembly 1, and sub disassembly 2. The engine disassembly is supported by setup activities performed to ensure that all requirements are well-prepared before the disassembly process itself begins, minimizing the risk of disruption to the disassembly process. Data collection for the setup activities of the disassembly process in this study was conducted 3 times.

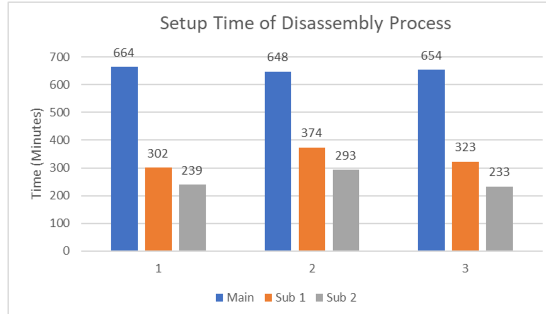


Figure 2. Data Collection Setup

As seen in *Figure 2*, it can be observed that from the three data collection points, the main disassembly part has a longer setup time, followed by sub disassembly 1, and sub disassembly 2. This is because the main disassembly part is the initial stage of engine disassembly, requiring longer inspection processes and involving larger and more numerous components to be dismantled, such as the oil pan, crankshaft, related parts, etc. On the other hand, the sub disassembly part involves dismantling specific engine components that are smaller and fewer in number. For example, sub disassembly 1 involves disassembling components such as the cylinder head, water pump, and oil cooler, while sub disassembly 2 involves disassembling components such as the starting motor and alternator. The more complex the components being dismantled, the longer the setup activities required, thus necessitating further analysis.

### 3.2 The Results of SMED's Method

*Table 7. Comparison of SMED Results Activities*

| Section | Identification Stage | | Conversion Stage | |
|---|---|---|---|---|
| | Internal | External | Internal | External |
| **Main Disassembly** | 28 | 3 | 22 | 6 |
| **Sub Disassembly 1** | 20 | 1 | 16 | 4 |
| **Sub Disassembly 2** | 27 | 1 | 18 | 9 |

The initial stage in Single Minute Exchange of Dies (SMED) is to identify the setup activities performed during the disassembly process. Subsequently, these activities need to be classified into internal and external activities to determine which tasks are conducted outside (external activities) of the main disassembly process (internal activities). The observation process for setup activities during the main disassembly is carried out over three disassembly processes of a Bulldozer engine, each performed by three different individuals. The classification of these setup activities into internal and external is based on observations and discussions with the relevant workers. The changes to the setup activities were made through discussions with several workers to identify internal activities that could potentially be converted into external activities. The process of modifying activities in Single Minute Exchange of Dies (SMED) can be approached by considering methods of substitution, elimination, and combination of activities (Mestanza et al., 2023). The results of the identification and conversion of setup activities for each section can be seen in Table 7.

### 3.2 The Results of Fuzzy FMEA's Method

Based on the internal activities of the SMED method that cannot be converted into external, these activities will be analyzed using Fuzzy FMEA. Activities with Fuzzy RPN values higher than the average will be converted into external activities. Here are the results of the Fuzzy RPN processing.

*Table 8. Fuzzy RPN for Main Disassembly*

| No | Activity | Fuzzy RPN | Rank |
|---|---|---|---|
| 1 | Documenting engine components | 5,77 | 20 |
| 2 | Operating the crane | 6,48 | 13 |
| 3 | Inspecting the initial condition of the engine | 6,05 | 17 |
| 4 | Setting height stand engine | 7,05 | 5 |
| 5 | Moving the engine to the engine stand (disassembly line) | 5,89 | 18 |
| 6 | Completing Quality Assurance (QA) documentation | 6,19 | 16 |
| 7 | Changing the socket | 6,77 | 9 |
| 8 | Taking a hammer | 7,14 | 2 |
| 9 | Bolt collection process | 6,35 | 15 |
| 10 | Preparing plastic bags to store removed components | 6,80 | 8 |
| 11 | Moving disassembled components to the washing area | 7,34 | 1 |
| 12 | Checking the parts book | 6,69 | 11 |
| 13 | Changing the impact | 6,87 | 7 |
| 14 | Cleaning the work area | 6,41 | 14 |
| 15 | Taking a wrench | 6,61 | 12 |
| 16 | Moving disassembled components to the sub disassembly area | 6,96 | 6 |
| 17 | Cleaning components | 6,77 | 10 |
| 18 | Waiting for the color check process | 5,87 | 19 |
| 19 | Wrapping components | 7,09 | 3 |
| 20 | Completing recommendation parts list (RPL) documentation | 5,00 | 22 |
| 21 | Setting the height of the engine stand | 7,09 | 4 |
| 20 | Preparing measuring tools | 5,59 | 21 |
| | **Average** | **6,49** | |

Based on Table 8, it is known that the average fuzzy RPN value in the main disassembly section is 6.49, so a total of 12 setup activities with values above 6.49 will be converted into external setup activities.

