APPLICATION OF LEAN MANUFACTURING TOOLS IN A SMALL AND MEDIUM-SIZED FURNITURE COMPANY

NGHIÊN CỨU ỨNG DỤNG CÔNG CỤ SẢN XUẤT TINH GỌN TẠI CÔNG TY GỖ NHỎ VÀ VỪA

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Abstract - To maintain competitiveness in the global market and aim for stable, long-term development, the most important task for furniture manufacturers is to reduce production time, minimize waste, and increase productivity. The SMED tool is applied to optimize changeover time between product codes in manufacturing, enhancing flexibility and efficiency as companies adapt to diverse customer demands and shorter product life cycles. The study was conducted at a small to medium-sized wood company, focusing on the CNC area, where SMED was integrated with other lean manufacturing tools. The results showed a reduction in changeover time from 21.25 minutes to 14.63 minutes, with a Benefit/Cost ratio of 2.63, confirming the feasibility and effectiveness of this approach.

Key words - SMED; B/C; Lean Manufacturing; PDCA; Gemba Walk

Tóm tắt - Để duy trì khả năng cạnh tranh trên thị trường toàn cầu và hướng đến sự phát triển ổn định và lâu dài, nhiệm vụ quan trọng nhất đối với các doanh nghiệp sản xuất đồ gỗ là giảm thời gian sản xuất, giảm thiểu các lãng phí cũng như tăng năng suất. Công cụ SMED (Single-Minute Exchange of Dies) được áp dụng nhằm tối ưu thời gian chuyển đổi giữa các mã hàng trong sản xuất, giúp nâng cao tính linh hoạt và hiệu suất trong bối cảnh doanh nghiệp phải đáp ứng nhu cầu đa dạng và vòng đời sản phẩm ngắn. Nghiên cứu được thực hiện tại một công ty gỗ vừa và nhỏ, tập trung vào khu vực CNC, với sự kết hợp của SMED và các công cụ tinh gọn khác. Kết quả cho thấy thời gian chuyển đổi giảm từ 21,25 phút xuống 14,63 phút, với tỷ số Benefit/Cost đạt 2,63, khẳng định tính khả thi và hiệu quả của phương pháp này.

Từ khóa - SMED; B/C; Lean Manufacturing; PDCA; Gemba Walk

1. Introduction

Lean Manufacturing (LM) is a production philosophy focused on reducing waste and maximizing value for customers, originating from the Toyota Production System (TPS). LM identifies eight major types of waste, including transportation, inventory, motion, waiting, overproduction, overprocessing, defects, and underutilization of talent [1]. To eliminate waste, LM applies tools such as 5S, Kanban, Value Stream Mapping (VSM), Single-Minute Exchange of Dies (SMED), and Total Productive Maintenance (TPM) to optimize processes and enhance performance. LM not only improves quality and reduces costs but also plays a critical role in the sustainable development strategies of enterprises.

Changeover time is defined as the period required to switch production from one product to another [2], directly affecting productivity and manufacturing efficiency. Reducing changeover time increases actual production time, decreases inventory, enhances flexibility, and reduces product defects [3]. In Lean Manufacturing, optimizing changeover time is a top priority, with the SMED method distinguishing between internal and external work, simplifying process steps, and aiming to reduce changeover time to under 10 minutes.

Single-Minute Exchange of Dies (SMED) is an essential tool in Lean Manufacturing, aimed at reducing changeover time between products to optimize processes and minimize waste [4]. This method focuses on direct observation, separating internal (performed while the machine is stopped) and external (performed while the machine is running) activities, converting as many internal tasks as possible into external ones, improving steps to reduce execution time, and documenting new standards [5]. Implementing SMED enables enterprises to increase productivity, reduce costs, and enhance production flexibility.

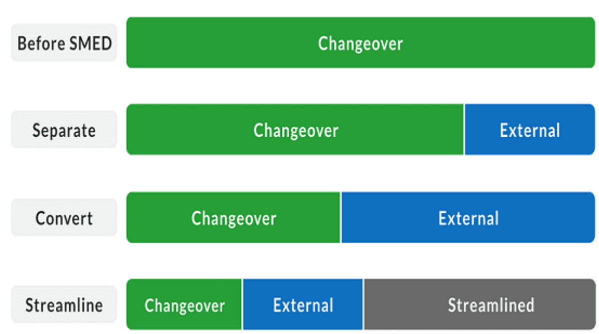

Figure 1. *The SMED implementation process*

Numerous studies have demonstrated the effectiveness of SMED in reducing changeover time and improving production efficiency. M. M. Maalouf et al. [6] applied SMED at a food company, reducing changeover time by 34% and increasing capacity by 11%. R. Sahin et al. [7] achieved over a 45% reduction in machine setup time in the bearing manufacturing industry. D. Sabadka et al. [8] optimized changeover time by 11.9% on abrasive machines. M. Amati et al. [9] applied SMED in healthcare, reducing changeover time between surgical cases by 25%. D. Agung et al. [10] combined SMED with 5S to reduce mold changeover time in injection molding machines by 18%. R. G. P. Junior et al. [11] implemented SMED and ECRS, optimizing changeover time, increasing overall equipment effectiveness (OEE) by 44.6%, and standardizing activities, thereby enhancing competitiveness in production. These findings demonstrate that SMED not only reduces downtime, increases productivity, and improves operational efficiency but also plays a vital role in optimizing production flow and promoting sustainable development across various industries.

