Lean Manufacturing to Improve the Efficiency in A Small and Medium Enterprise: Case in Tofu Production Processes

Sri Hartini, Nurin Salwa Nabila, Faradhina Azzahra, Heru Prastawa, and Yusuf Widharto
Department of Industrial Engineering
Diponegoro University
Prof Soedarto Tembalang, Semarang, Indonesia
srihartini@lecturer.undip.ac.id, nurinsalwa04@gmail.com, faradhinaazzahra@lecturer.undip.ac.id, heruprastawa@lecturer.undip.ac.id, and yusufwidharto@lecturer.undip.ac.id

Abstract

Lean manufacturing has been widely applied in companies and proven to improve operational performance. Lean is mainly applied to the automotive industry. However, now it has been widely applied in other sectors by considering the characteristics of the application field, including the agro-food sector. The purpose of this study is to evaluate the production process in SMEs, which is still done conventionally. The research begins by using value stream mapping to identify inefficiencies. The results of current-value stream mapping state that the efficiency of the production process is 71.34%. The failure mode effect analysis results state that the critical waste that occurs is overprocessing, waiting, and transportation time. Proposed improvements are made by applying the 5S concept, layout design of the production area, and mechanization of the boiling and filtering processes. Efficiency in future value stream mapping is estimated to increase by around 20%.

Keywords
Lean manufacturing, Value stream mapping, Failure mode effect analysis, Agro-food industry, Tofu.

1. Introduction

Tofu is a soy-based food that provides protein requirements for humans. In addition to being a good source of bioactive compounds, including isoflavones and soy saponin, tofu is also a rich source of vitamins, minerals, and healthy fats. Consuming tofu can lower the risk of several illnesses, such as hypertension, hyperlipidemia, hypercholesterolemia, arteriosclerosis, coronary heart disease, breast cancer, and other conditions (Q. Zhang et al. 2018). Tofu may reduce the risk of CHD in women (X. Zhang et al. 2003) and decreases lipogenesis in the liver via regulating gene expression, which could lower serum lipid levels (Takahashi and Konishi 2011).

Besides the several benefits of consuming tofu, it also has a delicious taste and affordable price for all levels of society. It causes that tofu includes as a popular food in Indonesia. The average tofu consumption in Indonesia grew from 7,956 kg per person in 2020 to 8,216 kg per person in 2021 (Badan Pusat Statistika 2021). Following the rise in tofu consumption, small tofu-producing businesses in Indonesia have emerged. One of the small and medium enterprises (SME) that produces tofu in Indonesia is Eko Budi's home industry in the village of Sugihmanik, Tanggungharjo, Grobogan, East Java.

Based on the preliminary observation in Eko Budi's home industry, it was indicated that there was time wasted during the tofu production process. The researchers indicated that set-up time in several processes took a long time. The percentage between set-up time and total production time in the boiling and frying processes was 59% and 49%, respectively. Besides, there was often a waiting time in the filtering process of 3-4 minutes if the tofu porridge in the previous process had not been processed. In addition, tofu production ran conventionally. The filtering process is done manually by humans as much as 50-60 times a day. The waste during the tofu production process led to an inefficient process.

One method for identifying waste in the production process is the lean manufacturing approach. Lean manufacturing is a production technique that considers using resources for any task other than producing value for the end user to waste (S. K. Sharma et al. 2011). Lean Manufacturing is a production practice that considers all existing resource expenditures to get economic value to customers without any waste, and this waste is the target to be reduced. Value stream mapping (VSM) is a lean manufacturing tool that may be used to find waste by showing the process (Grewal 2008). A value stream map, which includes information flows, material flows, and decision-making flows, is a compilation of all value-added and non-value-added operations that range from raw materials to final consumers (Forno et al. 2014; Singh et al. 2011; Hartini et al. 2017).

This research is expected to identify waste that occurs in tofu production process using the current state VSM and increase efficiency by giving recommendations related to the identified waste. It is proven, based on future state VSM that it is able to compare the efficiency between before and after the proposed improvement. Thus, this study aims to apply the lean manufacturing approach to tofu production in Eko Budi's SME.

2. Literature Review

2.1 Lean Manufacture

Lean Manufacturing is a Toyota Production System (TPS) process management approach. Lean Manufacturing was first applied to the Toyota Motor Company, an approach developed by Taiichi Ohno (Ohno 1988). Lean Manufacturing is a method of systematically reducing waste by continuously improving processes (Alaca and Ceylan 2011). According to Gaspersz and Fontana (2011), lean can be interpreted as a systemic and systematic approach to identify and eliminate non-value-adding activities or waste through a pull system from internal to external by streaming products (materials, work-in-process, output) and information through continuous improvement to pursue excellence and perfection.