*Table 9. Fuzzy RPN for Sub Disassembly 1*

| No | Activity | Fuzzy RPN | Rank |
|---|---|---|---|
| 1 | Preparing the worktable area for the cylinder head | 5,49 | 15 |
| 2 | Setting up the hydraulic jack | 6,91 | 4 |
| 3 | Preparing measuring tools | 6,05 | 11 |
| 4 | Setting up the tapping tool | 6,47 | 9 |

| No | Activity | Fuzzy RPN | Rank |
|---|---|---|---|
| 5 | Setting up the manual jack machine | 7,08 | 2 |
| 6 | Filling out the Quality Assurance (QA) document | 5,56 | 14 |
| 7 | Documenting components | 6,12 | 10 |
| 8 | Changing the socket | 6,76 | 5 |
| 9 | Filling out the recommendation part list (RPL) document | 5,60 | 13 |
| 10 | Finding the wrench | 5,65 | 12 |
| 11 | Setting up the spring test tool | 6,61 | 8 |
| 12 | Cleaning the worktable | 7,14 | 1 |
| 13 | Preparing measuring tools | 6,98 | 3 |
| 14 | Checking the cylinder head's surface cylinder | 4,77 | 16 |
| 15 | Preparing the grinder | 6,69 | 6 |
| 16 | Cleaning components | 6,67 | 7 |
| **Average** | | **6,28** | |

Based on Table 9, it is known that the average fuzzy RPN value in sub disassembly 1 section is 6.28, so a total of 9 setup activities with values above 6.28 will be converted into external setup activities.

*Table 10. Fuzzy RPN for Sub Disassembly 2*

| No | Activity | *Fuzzy* RPN | Rank |
|---|---|---|---|
| 1 | Removing components from the test bench | 6,39 | 11 |
| 2 | Installing components on the test bench | 5,43 | 18 |
| 3 | Documenting components | 6,76 | 7 |
| 4 | Setting up the hydraulic jack | 7,08 | 4 |
| 5 | Searching for screwdrivers | 5,84 | 16 |
| 6 | Taking the T wrench | 6,35 | 12 |
| 7 | Adjusting the position of components on the test bench | 6,06 | 15 |
| 8 | Cleaning the worktable area | 6,90 | 5 |
| 9 | Searching for bearings | 6,77 | 6 |
| 10 | Cleaning the test bench | 6,45 | 10 |
| 11 | Wrapping components | 7,14 | 3 |
| 12 | Changing the socket | 6,48 | 8 |
| 13 | Cleaning components | 7,20 | 1 |
| 14 | Filling out the Quality Assurance (QA) document | 6,48 | 9 |
| 15 | Preparing measuring tools | 6,22 | 14 |
| 16 | Filling out the recommendation part list (RPL) document | 6,32 | 13 |
| 17 | Removing rust | 7,15 | 2 |
| 18 | Waiting for the Quality Assurance (QA) document | 5,56 | 17 |
| **Average** | | **6,48** | |

Based on Table 10, it is known that, the average fuzzy RPN value in sub disassembly 2 section is 6.48, so a total of 9 setup activities with values above 6.48 will be converted into external setup activities.