Despite its high applicability, SMED and other LM tools are often only implemented in large companies. Therefore, this study focuses on small and medium-sized enterprises, specifically a woodworking company in Thu Duc, Ho Chi Minh City. Although advanced technology has not been strongly adopted, waste related to waiting time has been significantly reduced, demonstrating the effectiveness of LM in general and SMED in particular in any production model.

2. Research methodology

2.1. Research subject

This study focuses on the Lio Décor Factory in Ho Chi Minh City, under Lio Decor Trading & Service Co., Ltd., specializing in the design, production, and distribution of furniture. This factory is responsible for manufacturing wooden finished products for the head company and individual customers, handling an average of 30–40 orders per day, with a large proportion of small-batch orders (over 20 product units). Figure 2 shows the current layout of the factory, arranged according to the material flow from finished goods to packaging and delivery.

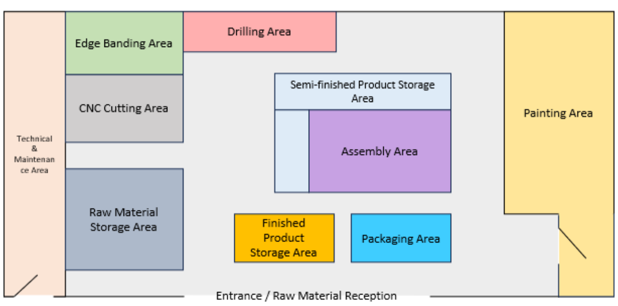

Figure 1. *Lio Décor Factory layout*

After two years of operation, senior management at the workshop expressed a desire to improve the working environment for employees, aiming to enhance production efficiency and reduce unnecessary costs during the manufacturing process.

The general daily workflow at the workshop is described in Figure PL.1 in the appendix. The daily workflow begins with receiving and reviewing requests from customers or the parent company. Upon approval, materials that meet quality standards are prepared and supplied before production. The design department creates technical drawings and CNC programs for product machining. The production process includes rough machining, edge banding, drilling, finishing, and assembly according to design specifications. The quality control (QC) department simultaneously inspects each stage to detect and correct errors, ensuring the quality of finished products. Products that meet standards are carefully packaged and delivered to customers or the parent company. After collecting and addressing any arising issues, the process is evaluated to improve and enhance production quality.

2.2. Methodology

The research was conducted following the methodology shown in Figure 3.

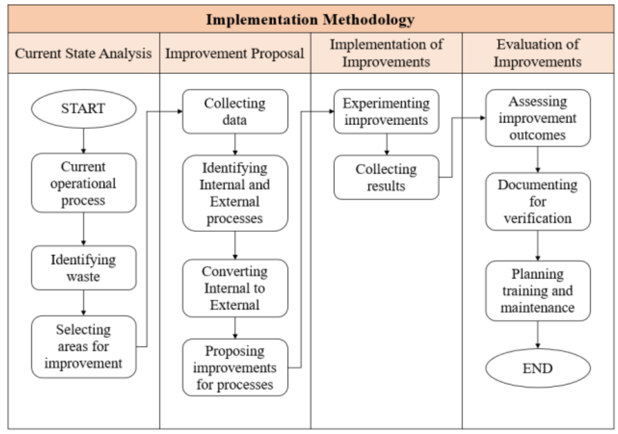

Figure 3. *Methodology*

2.2.1. Current state analysis

The analysis of the current state began with direct observation of the existing production process through Gemba Walks, aiming to understand actual operations and collect on-site data. Detailed records of operational steps, execution times, and factors affecting performance were taken. Figure 4 illustrates common material flows in the factory..

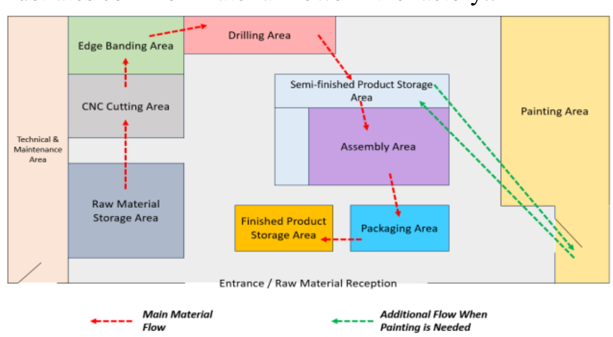

Figure 4. *Material flow in factory layout*

Next, wastes in the process were identified based on the Pareto Principle, helping to pinpoint the factors with the greatest impact on production efficiency. The most significant waste factors were then selected for improvement.

2.2.2. Improvement proposals

After analyzing the current state, the changeover process is separated, converted, and streamlined into tasks and data regarding the time and method of execution for each task were collected. The next step is to classify these tasks into Internal Setup (tasks that can only be done when the machine is stopped) and External Setup (tasks that can be done while the machine is still running) to identify opportunities for optimization. The primary focus of SMED is to convert as many internal tasks as possible into external tasks thereby significantly reducing unnecessary machine downtime. Finally, based on the analysis results, improvement proposals were made for both types of stages, including reorganizing processes, preparing materials ahead of production, and optimizing operations to reduce waste and enhance overall efficiency.

2.2.3. Implementation of improvements

After identifying optimal solutions, the team conducted improvement trials by applying adjustments to the actual production process. During this phase, the optimized steps were implemented as planned, ensuring compliance with safety and quality standards. The team continuously collected results, including changeover times and waste reduction levels. These data were compared to the initial state to evaluate the effectiveness of the improvements.

