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Analysis of Lean Manufacturing Implementation through the Single Minute Exchange of Dies (SMED) Method to Reduce Setup Time in the Injection Molding Machine Process

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Abstract

In an era of increasingly intense industrial competition, operational efficiency and reduced production time become the important factors to increase a company's competitiveness. The production improvement process must be carried out continuously to reduce waste in work methods and time. This research aims to analyze the implementation of lean manufacturing through the Single Minute Exchange of Dies (SMED) method in to reduce set-up time in the injection machine of molding processs. Lean manufacturing refers to a systematic approach for identifying and eliminating waste through continuous improvement, emphasizing the efficiency and effectiveness of production processes. The research results indicate that implementing SMED significantly reduces set-up time of molding injection machine, increasing productivity, and reducing production downtime. It was obtained a decrease in set-up time by 16.68%, where the mattress replacement time was successfully shortened to 236.96 minutes from the previous 197.44 minutes. Implementation of SMED succeeded in identifying internal and external activities that could be simplified or eliminated, as well as optimizing work preparation and completion steps. This can be concluded that the implementation of lean manufacturing through the SMED method is effective in increasing operational efficiency and providing added value for the company.

Keywords: lean manufacturing, single minute exchange of dies (SMED), set-up time, molding injection, production efficiency.

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1. Introduction

In the era of globalization and increasingly fierce industrial competition, companies are required to find ways to be more efficient in their production processes (Ariyanti et al., 2018; Prasetyo & Sutopo, 2017). The productivity of machines and labor is one of the strengths in producing products (*mass production*) to provide consumer satisfaction (*excellent service*) (Lacroix et al., 2023; Mostafa et al., 2020; Moura & Botter, 2017; Qin et al., 2023; Rahman & Perdana, 2019). In the plastics industry, the skill of the workforce in replacing mattresses in the shortest possible time is a challenge for companies to prove that the company has high productivity in meeting the needs of its consumers (Jain & Vaishya, 2021; Mostafa et al., 2020). One approach is Lean manufacturing, which focuses on lean tools in the form of the Single Minute Exchange of Dies (SMED) method (Malindzakova et al., 2021; Ondra, 2022; M. A. S. Ribeiro et al., 2022; R. B. Ribeiro et al., 2019).

Lean Manufacturing is a concept and principle used in companies and production processes to maximize work to achieve maximum profits by applying the five principles without separation (Hartanto, 2019). Lean manufacturing is a continuous effort to eliminate waste and increase the added value of products in the form of goods and services to consumers (Sarjono, 2021). The tools in lean are used properly to identify and reduce waste, each tool has various specifications depending on the function used, one of which is the Single Minute Exchange of Dies (SMED) method (Filla, 2016; Garcia-Garcia et al., 2022; Toki et al., 2023).

SMED (Single Minute Exchange of Dies) is one of the improvement methods from Lean Manufacturing used to speed up the time needed and changes from producing one type of product to another product model (Alfatah et al., 2022).

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The three main reasons for reduced setup time are flexibility, bottleneck capacity, reducing costs, Flexibility to respond quickly of changes in market demand, and production facilities must be able to economically produce products of any size or type (Yash Dave & Nagendra Sohani, 2012). Bottleneck Capacity the reducing setup time increases available capacity and can be seen as an alternative to purchasing new equipment. Reducing Costs is especially in process delays and production costs, which are directly related to machine performance (Majid et al., 2022). The working principle of an injection molding machine has a driving energy source as a piston press from an air source function and a heating source or heater that functions from an alternating electric current (Wijaya & Deharisdi, 2023). The definition of injection molding is a technique used to make products from plastic and is the most cost-efficient type of production.(Dave & Sohani, 2012; Jain & Vaishya, 2021; Malindzakova et al., 2021; Yash Dave & Nagendra Sohani, 2012).