Rawabdeh (2005) stated that at least seven areas could be investigated to reduce waste: motion excess, waiting time, overproduction, overprocessing, defects, inventory excess, and transportation. Implementing a lean manufacturing strategy offers numerous benefits, including reduced lead time, processing time, cycle time, set-up time, inventory, defects, and rework (Bhamu and Singh Sangwan 2014). Besides those benefits, the advantages of implementing lean production are also to increase customer satisfaction, increase productivity, change of bad attitude, improve product quality, and decrease delivery time (Čiarnienė and Vienažindienė 2012).

2.1 Value Stream Mapping

Value stream mapping or VSM is a fundamental lean tool for identifying waste and opportunities for value improvement using current VSM and future VSM (Hartini et al. 2017). VSM is a diagnostic technique derived from the principles of lean manufacturing. The goal of VSM is to identify value-added and non-value-added activities in value streams in order to eliminate non-value-added activities which is in line with the basic concept of lean manufacturing (Forno et al. 2014). VSM as a lean manufacturing tools had been applied in several different fields (Romero and Arce 2017), such as construction (Matt et al. 2013), transport (Villarreal et al. 2012), product development (Tyagi et al. 2015), reduction of food loses (De Steur et al. 2016), service maintenance (Kasava et al. 2015), agro-food secto (Suwasono et al. 2022), and others.

3. Methods

The data collection method was carried out by monitoring and communication study, which is by conducting direct observations and interviews with the owner of Eko Budi's tofu SME. The data gathered takes the form of SMEs layout, production process, and cycle time. The observation took twelve iterations of tofu production cycle.

Data procession in this study was done by applying the concept of lean manufacturing in the tofu production process. In describing the situation of the production process and mapping the waste that occurs in tofu SME, this study used value stream mapping as an analytical tool. The data collected was then mapped into value added (VA), necessary but non value added (NNVA), and non-value added (NVA) activities using process activity mapping (PAM). Efficiency calculations for each process were carried out. Based on the efficiency calculation, current state map VSM that described the actual conditions of production process was build. It could identify waste which was further analyzed using failure mode effect analysis (FMEA). Researchers, then, brainstormed to identify possible causes of waste using fishbone diagram. Literature study was done to give appropriate recommendations based on cause of waste.

Researchers finally constructed future state VSM to calculate the efficiency based on the given recommendation. This study also made layout planning based on the recommendations.

4. Data Collection

4.1 Tofu Production Process in Eko Budi's SME

The main raw materials for making a tofu are soybeans and water. The final product of Eko Budi tofu's SME is fried tofu. Thus, the raw materials should be processed through several steps which the end of the process is frying. The whole process consists of soaking, grinding, boiling, filtering, clumping, pressing, and frying. The input and output of each production process is shown in Figure 1, while the duration of each process is shown in Table 1.