2.2.4. Evaluation of improvements

Subsequently, the results comparing indicators before and after applying the optimization methods were documented for review, ensuring that the improvements met technical standards and were feasible for implementation. Finally, to maintain and enhance long-term effectiveness, the team developed training and maintenance plans, instructed operators on the new procedures, and established monitoring mechanisms to ensure compliance and continuous improvement in the future.

3. Research content

3.1. Current state analysis

There are a total of six main production stages: CNC cutting, edge banding, drilling, painting and surface finishing, assembly, and packaging. Correspondingly, there are six main areas: CNC machine area, edge banding area, drilling area, painting room, assembly area, and packaging area.

3.1.1. Problem identification

During factory operations following continuous improvement principles toward Lean Manufacturing, the Warehouse Management and QC departments jointly compiled waste statistics for the first two quarters of 2024. Using the Gemba Walk method, the analysis team observed actual operations, interviewed workers and workshop managers to identify 10 waste factors, converted into specific cost figures, as detailed in Table 1. The results, analyzed with a Pareto chart in Figure 5, show that 83.33% of waste arises from three main factors: warehouse rental costs, changeover time, and machine downtime. Warehouse rental costs account for the largest proportion, and the company has decided to contact a third party to reinstall and reconfigure the shelving for more flexible storage of various materials. In this study, changeover time is prioritized for improvement using methods such as SMED and Lean Thinking to optimize processes, reduce time, and enhance production efficiency.

3.1.2. Identification of improvement focus

The product code changeover process occurs in three areas: CNC machine, edge banding machine, and painting room. Among these, the painting room has a low changeover frequency due to limited customer requests for colors other than wood grain. Statistical data in Table 2, compiled from Figures 6 and 7, show that both the frequency and total changeover time at the CNC machine area are significantly higher than at the edge banding area. Therefore, this research focuses on improving the changeover process at the CNC machine area.

***Table 1.** Waste factors*

No.	Factor	Type of Waste	Cost ($)	Percentage of Each Part	Cumulative Percentage
1	Storage rental cost	Inventory	1963.86	44.45	44.45
2	Machine stoppage incidents	Waiting	942.66	21.34	65.79
3	Changeover time	Waiting Motion Overprocessing	774.93	17.54	83.33
4	Labor shortage	Skills Overprocessing	195.27	4.42	87.75
5	Transportation cost	Motion Overprocessing	146.39	3.31	91.07
6	Unnecessary production start/ stop	Overprocessing Waiting	119.65	2.71	93.78
7	Production slowdown	Overprocessing Waiting	89.22	2.02	95.79
8	Personnel change cost	Defects	85.4	1.93	97.73
9	Normal production loss	Defects	63.89	1.45	99.17
10	Unwanted production schedule adjustment	Waiting	36.48	0.83	100.00

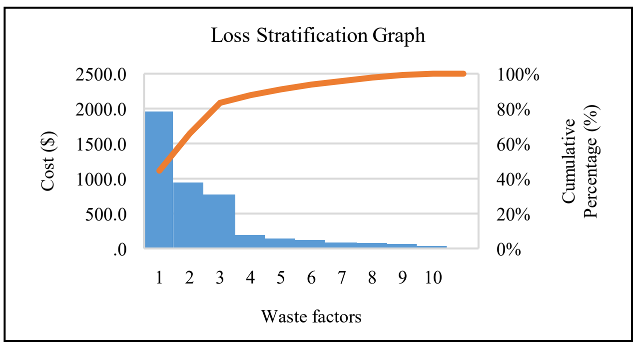

***Figure 5.** Loss Stratification Chart for waste factors*

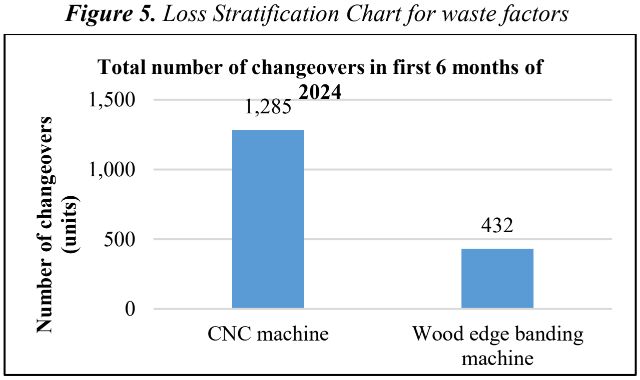

***Figure 6.** Total number of changeovers occurring on CNC machine and edge banding machine in the 1st 6 months of 2024*

***Table 2.** Total number and time of changeover on 2 machines*

Machine	Number (times)	Total time taken (mins)
CNC machine	1,285	28,800.15
Wood edge banding machine	432	6,579.36

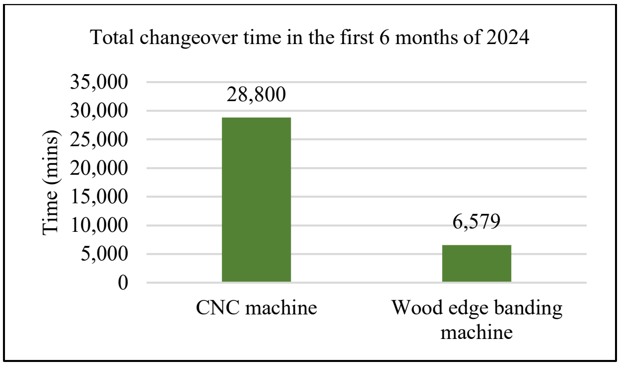

Figure 7. *Total changeover time in the CNC area and the edge banding machine area in the 1st 6 months of 2024*

3.2. Implementation of improvements

3.2.1. Stage 1: Observation and measurement of changeover time

The changeover schedule is updated every Monday by the workshop manager in coordination with the design and sales departments. The sequence of product code changes is regulated by columns, and workers follow this order. The numbers in the schedule represent the order of die changes for product codes on that day.