CV. XYZ is an industry engaged in the production of household appliances from plastic materials. There are several types of household products produced, the largest of which are crystal plates. Due to the many types of crystal plate products that need to be produced, mattress replacement is considered to be more frequent. However, the type of object mattress of this research is a 9" crystal plate mattress for 6 months. Problems regarding the inefficiency of the mattress replacement process result in frequent additional set up times. Consequently, this research describes the implementation of lean manufacturing in the form of lean tools through the SMED method in order to review, improve, and obtain recommendations for improvements in the form of standard replacement times on injection molding machines. This is expected that CV. XYZ is able to reduce activities that could not optimize productivity and shorten mattress replacement times

2. Research Method

The setup time for changing the injection molding machine mat is the period needed to replace and adjust the mat (mold) on the injection molding machine. Thus, it can start production with different specifications. This process includes several steps in sequence, namely: turning off the machine and removing the old mattress, cleaning and preparing, installing the new mattress, setting machine parameters as well as testing process, and final adjustments. Effective setup time can vary depending on machine complexity, mat design, and operator skill, typically ranging from a few minutes to several hours. Several efforts to reduce setup time become an important factor to increase efficiency and production capacity.

This observation was carried out at CV. XYZ. This is a plastic industry manufacturer of household appliances. Setup time data was collected six times using a stopwatch according to the frequency of mattress changes on the research object, namely a 9" crystal plate. Its type was the product most ordered type by customers during the six months research period. Meanwhile, data collection in the form of mattress replacement activities was carried out by direct observation and interviews with technician operators and helper operators. In general, the research stages conducted shown on Figure 1.

Data processing was validated using a data adequacy test to determine whether the data taken is sufficient or not. Then, a standard time calculation was done to obtain the total completion time of the mattress replacement setup time plus the allowance tolerated by the company. Several stages of the SMED method must be carried out to obtain the proposed setup time, including:

a. Stage 1: Record external setup and internal setup activities
b. Stage 2: Separating external setup activities into internal setup
c. Stage 3: Carry out external reduction and internal setup
d. Stage 4: Eliminate activities that hinder setup time

After reaching the fourth stage, comparing the results of the real setup time and the proposed setup time were carried out, then selected the smallest and optimal time. Data collection was carried out from November 2023 – April 2023.

3. Results and Discussion

Table 1 was standard time data per activity in changing mattresses. This was obtained from calculating the adequacy test first and then the standard time by considering the allowance.

