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Sustainable Value Stream Mapping to Increase Effectiveness and Efficiency in PE-Type Plastic Pellet Companies

Chika Gabriela Keren, Lithrone Laricha Salomon,
Wilson Kosasih
Department of Industrial Engineering
Faculty of Engineering
Universitas Tarumanagara
Jl. S. Parman No. 1, Jakarta, 11440,
Indonesia
chika.545200019@stu.untar.ac.id, lithrones@ft.untar.ac.id,
wilsonk@ft.untar.ac.id

Abstract

The research was conducted at a manufacturing company that produces polyethylene (PE) plastic pellets. This company recycles unused plastic so that it has more benefits, namely as a raw material for the plastic industry. This research aims to be able to assist companies in increasing effectiveness and efficiency using the Sustainable Value Stream Mapping method. The application of this method begins by first identifying several indicators related to the triple bottom line, which include economic, environmental, and social aspects. To find out which indicators need improvement, it is necessary to calculate the efficiency of each indicator. After the calculation was carried out, five indicators were obtained that needed improvement, namely waste (environmental aspect) with an efficiency of 32.13%, noise level (environmental aspect) with an average value of 85.57 dB, lighting level (environmental aspect) with a value of 75 Lux, room temperature (environmental aspect) with a temperature of 33.8 °C, and employee safety level (social aspect) with 50.00% efficiency. To be able to assist companies in improving the efficiency of these three indicators, the next stage that will be carried out is to provide some suggestions for improvements related to waste by recycling again, noise levels using earplugs, lighting levels by adding or replacing lamps with brighter light, room temperature by adding ventilation and hexos, and employee safety by conducting counseling on the importance of security and safety at work.

Keywords
Efficiency, Sustainable Value Stream Mapping, Triple Bottom Line, Waste

1. Introduction
Plastic waste is still one of the problems that is quite concerning in Indonesia today. According to the National Waste Management Information System (SIPSN) until 2022, plastic waste is ranked 4th based on the type of waste in Indonesia, which is 17.82% (Ministry of Environment and Forestry 2023). Plastic itself consists of various types, one of which is polyethylene (PE). Polyethylene (PE) plastic itself is a type of plastic polymer made from ethylene compounds. This type of plastic has good resistance to water and chemicals and is strong, elastic, and recyclable (Xiuhua et al. 2015). However, this type of plastic takes a long time to decompose naturally, so if it is used excessively, it will affect the environment (Ali et al. 2020).

This research was conducted on manufacturing companies that produce products in the form of plastic pellets. After conducting an interview process with one of the persons in charge of the company and direct observation at the production site, there were several problems related to defective products, hot and smoky work environments, and waste in melted plastic dough that came out of the machine due to leaks in the machine. In addition, there is waste in the form of sand washed from plastic as raw material in making plastic pellets, where the waste requires more costs for the disposal of the waste. In addition, there is an uncomfortable work environment that can affect the health and safety of the workers themselves. And also, after conducting a direct survey at the production site, it was found that workers did not use personal protective equipment, which could increase the risk of accidents at work.

Seeing these various problems, a change is needed with improvements because, of course, this waste can affect the environment and the costs incurred by the company. To overcome the problems that exist in this company, the author uses one of the concepts in lean manufacturing, namely sustainable value stream mapping. This method is a development of the value stream mapping method by combining several factors, namely economic, environmental, and social factors (Aatish et al. 2019). So this study aims to analyze problems related to the triple bottom line and help companies achieve effective and efficient production processes while still paying attention to the triple bottom line.

2. Literature Review

2.1 Sustainable Manufacturing

The integration of processes and systems that can produce products and services of the highest quality while utilizing fewer and more sustainable resources, as well as being safer for workers, clients, and the community at large, as well as having the ability to lessen negative effects on the environment and society, is known as sustainable manufacturing. (Carla et al. 2020). In implementing sustainable manufacturing itself, a company must pay attention to three factors, namely economic, environmental, and social. The purpose of sustainable manufacturing is to produce products and services that are quality resources for both energy and materials with a smaller amount but in a sustainable manner, which can create a sense of security for employees, customers, and communities around the production site.