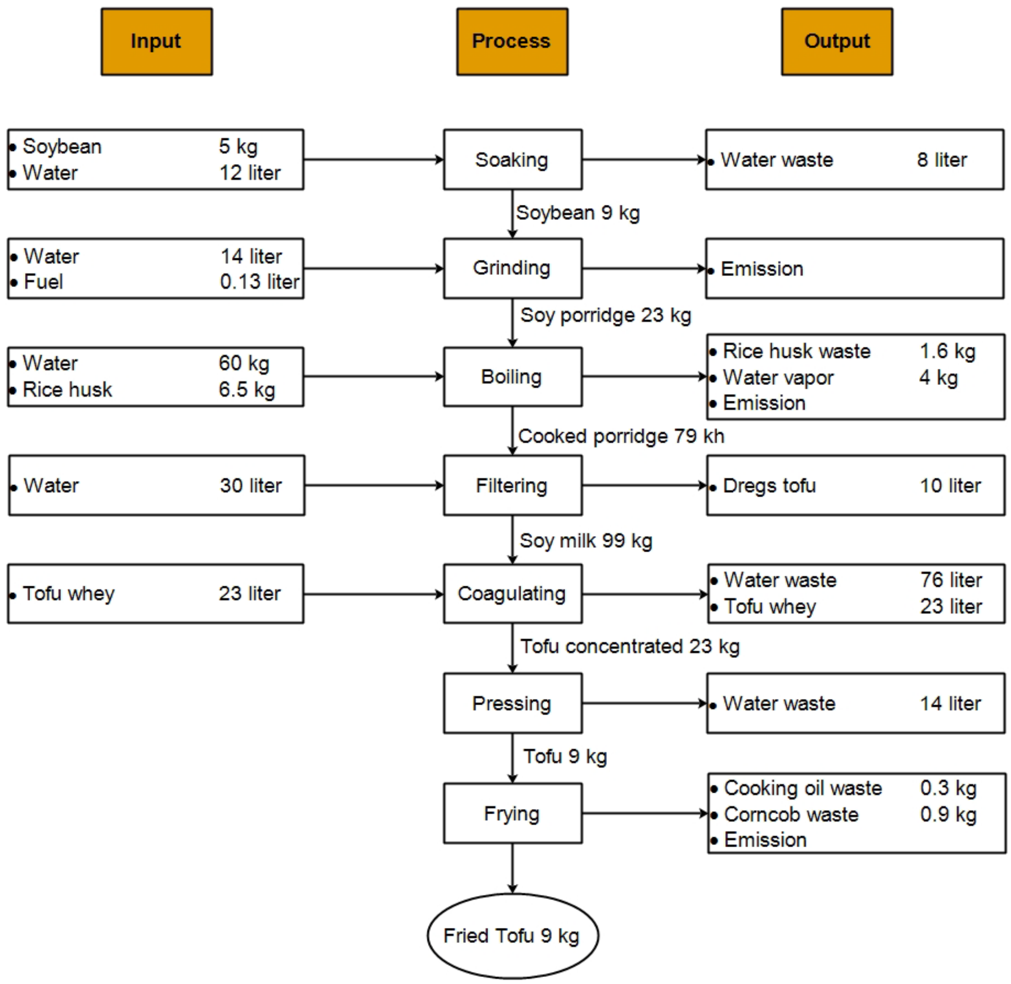

Figure 1. Input-output diagram of tofu production process

4.1 Initial Layout of Production Area

The production area of the Eko Budi tofu's SME has an area of about 180 m^2. The entire production process is carried out in this area. The process is done conventionally. The initial layout is shown in Figure 2. It was used as a baseline to create layout suggestions.

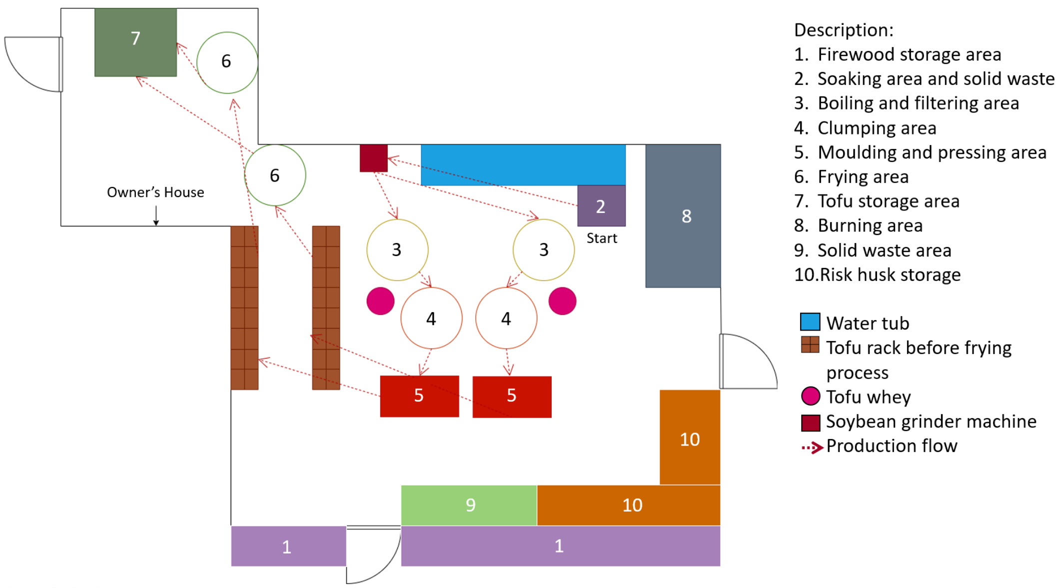

Figure 2. Initial Layout of Eko Budi's SME Production Area

5. Results and Discussion

5.1 Current State VSM Analysis

Based on the tofu production process and duration of each step, the percentage of efficiency is determined by identified the VA, NNVA, and NVA. Table 1 shows the recapitulation of time efficiency in each work process at Eko Budi tofu SME. There are 3 categories of company management in measuring efficiency, which are low category (efficiency ≤ 49%), medium category (efficiency = 50%-89%), and high category (efficiency ≥ 90%). Table 1 shows that the process of boiling, filtering, and frying has an efficiency of less than 49%, so that the three processes were included in the category of low efficiency. It was happened because the NNVA and/or NVA time was higher than the VA time. Based on the results of the initial efficiency calculations, it was then stated in the VSM current state map which is presented in Figure 3.