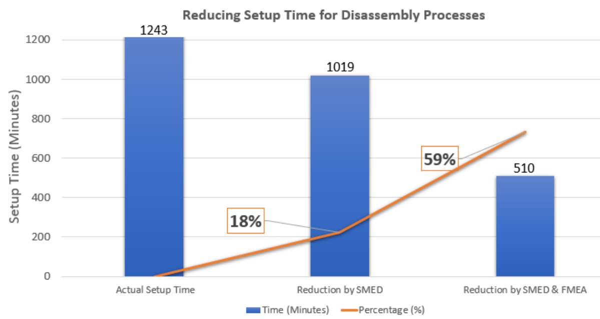


Figure 3. The Comparison of Reduction Results

Using the Single Minute Exchange of Dies (SMED) method, the classification of setup activities between internal and external activities is obtained. In the main disassembly, internal activities take 553 minutes and external activities take 102 minutes. In sub disassembly 1, internal setup activities take 272 minutes and external activities take 61 minutes. In sub disassembly 2, internal setup time is 194 minutes and external activities take 61 minutes. The total reduction in time using SMED is 18.02%, from 1243 minutes to 1019 minutes, consisting of a 15.57% reduction in main disassembly from 655 minutes to 553 minutes, a 18.31% reduction in sub disassembly 1 from 333 minutes to 272 minutes, and a 23.92% reduction in sub disassembly 2 from 255 minutes to 194 minutes. By combining the Fuzzy Failure Mode Effect and Analysis (FMEA) method, the total reduction in setup time is 58,94%, from 1019 minutes to 510 minutes. In the main disassembly, the setup time reduction is 44.42% from 553 minutes to 245.67 minutes, in sub disassembly 1 it is 61,27% from 241 minutes to 166.67 minutes, and in sub disassembly 2 it is 49.66% from 194 minutes to 96.33 minutes.

*Table 11. Analysis of External Activities*

| No | Setup Activity | *Why's* 1 | *Why's* 2 | *Why's* 3 | *Why's* 4 | *Why's* 5 | Solution |
|---|---|---|---|---|---|---|---|
| 1 | Retrieving hand gloves | Retrieving hand gloves from the warehouse | Insufficient stock of hand gloves in the line disassembly area | Refilling hand glove inventory is irregular | Lack of coordination in hand glove supply needs | Inadequate supervision of hand glove inventory | Hand glove inventory needs to be replenished whenever there is a new engine disassembly. |
| 2 | Preparing the engine stand | Repeated replacement of engine stands | Manual wooden support stands are still used | Wood is located in another area | - | - | Wood inventory needs to be placed at each disassembly line or replaced with rotating automotive engine stands. |
| 3 | Refilling oil | Need to retrieve oil from the warehouse | Lack of oil inventory at each work center | Refilling oil inventory is irregular | The coordination of oil inventory needs is insufficient | - | Oil needs to be replenished at each work center. |
| 4 | Retrieving hi-torque wrench | Tools need to be retrieved from another work center | Incomplete tools at each work center | Some tools are damaged and used by other work centers | The awareness of employees regarding equipment ownership responsibility is lacking | Inadequate supervision of tool completeness | Tool needs to be provided at each work center. |
| . | . | . | . | . | . | . | . |
| . | . | . | . | . | . | . | . |
| 27 | Cleaning rust | Severe rust on component level | Lack of complete cleaning | . | . | . | . |

| No | Setup Activity | *Why's* 1 | *Why's* 2 | *Why's* 3 | *Why's* 4 | *Why's* 5 | Solution |
|---|---|---|---|---|---|---|---|
| | | | equipment and materials at the work center | | | | |
| 28 | Retrieving T wrench | Frequent changing of T wrench types | T wrenches are located in another work center | - | - | - | Cleaning process needs to be moved to the washing area. |
| 29 | Documenting components | Repeated documentation | Workers lack attention to detail and understanding of documentation needs | Borrowed T wrenches are not returned | - | - | Creation of a tools checklist and increased responsibility and ownership of tools. |
| 30 | Cleaning worktable area | Messy and dirty worktable area | Lack of worker awareness to immediately clean | - | - | - | |
| 31 | Preparing the engine stand | Repeated replacement of engine stands | Manual wooden support stands are still used | | | | Regular cleaning activities and increased supervision needed |

## 4.CONCLUSION AND SUGGESTION

The conclusions drawn from the research findings are:

1. The disassembly process at PT XYZ involves significant setup time, with the main disassembly part requiring the longest setup time followed by sub disassembly 1 and sub disassembly .
2. Conversion of internal activities to external activities through discussions with workers and the implementation of fuzzy FMEA parameters have resulted in a significant increase in external setup activities across all disassembly parts, potentially reducing setup time.
3. The integration of the SMED and Fuzzy FMEA methods has shown promising results in reducing setup time in the disassembly process at PT XYZ. The combined approach has led to a substantial reduction in setup time of 18% with the SMED method, and when combined with the Fuzzy FMEA method, the reduction reaches 59%. This indicates the effectiveness of integrating these methods for process optimization. The reduction in setup time achieved through the integrated SMED and Fuzzy FMEA methods contributes to increased efficiency and productivity in the disassembly process, potentially leading to cost savings and improved customer satisfaction.

Overall, this research highlights the importance of implementing advanced methodologies such as SMED and Fuzzy FMEA for optimizing setup processes in manufacturing environments, particularly in disassembly operations like those at PT XYZ.

### References

Braglia, M., Frosolini, M. and Gallo, M. (2016) 'SMED enhanced with 5-Whys Analysis to improve set-up reduction programs : the SWAN approach', *The International Journal of Advanced Manufacturing Technology*, 90 (5–8), pp. 1845–1855. doi: 10.1007/s00170-016-9477-4.