2.2 Value Stream Mapping

Value stream mapping is a method used to see and understand the flow of materials and information about the manufacture of a type of product (Mike and Jhon 2003). In its use, this method refers more to identifying the source of waste and how to improve the system by reducing the waste as much as possible (Mahadeo and Jayadeva 2017). This method is also defined as mapping an action that both provides added value (value added) and does not provide added value (non-value added) that carries a product through the production process from raw materials to finished goods (Taufik and Dwi 2019).

2.3 Sustainable Value Stream Mapping

This method is a development of VSM by combining existing metrics with sustainability metrics, namely the triple bottom line that includes economic, environmental, and social (Vilia et.al. 2022). In its assessment, sustainable value stream mapping itself uses an assessment of the type of traffic light. This assessment uses three colors, namely red, yellow, and green. The red color itself indicates that the value is still below the target, while the yellow color indicates that the value obtained needs to be increased again, and the green color indicates that the value is in line with the target (Sri et al. 2020).

3. Methods

In conducting this study, there were several steps taken to get the results. The first stage was carried out, namely, the author conducted a field study first to be able to see the problems in the company. After the problem is found in the company, the formulation of the problem will be carried out and continued by conducting a literature study related to the method used to be able to analyze the problem further. For this study, the method used is sustainable value stream mapping. This method analyzes the triple bottom line (economic, environmental, and social). In applying this method, the stages are carried out, namely by setting several indicators, where the indicators used are as many as 11 indicators. After the indicators are selected, the next stage is to collect primary and secondary data. Primary data itself is data related to indicators, while secondary data is related to the company's vision, mission, and general description of the company. The next stage will be the calculation of the efficiency value of each indicator, and then the value will be entered into the Sustainable Value Stream Mapping chart and further analyzed using traffic lights. After knowing the indicators that require improvement, make conclusions and provide suggestions for improvements to be able to help the company increase effectiveness and efficiency in the production process.

4. Data Collection

In this study, there are 11 indicators related to the triple bottom line (economic, environmental, and social), which include time, product quality, energy consumption, use of raw materials, waste, noice level, lighting level, room temperature, employee safety level, employee health level, and employee satisfaction level. Next, identify the type of data needed for the efficiency assessment of each assessment indicator and the units to be used in this study. The following are the types of data used for each indicator that can be seen in Table 1.

Table 1. Primary Data

Indicator	Data Type	Amount	Unit
Time	Value Added Time	162.87	Second
	Non Value Added Time	55.04	
Quality of Products	Number of Defectives Product	87,924	Kg
	Number of Product Produced	661,402	
Energy Consumption	Value Added Energy	1,176	kWh
	Non Value Added Energy	320	
Use of Raw Material	Number of Product Produced	661,402	Kg
	Amount of Material Used	749,326	
Waste	Amount of Waste Generated	28,427	Kg
	Amount of Landfill Waste	19,293	
Noice Level	Measurement using the Multifunction Environment Meter 4 in 1 tool	85.57	dB
Lighting Level	Measurement using the Multifunction Environment Meter 4 in 1 tool	75	Lux
Room Temperature	Measurement using the Multifunction Environment Meter 4 in 1 tool	33.8	˚C
Safety Rate of Employee	Number of Activities at Risk	3	Activities
	Number of Activities	6	
Health Rate of Employee	Number of Employees Absent Due to Illness	15	People
	Number of Employees	38	
Satisfaction Rate of Employee	Number of employee turnovers	9	People
	Number of Employees	38	

5. Result and Discussion

5.1 Result

After data collection is carried out, the next stage that can be done is to calculate the efficiency level of each assessment indicator. In doing these calculations, there are several ways that can be done, which can be seen in Table 2.