Table 1 Efficiency Recapitulation

No.	Process	Cycle time	Time of *Value Added* (VA)	Time of *Necessary but Non-Value Added* (NNVA)	Time of *Non-Value Added* (NVA)	Efficiency	Category
1	Soaking	7355.52	7326.13	29.38	0.00	99.60%	High
2	Grinding	354.68	311.00	4.53	39.14	87.69%	High
3	Boiling	2225.03	939.89	1155.33	129.80	42.24%	Low
4	Filtering	544.69	89.58	153.98	301.13	16.45%	Low
5	Clumping	155.17	148.01	7.16	0.00	95.39%	High
6	Pressing	244.58	184.72	59.87	0.00	75.52%	Medium
7	Frying	3238.48	1180.69	1657.78	400.00	36.46%	Low

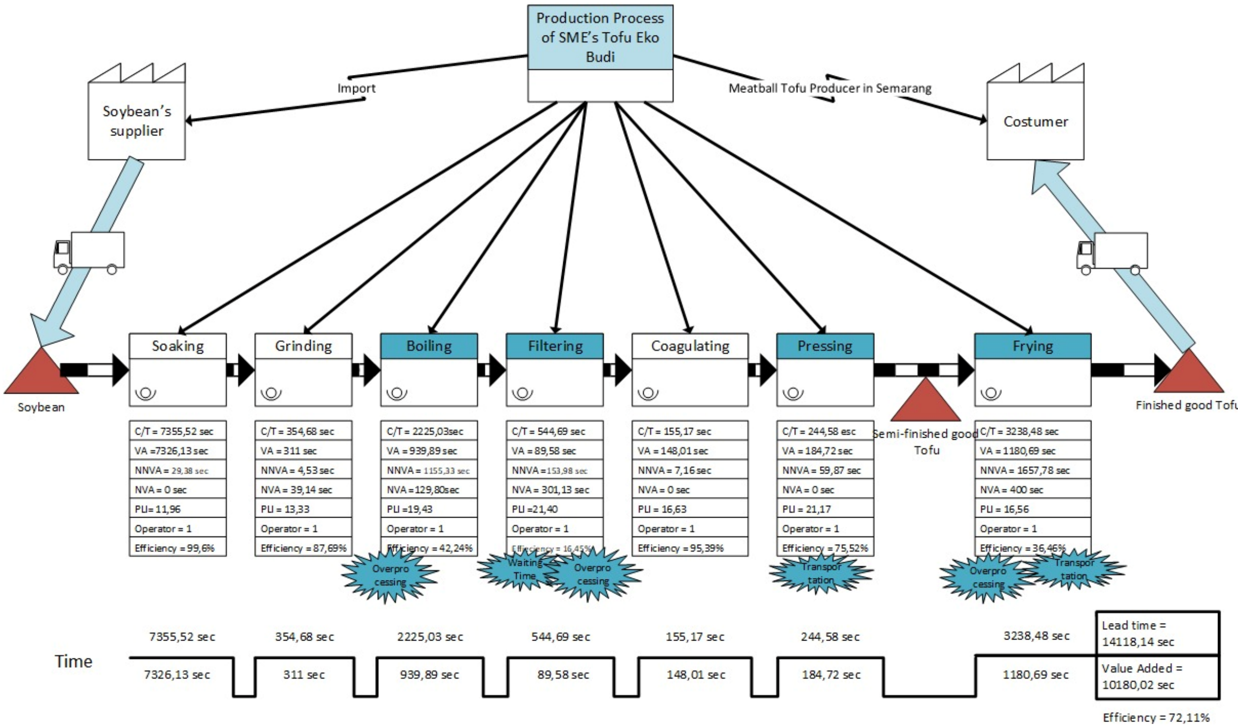

Figure 3. Current state VSM

5.2 Identification of Critical Waste

From the Figure 3 of the current state VSM, it can be seen that the overall efficiency of the tofu production process is 71.34%. There were several identified wastes that resulted in low efficiency category. To determine critical waste, this study used the failure mode and effect analysis (FMEA) method a fishbone diagram to analyzed it. The FMEA results is shown in Table 2.

Table 2. Failure Mode Effect Analysis (FMEA)

Waste	Failure	Effect of Failure	Sev.	Cause of Failure	Occ.	Det.	RPN	Rank
Overprocessing	Take a long time to turn on the boiling stove	A long lead time	5	Moist rice husks	6	3	90	6
	Repetition on the installation and removal of the filter	A long lead time	6	The tofu filter is installed and removed manually by workers	10	5	300	1
	Worker trying to repair blower machine	Extra time to repair the machine	5	The blower machine is sometime damaged	3	4	60	7
	Take a long time to turn on the frying stove fire	Tofu that is ready to be fried is idle	4	Moist fuel	6	4	96	4
Transportation	Back and forth workers delivering tofu to storage	A long lead time	6	The distance between tofu storage and pressing area is too far	10	2	120	2

Waste	Failure	Effect of Failure	Sev.	Cause of Failure	Occ.	Det.	RPN	Rank
	Back and forth workers delivering tofu from storage to frying stove	A long lead time	5	The distance between the tofu storage and frying area is too far	9	2	90	5
Waiting	Idle workers waiting for finished boiling tofu	Idle raw materials that have been boiled	4	Installation of tools in the next process is done by the same worker	4	6	96	3

The calculation using FMEA revealed the risk priority number (RPN) value. RPN is calculated by multiplying three factors which are severity (Sev.), occurrence (Occ), and detection (Det). FMEA reveal that waste overprocessing in the filtering process had the highest risk priority number (RPN) value, followed by transportation time in the pressing and waiting time in the boiling process. The failure with the highest RPN value was happened because the production process was done conventionally. In filtering process, the tofu is installed and removed manually by workers.