Mold change schedule week 10/7/24

CNC Machine

Item	07/10	8	9	10	11	12
ITEM CHANGE DETAILS						
L98DF	6	3,5		2	1	6
S3332	1		4,7	3,5	2,10	8
L98DE		4	11	6,9		5,11
L220S	2,10		3		9	12
SL745		7	1,9	1,10	5,11	7
S3332	3,7	8	8		6	4
SL890	4	1,10		4		1
KD900		2	5,10	7	3,7	2,10
KD875	9	6,9			12	3,5
KD400	5		2,6	8	4	

Figure 2. *Mold change schedule for the week of 07/10/2024 to 12/10/2024*

The Gemba Walk method was applied at the CNC area for two weeks, combining observation, video recording, and worker interviews for data collection. A total of 15 sample videos were selected (detailed in Table PL.1), capturing the actions of experienced workers to ensure accuracy. At the time of the study, the CNC technical team consisted of three people, two of whom had over three years of experience. The remaining person was still in training and did not participate significantly in changeovers to avoid affecting the results. Thus, the research team focused on recording experienced workers. After three weeks of analysis, the current changeover process consisted of 18 main steps, as shown in Table 3, with an average time of 1,274.98 seconds (≈21.25 minutes). The 95% confidence interval was [1,262.71; 1,287.25] seconds, with a width of 24.545 seconds. With a changeover frequency of 5–7 times per day, the CNC machine lost approximately 1.77–2.48 hours per day to this process.

Table 3. *Operations in changeover process at CNC machine*

Average time (seconds)		
No.	**Name of the step**	**Time**
1	Waiting for the machine to completely stop	5
2	Turning on the machine	20
3	Checking the air system	5.32
4	Checking cooling water for the vacuum system	40.31
5	Returning the machine axis to the original coordinates	16.30
6	Preparing necessary tools	122.43
7	Placing the new mold on the workpiece lifting table. adjusting it for machine operation	79.97
8	Selecting the correct spacer rings and fixtures for the new mold	101
9	Loading the CNC program for the new product code	123.65
10	Checking and adjusting parameters: spindle speed. cutting depth. operating mode	238.57
11	Feeding the new workpiece into the machine	43.18
12	Adjusting clamps to secure the workpiece firmly	36.20
13	Adjusting the output table to coordinate with the new workpiece	43.44
14	Test cutting the new product workpiece	134.81
15	Transferring the test-cut workpiece to the output table	17.23
16	Checking and readjusting parameters: spindle speed. cutting depth. operating mode	108.23
17	Stacking the new workpiece batch onto the lifting table	134.33
18	Starting the machine	5
	Total time	**1,274.98**

3.2.2. Stage 2: Internal/External Classification and Improvement Analysis

At this stage, all 18 current changeover steps were classified as Internal (only performed when the machine is stopped). Upon observation, the process was found to lack consistency, with redundant actions and no utilization of External steps (which can be performed while the machine is running). Six steps were identified for improvement, focusing on optimizing actions and standardizing procedures. The current state and improvement direction for each step are summarized in Table 4. These improvements leverage the conversion of steps to External, reducing changeover time and increasing CNC machine efficiency.

3.2.3. Stage 3: Converting Internal Steps to External Steps

The improvement team converted several steps from Internal to External to optimize changeover time:

Step 5: Previously, workers spent time retrieving tools from storage. Now, necessary tools are pre-arranged on a stainless-steel rack near the CNC machine, allowing immediate access.

Step 7: Placing the new die on the lifting table can now be done in parallel with the last operation of the previous product, rather than waiting for the machine to return to home position.

Step 13: Instead of waiting for clamp adjustment to finish, workers can adjust the outfeed table as soon as the test cut begins, maximizing machine waiting time.

These changes not only optimize time usage but also ensure the CNC machine operates at maximum capacity, minimizing production downtime.

Table 4. *Selected Processes for Improvement*

Process	Current State Description	Improvement Direction
4. Checking cooling water for the vacuum system	Workers move to inspect the water tank and fetch the hose if needed.	Improve workspace layout to eliminate unnecessary movement.
6. Preparing necessary tools	Workers go to get tools such as cleaning cloths or toolboxes.	Redesign workspace to keep tools readily available at the workstation.
7. Placing the new mold on the workpiece lifting table	Performed after the CNC machine stops.	Can be done before the machine completes the current cutting command.
10. Checking and adjusting machine parameters	Adjustments are made based on the product code, recorded manually.	Standardize and digitize data to shorten lookup time.
13. Adjusting the output table	Workers adjust the table according to the workpiece dimensions.	Standardize actions to shorten execution time.
16. Final checking and adjustment of parameters	Adjustments are made after test cutting.	Optimize recording methods from process 10 to increase efficiency.