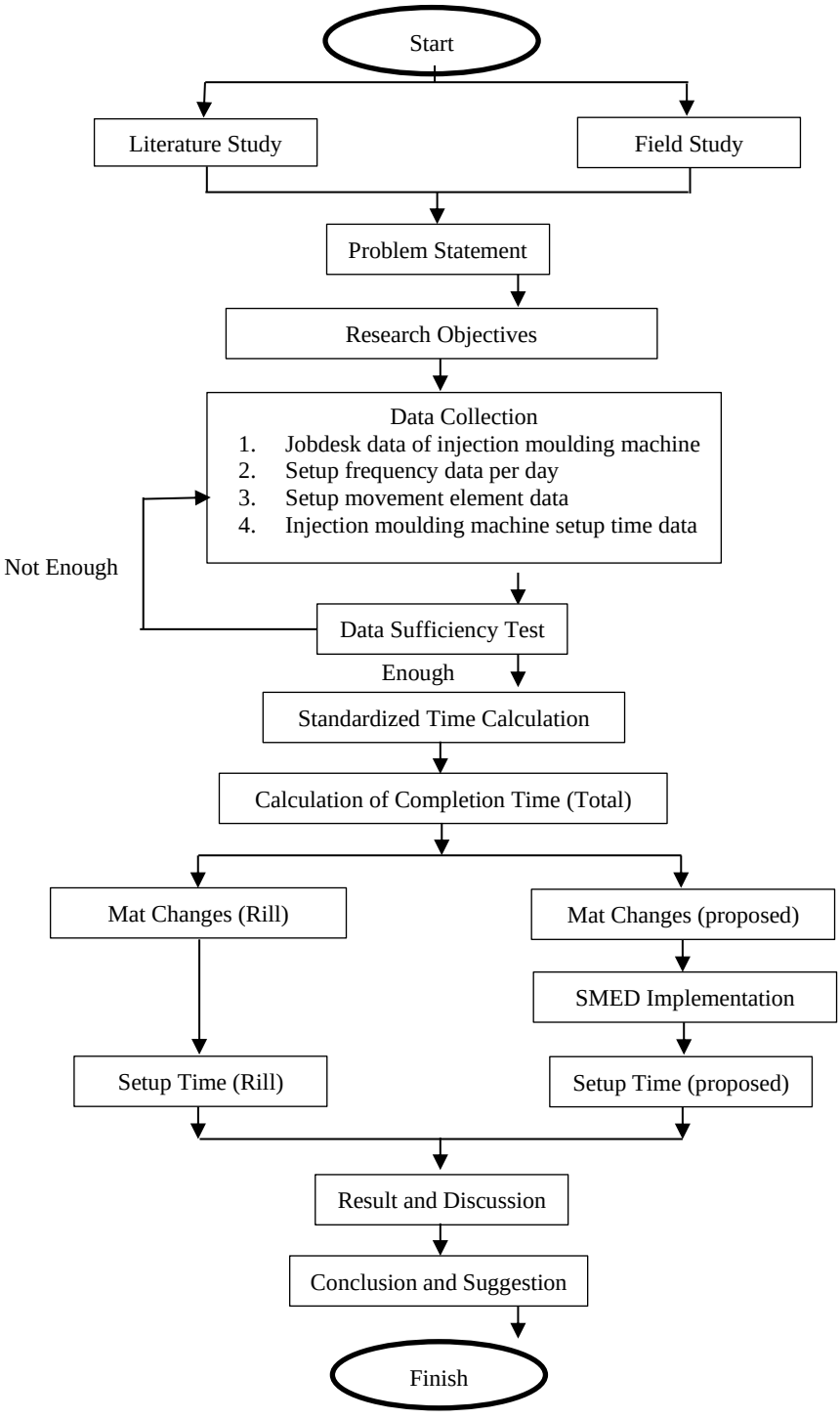

Figure 1. Flowchart Study

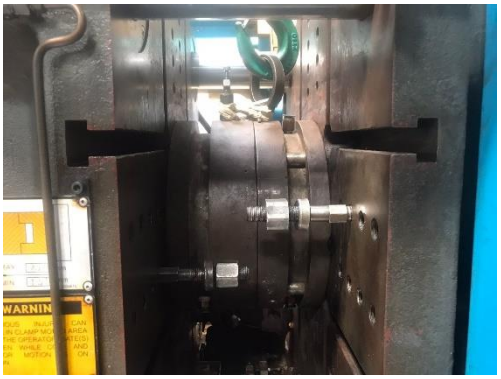

Figure 2. Mat set in machine

Figure 3. Molding Injection Machine

Table 1. Standard Time Recapitulation Results

Step	Activity	Setup Time of Observation Data (Minutes)						%Allowance	Ws	Wb
		1	2	3	4	5	6			
1	Pre-discontinuation of production of old mattresses	3.3	3.3	3.4	3.3	3.3	3.3	19.5	3.32	4.28
2	Taking note the settings on the monitor screen	2.3	2.1	2.3	2.2	2.2	2.4	19.5	2.25	2.91
3	Recording production performance	2.1	2.2	2.1	1.9	1.8	2.0	19.5	2.02	2.61
4	Stopping the production process	4.6	5.0	5.1	4.8	4.9	4.9	19.5	4.88	6.31
5	Completing production until the material in the hopper runs out	5.9	6.0	6.2	5.8	5.8	6.1	19.5	5.97	7.71
6	Washing the hopper with clear material	5.4	4.9	4.8	5.2	4.9	5.0	19.5	5.03	6.50
7	Picking up the tool by the operator	2.2	2.3	1.9	1.8	2.1	2.1	19.5	2.07	2.67
8	Directing the gantry crane to the old mattress	2.9	3.1	3.2	2.9	2.8	2.7	19.5	2.93	3.79
9	Turning off the temperature on the barrel	2.6	3.2	3.1	2.9	2.8	2.7	19.5	2.88	3.73
10	Waiting *nozzle* heater temperature decrease	6.9	7.0	7.3	6.8	7.1	6.0	19.5	6.85	8.85
11	Removing the mattress clamp bolts with the key	11.9	12.0	12.1	12.2	10.8	12.2	19.5	11.87	15.33
12	Setting the machine to pull the moving platten	1.1	1.0	1.3	1.1	1.2	1.4	19.5	1.18	1.53
13	Cleaning the mattress with *mold spray* and removing the old mattress from the machine	3.7	3.6	3.9	4.0	3.5	3.8	19.5	3.75	4.84
14	Moving the mattress with a transport trolley	3.2	3.4	3.1	2.9	3.6	3.2	19.5	3.23	4.18
15	Taking the old mattress to storage	2.5	3.1	2.9	2.9	2.4	3.0	19.5	2.80	3.62
16	Unhooking the old mattress to lower it	1.0	1.3	1.1	1.1	1.4	1.0	19.5	1.15	1.49
17	Preparing and taking new mattresses by *gantry crane* to the machine	2.9	2.3	2.8	2.4	2.7	3.0	19.5	2.68	3.47