5.3 Fishbone

Based on the top tree highest RPN calculated from FMEA, the researchers define the top three waste as the critical waste in this study. A fishbone diagram then created for each waste and is shown in Figure 4, Figure 5, and Figure 6.

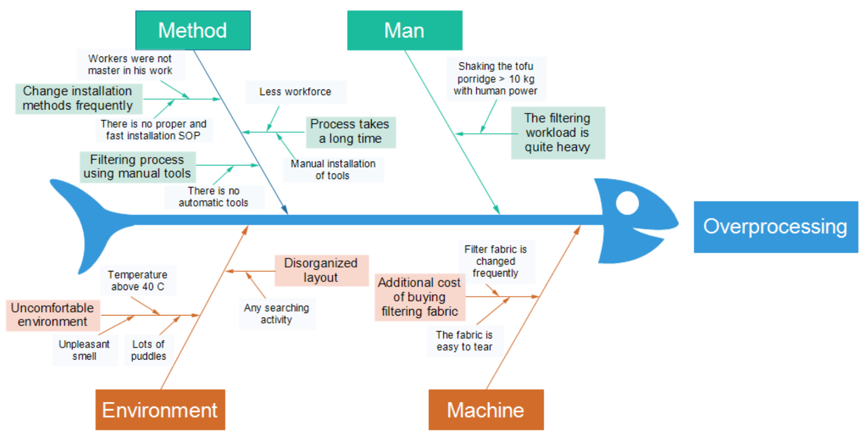

Figure 4 Fishbone of overprocessing waste at filtering process

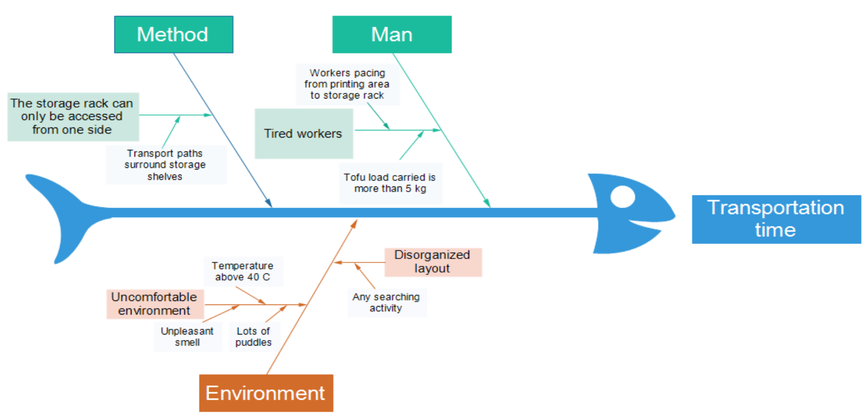

Figure 5 Fishbone of transpotation time waste at pressing or molding process

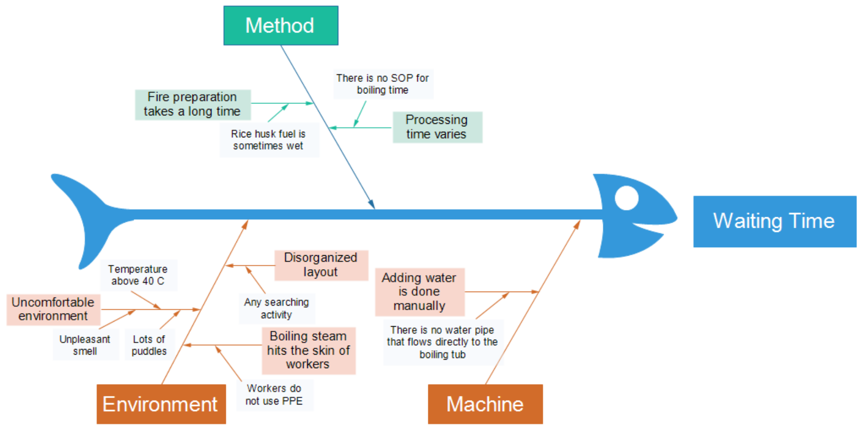

Figure 6 Fishbone of waiting time waste at boiling process

5.3 Improvement Design Analysis using 5S

Based on the waste that occurs, recommendations for improvement with the most suitable lean manufacturing tools approach are 5S. The term 5S comes from five Japanese word that includes *seiri, seiton, seiso, seiketsu,* and *shitsuke*. It is often translated in English into sort, set in order, shine, standardize, and sustain. It is a five-step workplace arrangement and maintenance system developed through intensive manufacturing efforts (S. S. Sharma et al. 2019).