3.2.4. Stage 4: Reducing Time for Internal and External Steps

In addition to converting steps from Internal to External, the improvement team proposed solutions to further optimize the remaining Internal steps:

Step 4: Workers previously spent 10 seconds if coolant was sufficient, up to 70 seconds if more water was needed due to the distant water source. Installing a nearby water hose with a convenient shutoff valve eliminated unnecessary movement, significantly reducing handling time.

Steps 10 & 16: Technical parameter checks (spindle speed, cutting depth, operation mode) were time-consuming due to referencing old notes. A redesigned, easily updatable parameter board now allows for quick, accurate adjustments, reducing errors and speeding up the process.

These proposals contributed to shortening changeover time. Figure PL.2 summarizes detailed improvement proposals for each step, clearly reflecting their positive impact on CNC machine operations.

3.2.5. Stage 5: Documentation and Approval of Improvement Proposals

To report to management, a PDCA-based reporting form was used to record and evaluate the effectiveness of improvement proposals. Figure PL.3 illustrates a completed improvement report for step 4. The standard structure includes:

- **Plan:** Identify the problem using 5W1H to clarify causes, impacts, stakeholders, and improvement direction.
- **Do:** Implement improvements via brainstorming, method selection, workspace adjustment, trial runs, and feasibility assessment using the Benefit/Cost (B/C) ratio.
- **Check:** Compare pre- and post-improvement results to measure effectiveness in time, labor, and redundant actions.
- **Act:** Train staff, maintain improvements, and document for future optimizations.

The report also includes information on implementers, costs, annual benefits, and approval status, ensuring a systematic and transparent improvement process. Proposals are implemented after managerial approval.

3.2.6. Stage 6: Experimentation and Results Analysis

Six improvement proposals were piloted over two weeks, optimizing changeover time and enhancing operational efficiency.

Step 4: Coolant check time reduced from 40.31 seconds to 22.42 seconds by installing a direct water hose, eliminating long-distance movement.

Step 5: Tool retrieval was moved to External. A 10kg stainless rack was installed, allowing workers to prepare tools at shift start, eliminating this step from the changeover process.

Step 7: Placing and adjusting the new die can now be done while the last product is being cut, significantly reducing waiting time.

Steps 10 & 16: Parameter checking and adjustment were streamlined with a new, continuously updated parameter board. Time for step 10 dropped from 238.57 seconds to 189.32 seconds; step 16 from 108.23 seconds to 23.90 seconds.

Step 13: Outfeed table adjustment was moved to External, performed concurrently with the test cut, removing this step from changeover time.

These improvements optimized the process, shortened time, and increased efficiency at the CNC area. Trial results showed a marked reduction in step durations, optimizing changeover and boosting production effectiveness. Over two weeks, 15 samples were collected (see Table PL.2). With a 95% confidence interval and a mean of 877.735 seconds, the sample interval was [872.29; 883.18] seconds (±5.445 seconds), with a width of 10.89 seconds. Average step times are shown in Table 5.

Table 5. *Execution Time for the Changeover Process After Improvement*

Average time (seconds)			
No.	**Name of the step**	**Time (seconds)**	
1	Waiting for the machine to completely stop	5	
2	Turning on the machine	20	
3	Checking the air system	5.32	
4	Checking cooling water for the vacuum system	22.42	
5	Returning the machine axis to the original coordinates	16.30	
6	Preparing necessary tools	0	*Performed at the beginning of the shift*
7	Placing the new mold on the workpiece lifting table, adjusting it for machine operation	0	*Performed before the changeover process takes place*
8	Selecting the correct spacer rings and fixtures for the new mold	101	

9	Loading the CNC program for the new product code	123.65	
10	Checking and adjusting parameters: spindle speed, cutting depth, operating mode	189.32	
11	Feeding the new workpiece into the machine	43.18	
12	Adjusting clamps to secure the workpiece firmly	36.20	
13	Adjusting the output table to coordinate with the new workpiece	0	*Performed simultaneously with process 14*
14	Test cutting the new product workpiece	134.81	
15	Transferring the test-cut workpiece to the output table	17.23	
16	Checking and readjusting parameters: spindle speed, cutting depth, operating mode	23.9	
17	Stacking the new workpiece batch onto the lifting table	134.33	
18	Starting the process	5	
	Total time	**877.735**	

3.3. Results evaluation

After applying the SMED method, the changeover time at the CNC machine was significantly reduced from approximately 21.25 minutes to 14.63 minutes. This was achieved by eliminating unnecessary steps from the changeover process, improving actions, and standardizing the work sequence. The final Benefit/Cost (B/C) ratio reached 2.63, demonstrating the effectiveness of the improvements.

Results by Step:

+ ***Internal to External Conversion:*** Steps 6, 7, and 13 were improved by adding a changeover tool rack (step 6) and redesigning the work sequence (steps 7 and 13) to optimize the process.

+ ***Reduced Execution Time:*** Steps 4, 10, and 16 were made more efficient by adding a water hose (step 4) and designing a new parameter board (steps 10 and 16) for quick, accurate parameter adjustments.

In addition to SMED, the successful implementation of Gemba Walk and PDCA methods enabled the Lean Manufacturing improvement team to enhance their process evaluation and improvement skills. The team now has more practical experience for future improvement projects.

In the future, efforts will not only focus on reducing changeover time but also on addressing other waste factors. These initiatives aim to increase productivity and improve the service quality of Lio Decor's woodworking workshop, thereby enhancing its competitive position in the market.