Step	Activity	Setup Time of Observation Data (Minutes)						%Allowance	Ws	Wb
		1	2	3	4	5	6			
18	Installing new mat into the machine	3.2	3.1	3.3	3.3	3.0	3.8	19.5	3.28	4.24
19	Tightening the clamp bolts on the new mattress	10.7	10.8	11.2	10.9	11.0	11.1	19.5	10.95	14.15
20	Installing the cooling water hose on the mattress	6.7	6.9	6.9	6.8	6.5	7.0	19.5	6.80	8.79
21	Installing the material *nozzle* on the *screw*	6.6	6.5	6.8	6.4	6.0	6.1	19.5	6.40	8.27
22	Installing the heater on the *screw*	5.1	5.7	5.5	5.2	5.6	5.9	19.5	5.50	7.11
23	Set at the center point of the *nozzle material hole* with the mat	6.5	6.7	7.0	6.9	7.1	6.1	19.5	6.72	8.68
24	Tighten all mold fastening bolts	5.0	5.1	5.0	5.2	5.3	5.0	19.5	5.10	6.59
25	Entering new product setting parameters	7.1	6.9	7.2	6.8	6.5	7.2	19.5	6.95	8.98
26	Running the machine without materials	12.4	11.0	12.1	12.6	12.3	12.1	19.5	12.08	15.61
27	Filling material into the hopper	3.4	3.2	3.5	3.9	3.2	3.4	19.5	3.43	4.44
28	Heating the material	16.3	15.9	15.8	16.2	16.0	15.0	19.5	15.87	20.50
29	Increasing the barrel temperature	11.2	12.1	11.4	11.3	12.1	11.2	19.5	11.55	14.92
30	Cleaning the mattress with a spray mold then checking trial and error (adjust) product samples	11.9	12.0	12.1	13.0	12.3	12.0	19.5	12.22	15.78
31	Waiting for approval from Quality Control	8.3	7.9	7.6	8.1	7.9	7.5	19.5	7.88	10.18
32	Starting production	3.6	3.9	3.7	4.1	3.8	3.8	19.5	3.82	4.93

Data adequacy test was carried out with a confidence level of 95% and a degree of accuracy of 5% and s = 0.05 to prove the sufficient data.

With the formula, $N' = \left[\frac{k/s\sqrt{N\sum x^2-(\sum x)^2}}{\sum x}\right]^2$

Value obtained:

$\sum x$ = 1100.5
$\sum x^2$ = 8968.95

Then the value of N' is:

$N' = \left[\frac{k/s\sqrt{N\sum x^2-(\sum x)^2}}{\sum x}\right]^2$

$N' = \left[\frac{2/0.05\sqrt{192(8968.95)-(1100.5)^2}}{1100.5}\right]^2$

$N' = \left[\frac{2/0.05\sqrt{1722038-1211100}}{1100.5}\right]^2$

N' = 25.9809

Based on the results of data adequacy test calculations in step 1 of preparing to stop production of old mattresses, it can be said to be sufficient because N' < N or 25.9809 < 192. Meanwhile, for the standard time calculation, the allowance is determined according to the company's criteria shown on Table 2.

The calculation of Standard Time (Wb) for the example of the activity of preparing to stop production of old mattresses is presented as follows:

$Wb = Wn \times \frac{100\%}{100\%-\%allowance} = 3.45 \times \frac{100\%}{100\%-19.5\%} = 4.28$ minutes

The standard time needed for a worker to carry out step 1: preparation for stopping production of old mattresses is 4.28 minutes/mattress change.

Table 2. Looseness Factor for Replacing 9" Crystal Plate Mats

Allowance Factor	
Types of Allowances	Allowance %
1. For Personal Needs	2.0
2. To relieve fatigue	
a. Energy expended	4.5
b. Work attitude	1.0
c. Work movement	0
d. Eye fatigue	1.0
e. Workplace temperature conditions	5.0
f. Atmospheric conditions	3.0
g. Environmental conditions	1.0
3. To inevitable obstacles	2.0
Large Allowance	19.5

Source: Data processing results Appendix

Based on the calculation results in Table above, the real setup times for mattress replacement are obtained, divided into internal activities and external activities. Internal activities define the activity elements when the machine is turned off or stops operating. Meanwhile, external activity is an activity element that is obtained when the machine is on or operating.