First, at the *seiri* or sort stage, tools and goods in the production area that are needed and not needed are selected. It helped to expand the production area because unused goods can be discarded or destroyed. Second, at the *seiton* or set in order stage, the goods are grouped based on the work process and placed on a small shelf to facilitate easier storage process. The tofu storage rack needs wheels to make it more convenient for workers to take and place the tofu. The grouping goods based on the manufacturing process aims to make it easier for workers to find tools based on their work and able to reduce searching activities. The production area is then rearranged in accordance with the production flow. Third, at the *seiso* or shine, cleaning needs to be done in the manufacturing process area. Cleaning the production area aimss to reduce workplace accidents probability. The use of full personal protective equipment is also included in the parameters of the hygiene standards that have been developed. Fourth, at the *seiketsu* or standardize stage, maintenance needs to be done in the production area periodically. Maintenance can be accomplished by dividing the responsibility among workers for daily cleaning and routine inspections before leaving the workplace. Last stage which is *shitsuke* or sustain stage, socialization about 5S in the work area should be held, as well as impromptu inspection by SME owner once a month to evaluate the implementation of the 5S concept in the workplace.

Based on 5S concept, the improvement production layout was developed. Figure 7 shows the layout planning after having improvement based on 5S concept. The distance between pressing area and storage was changed from 350 cm in initial layout to be 180 cm in first proposed recommendation layout. The distance between storage rack and fryerwas also closer from 293 cm into 150 cm. The closer and enough distance for each machine had, it could decrease the transportation time.

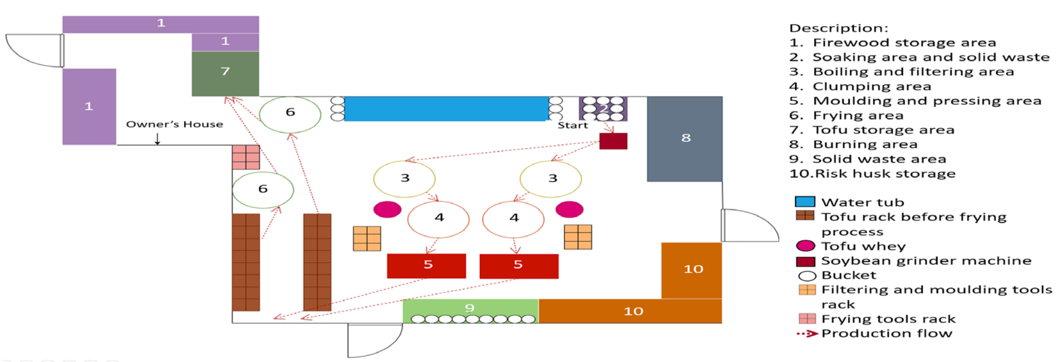

Figure 7 Proposed production area layout based on 5S approach

5.3 Improvement Design Analysis with Mechanization

The waste that can be eliminated immediately using the 5S approach is transportation time. Other treatments are required for waste overprocessing and waiting time reduction. The production process that is carried out manually or using human power in several processes is one of the root causes of the waste. To reduce waste, changing the manual process to mechanization system or use a machine. In this case, the process that needs to change from manual to machine was boiling and filtering process. In the boiling process, it is suggested to use a boiler machine. By using less firewood, this machine can reduce cycle times. The boiler machine uses electricity to accelerate the cooking of soybeans. In other hand, during the filtering process, it is suggested that an automatic filter machine be used. The filter machine's design makes it easier for workers to filter because there is no need to use human power but rather an electric motor. Furthermore, the researchers suggest for using a piping system in water use. Previously, water was carried out by taking it with a bucket back and forth between the water bath and the process area. By installing pipes in area that require water, the activity of taking water can be reduced. Figure 8 and Figure 9 depict a boiler machine and an automatic filter machine respectively.

Figure 8. Boiling machine (Mitra Boiler 2022)

Figure 9. Automatic filter machine (Seyegan Serasi 2020)

The capacity of the boiling machine is able to boil water 500 kg each day. The energy of this boiling machine comes from firewood and electricity. To transport the water, it uses pipelines mechanism. In the other hand, automatic filter machine that is build using an iron frame has a hook with a design that does not come off easily. The actuator of the filter machine is a 1/2 HP electric motor. Figure 10 shows a layout design for the production area after using a boiler machine and a filter and piping machine.