4. Conclusion and recommendations

The application of Lean Manufacturing to the changeover process at the CNC machine has yielded significant results. Specifically, 3 out of 18 steps were converted from Internal to External, and 3 Internal steps were improved through the addition of materials and standardization of work procedures. The Benefit/Cost (B/C) ratio reached 2.63, demonstrating the feasibility of the proposed improvements. The average changeover time was reduced from 21.25 minutes to 14.63 minutes, with a stable execution time ranging from 14 to 16 minutes. Process error rates and workplace accidents were nearly zero. Notably, during a random inspection on November 14, 2024, the recorded changeover time was 15 minutes and 3 seconds, indicating that the improvements have been effectively maintained. However, the study faced certain limitations, such as the inability to provide detailed data like images, videos, and the specific B/C coefficient due to company confidentiality policies.

These results highlight the importance of continuous improvement, not only in addressing current challenges but also in creating future competitive opportunities. The SMED method will continue to be expanded to other departments within the workshop, helping the company move towards greater satisfaction for both the parent company and customers, while remaining adaptable to strengthen its market position.

The successful implementation of SMED across the entire industry depends not only on the technical effectiveness of the method but is also influenced by various contextual factors. Some challenges to scaling up include limited improvement budgets (unfavorable B/C ratios), resource constraints (complex or outdated machinery, insufficiently skilled labor, resistance to change), or a corporate culture not yet accustomed to continuous improvement. Additionally, factors such as company size, worker skill level, and the complexity of the production line also affect the feasibility of SMED deployment. Therefore, scaling up this model should be carefully evaluated based on the actual conditions of each enterprise.

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APPENDIX

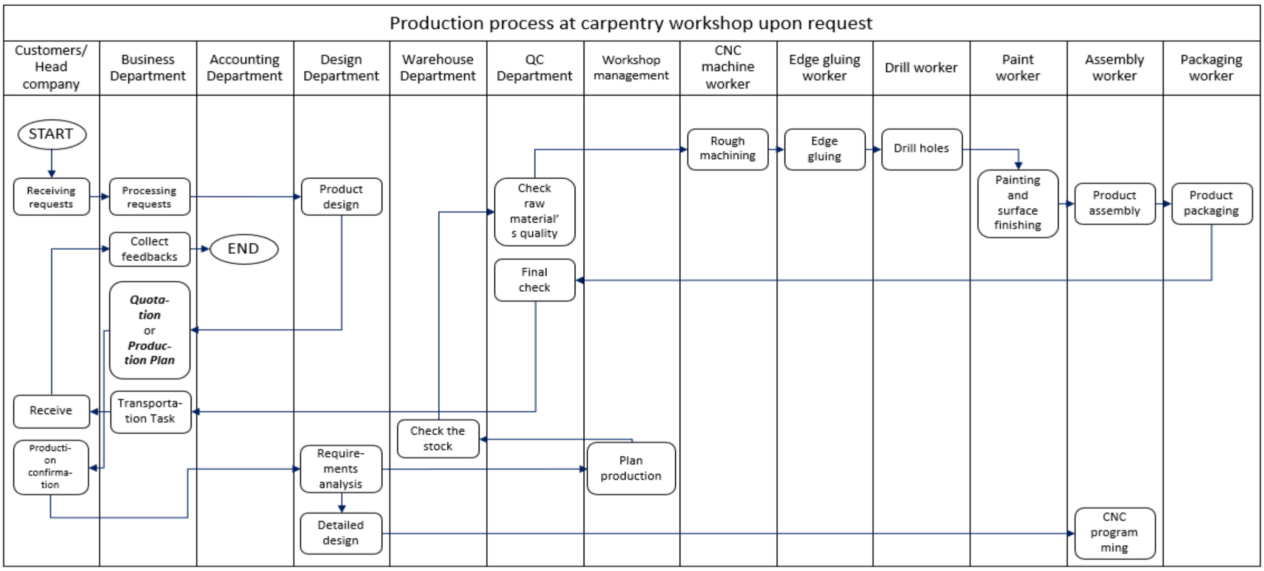


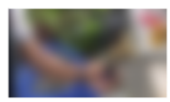
Figure PL.1. *Process from receiving request to handing over product at carpentry workshop*

Table PL.1. *Summary of 15 samples obtained from Gemba Walk method after 2 weeks*