Godina, R., Silva, B. G. . and Espadinha-Cruz, P. (2021) 'A DMAIC Integrated Fuzzy FMEA Model: A Case Study in the Automotive Industry', *Applied Science*, 11, p. 3726. doi: https://doi.org/10.3390/app11083726.

Jacob, D. E. *et al.* (2023) 'Single Minute Exchange of Die ( SMED ) to improve productivity in the industrial sector .', *21 st LACCEI International Multi-Conference for Engineering, Education, and Technology:*, pp. 1–7. doi: https://dx.doi.org/10.18687/LACCEI2023.1.1.489.

Kaafi, A. Al (2017) 'Model Deteksi Autis Secara Dini Berdasarkan Pendekatan Logika Fuzzy Inference System Metode Mamdani', 5(2), pp. 12–21.

Karatop, B. *et al.* (2021) 'Decision analysis related to the renewable energy investments in Turkey based on a Fuzzy AHP-EDAS-Fuzzy FMEA approach ☆', *Computers & Industrial Engineering*, 151(November 2020). doi: 10.1016/j.cie.2020.106958.

Mestanza, M. T. *et al.* (2023) 'Improvement model to increase the efficiency of the sewing area in a textile SME by applying SMED , 5S and Standardized Work - A Peruvian case study', *21st LACCEI International Multi-Conference for Engineering, Education, and Technology*, pp. 1–9. doi: https://dx.doi.org/10.18687/LACCEI2023.1.1.1051 Improvement.

Mughitsa, H. S. *et al.* (2023) 'Literature Review: Penerapan Metode Single Minutes Exchange of Die (SMED) di Berbagai Sektor Industri Manufaktur', in *Jurnal KaLIBRASI*. Jakarta, pp. 59–69. Available at: https://ejournal.borobudur.ac.id/index.php/teknik/index.

Nurrizky, M. F. *et al.* (2021) 'Peningkatan Efisiensi Mesin Cnc Turning Menggunakan Metode Single Minutes Exchange Of Dies di PT . X', *Jurnal Ilmiah Teknologi Informasi Terapan*, 7(2), pp. 94–100.

Pristianingrum, N. (2017) 'Peningkatan Efisiensi Dan Produktivitas Perusahaan Manufaktur Dengan Sistem Just In Time', *Jurnal Ilmiah Ilmu Akuntansi Keuangan dan Pajak*, 1(1), pp. 41–53. doi: https://doi.org/10.30741/assets.v1i1.20.

Purnomo, E. *et al.* (2021) 'Analisa dan Perbaikan Waktu Set-up Pergantian Cetakan dengan Metode Single-Minute Exchange of Dies ( SMED ) ( Studi Kasus : PT . XYZ ) Jurusan Teknik Industri , Institut Teknologi Adhi Tama Surabaya Jurusan Teknik Mesin , Institut Teknologi Adhi Tama Sura', *Seminar Nasional Teknologi Industri Berkelanjutan I (SENASTITAN I)*, pp. 26–34. Available at: http://ejurnal.itats.ac.id/senastitan/article/view/1633.

Rambe, I. H. and Syahputra, M. R. (2017) 'Aplikasi Data Envelopment Analysis (Dea) Untuk Pengukuran Efisiensi Aktivitas Produksi', *MES (Journal of Mathematics Education and Science)*, 2(2), pp. 38–43. doi: https://doi.org/10.30743/mes.v2i2.129.

Setiawan, A., Yanto, B. and Yasdomi, K. (2018) *Logika Fuzzy Dengan Matlab*. Bali: Jayapangus Press.

Tambun, I. B. *et al.* (2019) 'Penentuan Manufacturing Lead Time Rubber Roller Pada Pt . Growth Sumatera Industri , Ltd Medan', *Jurnal Sains dan Teknologi*, 11(01), pp. 11–19.

Wibowo, P. A. and Pramudika, B. P. (2023) 'Implementasi Single Minute Exchange of Dies ( SMED ) Saat Pergantian Mold Pada Proses Produksi di PT . IMC Tekno Indonesia', *JUTIN : Jurnal Teknik Industri Terintegrasi*, 6(4), pp. 1085–1093. doi: 10.31004/jutin.v6i4.2041.

Yazıcı, K., Gökler, S. H. and Boran, S. (2020) 'An integrated SMED-fuzzy FMEA model for reducing setup time', *Journal of Intelligent Manufacturing*. doi: 10.1007/s10845-020-01675-x.
Zainul, M. (2019) *Buku Manajemen Operasional.pdf*. Yogyakarta: Deepublish Publisher.