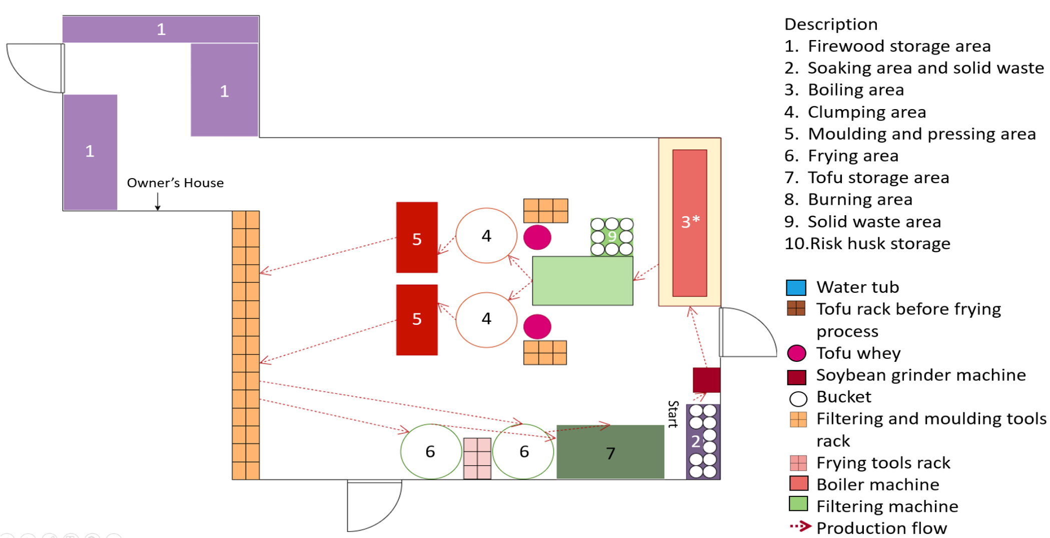

Figure 10 Proposed production area layout based on 5S approach and mechanization

5.4 Machine Cost Feasibility Analysis

According to Čiarnienė and Vienažindienė (2012), in order to increase productivity by eliminating waste, there is an initial investment made in achieving standard processing levels, which may be detrimental during the implementation process. Purchasing an efficient machine can significantly increase a company's expenses. By including machines in the recommendations, it is necessary to conduct a cost-feasibility analysis to determine when the profits and feasibility of investing in the machine will be realized using an economic engineering approach. A boiler machine costs around Rp. 40,000,000, a filter machine costs around Rp. 11,000,000, and a suction machine on a filter cost around Rp. 4,000,000.

The payback period is a measure of an investment's feasibility based on the rate of return on investment. The investment in boiler and filter machines will pay off in the third year, totaling Rp. 58,593,653. Meanwhile, the Net Present Value (NPV) calculates the feasibility of an investment based on the net profit from the final work. If the NPV0 of the investment in boiler and filter machines is less than the NPV1 of the investment in machines, then the investment in machines is feasible to implement. Internal Rate of Return (IRR) is a method of calculating the viability of investment costs based on interest rates. The interest rate used is 5%, and as a result, the investment in the boiler and filter machine is feasible because the IRR value is greater than the interest rate. Profitability Index (PI) compares the value of initial investment receipts to a profit index to determine the feasibility of investment costs. The investment in boiler and filtering machines is feasible in the profitability index method because the PI value is higher than 1. According to the four methods, the investment costs for boilers and screening machines are feasible because there will be no loss.

5.5 Future State VSM Analysis

The future state VSM is established using an estimated calculation of proposed improvements. The implementation stage of improvement recommendations was not monitored in this study. The future VSM depicted in Figure 11.