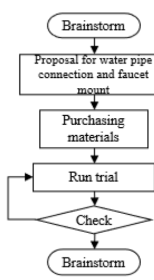
Name of the step	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***	***13***	***14***	***15***
Waiting for the machine to completely stop	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Turning on the machine	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Checking the air system	4,3	5,2	4,49	6,38	4,37	5,6	4,88	5,55	5,85	5,02	4,97	6,29	6,03	6,11	4,73
Checking cooling water for the vacuum system	12	53	14	11	10	55	48	47	62	49	58	53	54	64	15
Returning the machine axis to the original coordinates	16	15,5	16	17	15,9	16,8	16,5	16,4	15,7	16,1	16,7	15,7	16,4	17,3	16,3
Preparing necessary tools	124	119	120	123	124	120	124	123	121	123	124	123	123	123	122
Placing the new mold on the workpiece lifting table, adjusting it for machine operation	80	78	79	80	82	83	81	83	77	83	79	81	78	78	77
Selecting the correct spacer rings and fixtures for the new mold	101,5	101,5	98,7	100,5	103,4	99,9	99,1	102,9	100,2	99,8	101,5	99,3	102,9	101,4	103,2
Loading the CNC program for the new product code	117,56	125,34	123,01	127,67	122,89	124,12	122,45	129,67	123,49	120,45	129,23	126,78	115,89	123,91	122,34
Checking and adjusting parameters: spindle speed, cutting depth, operating mode	237,89	240,23	240,34	241,23	236,4	236,89	239,89	235,12	238,5	242,67	237,45	239,78	239,01	234,34	238,56
Feeding the new workpiece into the machine	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18	43,18
Adjusting clamps to secure the workpiece firmly	33,79	38,09	35,86	38,36	36,45	37,72	32,79	33,14	36,56	36,12	34,94	36,64	38,5	37,19	37,45
Adjusting the output table to coordinate with the new workpiece	40,46	42,54	42,77	42,81	41,4	45,17	46,11	43,31	44,72	49,72	42,07	43,62	41,96	40,06	44,82
Test cutting the new product workpiece	135,36	135,01	137,47	134,96	134,29	126,57	138,95	133,85	133,31	137,54	125,12	138,46	138,83	137,87	134,49
Transferring the test-cut workpiece to the output table	16,7	17,5	18	17	17,8	16,6	17,4	16,8	17,1	17,3	17,6	16,5	17,2	17,9	17
Checking and readjusting parameters: spindle speed, cutting depth, operating mode	100,47	100,37	109,79	106,23	104,3	107,35	100,04	117,33	100,55	118,46	111,83	116,85	113,79	111,35	104,69
Stacking the new workpiece batch onto the lifting table	139,13	124,9	127,65	134,23	140,73	136,98	135,27	124,9	141,71	130,79	125,61	134,22	138,38	138,5	142,01
Starting the process	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total	**1232,3**	**1269,4**	**1240,3**	**1253,6**	**1247,1**	**1284,9**	**1279,6**	**1285,2**	**1290,9**	**1302,2**	**1281,2**	**1304,3**	**1297,1**	**1304,1**	**1252,8**

Average time (seconds)				
No.	**Name of the step**	**Time**	**Int/Ext**	**Improvement proposal**
1	Waiting for the machine to completely stop	5	Internal	
2	Turning on the machine	20	Internal	
3	Checking the air system	5,32	Internal	
4	Checking cooling water for the vacuum system	40,31	Internal	Move the water tap closer to the machine's water tank
5	Returning the machine axis to the original coordinates	16,3	External	Design the basket right next to the CNC machine
6	Preparing necessary tools	122,43	Internal	
7	Placing the new mold on the workpiece lifting table, adjusting it for machine operation	79,97	External	Do it before the final product of the old code is completed
8	Selecting the correct spacer rings and fixtures for the new mold	101	Internal	
9	Loading the CNC program for the new product code	123,65	Internal	
10	Checking and adjusting parameters: spindle speed, cutting depth, operating mode	238,57	Internal	Redesign the new, intuitive note board for users
11	Feeding the new workpiece into the machine	43,18	Internal	
12	Adjusting clamps to secure the workpiece firmly	36,2	Internal	
13	Adjusting the output table to coordinate with the new workpiece	43,44	External	Do it right when starting the test process of the new code blank
14	Test cutting the new product workpiece	134,81	Internal	
15	Transferring the test-cut workpiece to the output table	17,23	Internal	
16	Checking and readjusting parameters: spindle speed, cutting depth, operating mode	108,23	Internal	Redesign the new, intuitive note board for users
17	Stacking the new workpiece batch onto the lifting table	134,33	Internal	
18	Starting the process	5	Internal	
Total time		**1.274,98**	Internal	

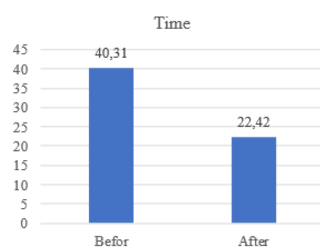
Figure PL.2. *Summary of Improvement Proposals for Changeover Processes*

LIO DECOR	**IMPROVEMENT REPORT**	Area: CNC Improvement Name: Water Pipe Next to the Tank
Plan	**5W1H (Problem Description)**	**Illustration**
Problem:	Unsuitable location of water pipe	
What	**The water pipe is too far from the CNC machine's tank.**	
Why	Moving is not necessary.	
When	During the item conversion process, when the water in the tank needs to be replenished	
Where	CNC machine area	
Who	CNC machine worker, with item changeover schedule	
How	Connect the hose and faucet close to the water tank to eliminate movement.	

Do — **Develop and implement idea**

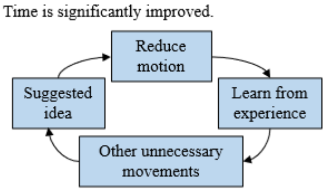


Check — **before and after improvement**



Act — **Implementation and maintenance, development plan**

Complete the improvement after run trial in 1 week
→ Time is significantly improved.



SUMMARY:

Reduced the time of the "Checking cooling water for the vacuum system" step from 40.31 → 22.42 seconds.