Table 3. Mattress Change Setup Time (Real)

Step	Activity	Time (Minutes)	Internal	External
1	Pre-discontinuation of production of old mattresses	4.28		✓
2	Taking note the settings on the monitor screen	2.91	✓	
3	Recording production performance	2.61	✓	
4	Stopping the production process	6.31	✓	
5	Completing production until the material in the hopper runs out	7.71	✓	
6	Wash *the hopper* with clear material	6.50	✓	
7	Washing the hopper with clear material	2.67	✓	
8	Picking up the tool by the operator	3.79	✓	
9	Directing the gantry crane to the old mattress	3.73	✓	
10	Turning off the temperature on the barrel	8.85	✓	
11	Waiting *nozzle* heater temperature decrease	15.33	✓	
12	Removing the mattress clamp bolts with the key	1.53	✓	
13	Setting the machine to pull the moving platten	4.84	✓	
14	Cleaning the mattress with *mold spray* and removing the old mattress from the machine	4.18	✓	
15	Moving the mattress with a transport trolley	3.62	✓	
16	Taking the old mattress to storage	1.49	✓	
17	Unhooking the old mattress to lower it	3.47	✓	
18	Preparing and taking new mattresses by *gantry crane* to the machine	4.24	✓	
19	Installing new mat into the machine	14.15	✓	
20	Tightening the clamp bolts on the new mattress	8.79	✓	
21	Installing the cooling water hose on the mattress	8.27	✓	
22	Installing the material *nozzle* on the *screw*	7.11	✓	
23	Installing the heater on the *screw*	8.68	✓	
24	Set at the center point of the *nozzle material hole* with the mat	6.59	✓	

Step	Activity	Time (Minutes)	Internal	External
25	Tighten all mold fastening bolts	8.98	✓	
26	Entering new product setting parameters	15.61	✓	
27	Running the machine without materials	4.44	✓	
28	Filling material into the hopper	20.50	✓	
29	Heating the material	14.92	✓	
30	Increasing the barrel temperature	15.78	✓	
31	Cleaning the mattress with a spray mold then checking trial and error (adjust) product samples	10.18	✓	
32	Waiting for approval from Quality Control	4.93		✓
	Total (Minutes)	236.96	227.78	9.21

3.1. Implementation of Single Minute Exchange of Dies (SMED)

3.1.1. Stage 3: Carry out external reduction and internal setup

Table 4. Time Reduction Efforts for Internal Activities Taken

No.	Step	Activity	Time (Minutes)	Change	Executor	Corrective action
1	**9**	Turning off the temperature on the barrel	3.73	3.0	Operator	Stop the operation gradually before changing the mattress
2	**10**	Waiting the *nozzle* heater temperature to drop	8.85	8.0	Operator *Helper*	
3	**11**	Removing the mattress clamp bolts with the key	15.33	10.0	2 *Helper Operators*	Do together on the right and left sides of the mat
4	**14**	Moving the mattress with a transport trolley	4.18	3.0	2 *Helper Operators*	At least two skilled helper operators needed to carry out tasks outside of handling machine settings
5	**15**	Taking the old mattress to storage	3.62	2.5	2 *Helper Operators*	
6	**16**	Unhooking the old mattress to lower it	1.49	0.5	Operator *Helper*	Done in stages after placing the old mattress on the new mattress
7	**17**	Preparing and taking new mattresses by *gantry crane* to the machine	3.47	2.3	2 *Helper Operators*	
8	**19**	Tightening the clamp bolts on the new mattress	14.15	10.0	2 *Helper Operators*	Performed simultaneously on the right and left sides of the mat
9	**20**	Installing the cooling water hose on the mattress	8.79	5.5	Operator	
10	**21**	Installing the material nozzle on the screw	8.27	5.5	Operator *Helper*	Work together to carry out these three stages in stages
11	**22**	Installing the heater on the screw	7.11	4.5	Operator *Helper*	
12	**25**	Entering new product setting parameters	8.98	6.5	Operator	Done simultaneously because the machine is ready to operate
13	**29**	Increasing the barrel temperature	14.92	10.0	Operator	
14	**30**	Cleaning the mattress with a spray mold then trial and error (adjust) product samples	15.78	10.0	Operator	QC together with the operator to check whether the printed product is appropriate or not
15	**31**	Waiting for approval from Quality Control	10.18	8.0	QC	
		Total (Minutes)	**128.85**	**89.3**		

Stages 1 and 2 are presented in Table above. The next stage, namely carrying out external reduction and internal setup, is part of the Single Minute Exchange of Dies (SMED) methodology which aims to reduce the time required for machine changes or adjustments in the production process. The following process for reducing the time for internal mattress replacement activities can be shown in Table 4.