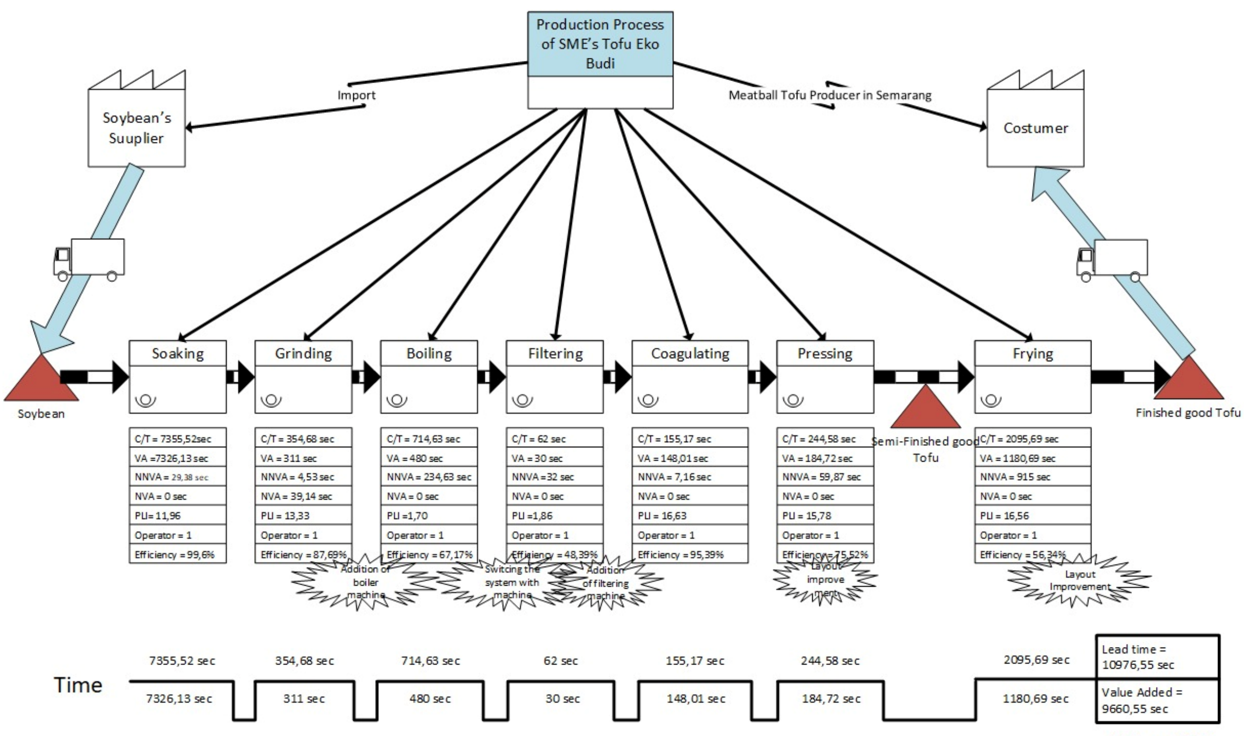

Figure 11. Future State VSM

Table 3 shows a comparison table of efficiency before and after improvements. After using the 5S approach and mechanization approach, the percentage of efficiency was increased. According to a comparison of the two designs, the increasing efficiency number was happened in boiling, filtering, pressing, and frying processes. Thus, the total efficiency of the VSM in future has increased by an average of 20%.

Table 3. Comparison of Efficiency Before and Expectation After Repair

No	Proses	*Current State Map* (%)	*Future State Map* (%)
1	Soaking	99,60%	99,60%
2	Grinding	87,69%	87,69%
3	Boiling	42,24%	69,10%
4	Filtering	16,45%	48,39%
5	Clumping	95,39%	95,39%
6	Pressing	75,52%	80,36%
7	Frying	36,46%	56,34%
	Total	72,11%	88,2%

6. Conclusion

This study aims to apply the lean manufacturing approach to the tofu production in Eko Budi's SME using VSM. Calculations using current state value stream mapping revealed that some waste occurred at UKM Tahu Eko Budi. Waste is identified based on time inefficiencies that have been measured. The efficiency of the boiling, filtering, and frying processes was discovered to be in the low category. To increase efficiency in the tofu production process, researchers recommend two strategies. First, implement the 5S concept in the manufacturing process and redesign the manufacturing floor layout to reduce transportation time. Second, shifting the production system from manual or human power to mechanical or machine assistance, particularly in the filtering process, to reduce cycle time in tofu production and worker workload, thereby reducing overprocessing waste. With several recommendation for improvement, an estimated time calculation for the future VSM design is performed and compared with the current VSM design. According to a comparison of the two designs, the efficiency of the VSM future has increased by an average of 20%.

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Biography

Sri Hartini is an Associate Professor and a Lecturer in the Department of Industrial Engineering, Diponegoro University. She received a Master's Degree in Industrial Engineering from Bandung Institute of Technology and Doctoral program of the Department Of Industrial And Systems Engineering, Ten November Institute of Technology. Now, she is head of the lean and sustainable supply chain laboratory. Her research interests include lean manufacturing, sustainable manufacturing, sustainable supply chain management and circular economy.

Nurin Salwa Nabila is a freshgraduated student. She's from Batubara, North Sumatra. She completed her bachelor's degree in Industrial Engineering at Diponegoro University in 2022. She's interested in lean manufacturing, sustainable and suppy chain management.

Faradhina Azzahra is a lecturer on Industrial Engineering Department, Faculty of Engineering, Diponegoro University, Semarang, Indonesia She earned a bachelor degree at Universitas Islam Indonesia (UII) in 2018 and a master of science degree at Universitas Gadjah Mada (UGM) in 2021. Her research interests include Ergonomic Cognitive, Agent-based Model, and related with Environmental Issue.

Heru Prastawa is an Associate Professor, member on Work System Engineering and Ergonomic Laboratory, in Industrial Engineering, Diponegoro University. He earned B.S. in Mechanical Engineering from Sepuluh Nopember Institute of technology (ITS) Surabaya, Masters in Technology Assessment from Universite Marseille III, Marseille, France. Doctorate in Industrial Engineering from Sepuluh Nopember Institute (ITS) Surabaya. His research interests include Human Factors, Ergonomics, User Experience, and manufacturing System. He is member of IAE.

Yusuf Widharto is a lecturer at Department of Industrial Engineering Diponegoro University. He earned his bachelor degree form Atma Jaya University Jogjakarta and his Master Degree from Gadjah Mada University