Main responsibility	Start date	Approval date	Expense	Cost saving	B/C ratio	Status
Huy Thái	15/10/2024	03/11/2024	231.000đ	429.360đ	2,02	Applicable

Figure PL.3. *PDCA-based reporting*

Table PL.1. *Test samples obtained after improvement*

Operations for Executing the Changeover Process	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*
Waiting for the machine to completely stop	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Turning on the machine	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Checking the air system	4.97	5.02	5.2	6.03	4.3	4.37	4.49	6.11	4.88	6.29	5.55	4.73	6.38	5.6	5.85
Checking cooling water for the vacuum system	22.58	24.87	24.42	23.16	23.91	22.97	23.77	12.86	17.91	23.23	19.09	24.6	24.62	24.11	24.23
Returning the machine axis to the original coordinates	15.7	15.7	15.5	16	16.4	15.9	16	16.4	16.7	17.3	16.1	16.3	16.5	16.8	17
Preparing necessary tools	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Placing the new mold on the workpiece lifting table, adjusting it for machine operation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Selecting the correct spacer rings and fixtures for the new mold	99.9	101.5	101.5	102.9	101.5	101.4	100.5	102.9	98.7	100.2	103.4	99.3	103.2	99.1	99.8
Loading the CNC program for the new product code	129.67	127.67	122.34	129.23	123.01	125.34	122.45	117.56	115.89	123.49	126.78	124.12	122.89	123.91	120.45
Checking and adjusting parameters: spindle speed, cutting depth, operating mode	196.52	197.32	198.76	193.2	197.18	177.04	175.93	170.19	191.21	198.12	175.61	189.11	192.39	197.83	189.41
Feeding the new workpiece into the machine	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18	43.18
Adjusting clamps to secure the workpiece firmly	37.72	38.5	36.56	35.86	33.14	33.79	38.36	36.64	37.19	34.94	37.45	36.45	38.09	36.12	32.79
Adjusting the output table to coordinate with the new workpiece	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Test cutting the new product workpiece	133.31	135.01	134.96	126.57	125.12	138.83	134.29	133.85	137.47	135.36	138.46	137.54	134.49	138.95	137.87
Transferring the test-cut workpiece to the output table	16.6	16.7	17.1	17.9	17.8	16.8	17.5	17	17.6	17	17.3	18	17.2	16.5	17.4
Checking and readjusting parameters: spindle speed, cutting depth, operating mode	21.52	20.61	27.81	24.6	20.58	29.95	20.58	26.95	29.84	22.39	21.42	21.21	23.03	21.01	26.92
Stacking the new workpiece batch onto the lifting table	141.71	134.23	124.9	136.98	130.79	138.38	142.01	139.13	125.61	127.65	138.5	135.27	124.9	134.22	140.73
Starting the process	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Total	**893.38**	**890.31**	**882.23**	**885.61**	**866.91**	**877.95**	**869.06**	**852.77**	**866.18**	**879.15**	**872.84**	**879.81**	**876.87**	**887.33**	**885.63**

Table PL.3. *Cost for improvement ideas*

No.	***Name***	***Time before***	***Improvement ideas***	***How to do***	***Buying materials***	***Expense***	***Time after***	***Time saving***	***1st week benefit***	***B/C ratio***
1	Waiting for the machine to completely stop	5	x	x	x	,	5	,	,	,
2	Turning on the machine	20	x	x	x	,	20	,	,	,
3	Checking the air system	5.32	x	x	x	,	5	,	,	,
4	Checking cooling water for the vacuum system	40.31	Directly connect the water tap to the tank	Connect silicone hose from faucet to tank mouth	Silicone tube; Water pipe band; Wall nail	170,000	22	18	23,480.63	0.138
5	Returning the machine axis to the original coordinates	16.3	x	x	x	,	16	,	,	,
6	Preparing necessary tools	122.43	Mount the 10kg stainless rack. get the tools ready at the beginning of the day	Buy rack and mount on wall. near the machine	Self-making wooden shelf; Wall nail	28,000	,	122	160,689.38	5.739
7	Placing the new mold on the workpiece lifting	79.97	Do it immediately	Change process	None	,	,	80	104,960.63	,

No.	Name	Time before	Improvement ideas	How to do	Buying materials	Expense	Time after	Time saving	1st week benefit	B/C ratio
	table, adjusting it for machine operation		when the last product of the previous item starts to be cut							
8	Selecting the correct spacer rings and fixtures for the new mold	101	x	x	x	,	101	,	,	,
9	Loading the CNC program for the new product item	123.65	x	x	x	,	124	,	,	,
10	Checking and adjusting parameters: spindle speed, cutting depth, operating mode	238.57	Design a new parameter board. easier to use	Self – Design for testing	None	,	189	49	64,640.63	,
11	Feeding the new workpiece into the machine	43.18	x	x	x	,	43	,	,	,
12	Adjusting clamps to secure the workpiece firmly	36.2	x	x	x	,	36	,	,	,
13	Adjusting the output table to coordinate with the new workpiece	43.44	Do it immediately when starting to test cut the blank for the new item	Change process	None	,	,	43	57,015.00	,
14	Test cutting the new product workpiece	134.81	x	x	x	,	135	,	,	,
15	Transferring the test-cut workpiece to the output table	17.23	x	x	x	,	17	,	,	,
16	Checking and adjusting parameters: spindle speed, cutting depth, operating mode	108.23	Design a new parameter board. easier to use	Self – Design for testing	None	,	24	84	110,683.13	,
17	Stacking the new workpiece batch onto the lifting table	134.33	x	x	x	,	134	,	,	,
18	Starting the machine	5	x	x	x	,	5	,	,	,
						198,000			521,469	2.634