Based on the results obtained, it is known that the time can be reduced significantly. From a total of 15 initial activity steps, there is an increase of 39.55 minutes or 30.69% from 128.85 minutes before improvement to 89.3 minutes after improvement.

3.1.2. Stage 4: Eliminate activities that hinder setup time

The final stage in implementing SMED is changing internal activities to external ones. This was done to streamline several activities while the machine is operating. Based on the research results, changes in these activities are presented in Table 5.

Table 5. Changing Internal Activities to External

No.	Step	Activity	Time (Minutes)	Change	Executor	Corrective action
1	**2**	Taking notes the settings on the monitor screen	2.91	Internal to External	Operator	The operator notes when the machine will stop
2	**3**	Recording production performance	2.61	Internal to External	Operator	
3	**5**	Completing production until the material in the hopper runs out	7.71	Internal to External	Operator *Helper*	Material is drained when the machine stops
4	**6**	Washing the hopper with clear material	6.50	Internal to External	Operator	The operator cleans up any remaining product before the machine stops
5	**7**	Picking up the tool by operators	2.67	Internal to External	Operator	Prepared when the engine is running and will stop to change the mattress
6	**8**	Directing the *gantry crane* to the old mattress	3.79	Internal to External	Operator *Helper*	
7	**27**	Filling material into the hopper	4.44	Internal to External		The material has started to be filled into the hopper when changing the mattress.
		Total (Minutes)	**30.63**			

Through improvements that changed internal activities to external activities, the setup time was successfully reduced by 30.63 minutes. The identification has resulted in seven activities that have been successfully changed from internal activities to external activities. Therefore, based on the implementation of SMED in four stages, results are obtained in the form of real time and proposed time. So, it can be seen that the reduction in mattress replacement time can be calculated as follows:

$$\frac{changeover\ time\ before - current\ changeover\ time}{changeover\ time\ before} x\ 100\% = \frac{236.96 - 197.44}{236.36} x\ 100\%$$

$$= 16.68\%$$

The mattress replacement evaluation process above indicates that the proposed setup time is more optimal than the real setup time, which was obtained at 236.96 minutes. By making improvements using the Single Minute Exchange of Dies (SMED) method, the resulting setup time is 197.44. When compared, the setup time results show that the proposed setup time < real setup time or 197.44 minutes < 236.96 minutes. As a result, the reduction in changeover time as a percentage is 16.68%. This efficiency shows that the Single Minute Exchange of Dies (SMED) method is good enough to increase productivity in production.

4. Conclusions and Recommendations

In this calculation, the researchers use standard time as a time parameter, plus adjustment factors and allowance factors used by operators to complete one job. In its calculation, the total setup time for replacing a 9" Crystal plate mattress is

236.96 minutes with 36 activities or steps, consisting of 30 internal activities and two external activities. From the results of this calculation, a total of 15 initial activity steps were found, with an increase in time of 39.55 minutes or 30.69% from 128.85 minutes before repair to 89.3 minutes after repair. Meanwhile, through improvements that changed internal activities to external ones, the setup time was reduced by 30.63 minutes. After the calculations are carried out, the results of the calculations are compared and the most optimal is chosen between the setup time (real) or the setup time (proposed), which has a reduction in setup time of 16.68%. It is known that the SMED method is the most optimal method for carrying out repairs on mattress replacement. The researchers propose several suggestions, namely CV. XYZ that needs to hold regular training for machine operators to improve their skills in implementing the SMED method, so that the setup process can be carried out more quickly and efficiently. Then, create standard procedures for each step in the setup process, both for internal and external activities, so that consistency and efficiency are maintained. In addition, routine maintenance and maintenance on the machine and mattress aim to prevent damage or technical problems that can slow setup time.

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