Table 2. Formula for Calculating the Efficiency of Each Indicator

Indicator	Formula	Source
Time	$\text{Efficiency} = \frac{\text{Value Added Time}}{\text{Total Use}}$ $\text{Total Time} = \text{Value Added Time} + \text{Non Value Added Time}$	(Sri et al. 2020)
Quality of Products	$\text{Efficiency} = 1 - \frac{\text{Product Defect}}{\text{Number of Product Produced}}$	(Sri et al. 2020)
Energy Consumption	$\text{Efficiency} = \frac{\text{Value Added Energy}}{\text{Total Energy}}$ $\text{Total Energy} = \text{Value Added Energy} + \text{Non Value Added Energy}$	(Farkhan and Sri 2020)
Use of Raw Material	$\text{Efficiency} = \frac{\text{Number of Product Produced}}{\text{Amount of Material Used}} \times 100\%$	(Sri et al. 2020)
Waste	$\text{Efficiency} = 1 - \frac{\text{Amount of Landfill Waste}}{\text{Amount of Waste Generated}}$	(Farkhan and Sri 2020)
Noice Level	Measurement using the Multifunction Environment Meter 4 in 1 tool	(Minister of Industry of the Republic of Indonesia 2020)
Lighting Level	Measurement using the Multifunction Environment Meter 4 in 1 tool	(Minister of Industry of the Republic of Indonesia 2020)

Indicator	Formula	Source
Room Temperature	Measurement using the Multifunction Environment Meter 4 in 1 tool	(Minister of Industry of the Republic of Indonesia 2020)
Safety Rate of Employee	$\text{Efficiency} = 1 - \frac{\text{Number of Activities at Risk}}{\text{Number of Activities}}$	(Farkhan and Sri 2020)
Health Rate of Employee	$\text{Efficiency} = 1 - \frac{\text{Number of Employees Absent}}{\text{Number of Activities}}$	(Sri et al. 2020)
Satisfaction Rate of Employee	$\text{Efficiency} = 1 - \frac{\text{Number of employee turnovers}}{\text{Number of Activities}}$	(Farkhan and Sri 2020)

After the calculation is done, the results for each efficiency of the assessment indicator are obtained. The results of efficiency calculations can be seen in Table 3, which is a summary of all calculations.

Table 3. Summary of Calculation of Efficiency Value of Assessment Indicators

Indicator	Efficiency Value					
Time	82,95%	66,52%	69,42	66,21%	66,52%	80,22%
Quality of Products	86,41%					
Energy Consumption	85,71%	85,71%	75,00%	75,00%	75,00%	81,82%
Use of Raw Material	88,27%					
Waste	32,13%					
Noice Level	93,1 dB	96,9 dB	82,6 dB	79,2 dB	76,4 dB	85,2 dB
Lighting Level	75 Lux					
Room Temperature	33,8˚C					
Safety Rate of Employee	50,00%					
Health Rate of Employee	96,97%					
Satisfaction Rate of Employee	95,68%					

This efficiency calculation aims to be able to see whether these indicators fall into critical, moderate, or very good categories. This efficiency value will be included in the Sustainable Value Stream Mapping chart. To determine the efficiency value categorized as critical, moderate, and very good, there are several limits to the efficiency value set by the company, which can be seen in Table 4.

Table 4. Range of Efficiency Value in the Company

Range	Category	Marked with Color
<65%	Critical	Red
65% - 90%	Moderate	Yellow
>90%	Excellent	Green

Meanwhile, to assess the noice level, lighting level, and room temperature, they are included in the critical category by using the threshold value or standard recorded in government regulations. The following are the threshold values for the three indicators, which can be seen in Table 5 (Minister of Manpower of the Republic of Indonesia 2018).

Table 5. Threshold/Standard Value

Indicator	Threshold/Standard Value
Noice Level	85 dB
Lighting Level	100 Lux
Room Temperature	23˚C - 26˚C

Knowing that the range of efficiency values can be categorized as critical, moderate, or very good, it can be seen that there are several indicators that fall into each category. For the very good category, there are two indicators that have an efficiency value above 90%, namely health rate of employee and satisfaction rate of employee. As for the moderate category, there are four indicators, namely time, product quality, energy consumption, and use of raw materials. Then, for the critical category, there are five indicators with an efficiency value of less than 65%, namely waste, noise level, lighting level, room temperature, and safety rate of employee. A summary of categories based on efficiency values can be seen in Table 6.

Table 6. Categories for Each Indicator

Category	Indicator
Critical	Waste
	Noice Level
	Lighting Level
	Room Temperature
	Safety Rate of Employee
Moderate	Time
	Quality of Products
	Energy Consumption
	Use of Raw Material
Excellent	Healthy Rate of Employee
	Satisfaction Rate of Employee

For waste indicators included in the critical category, this is because most of the waste from the production process, namely in the form of sand from washing raw materials, has not been used properly, is directly disposed of in a field, and requires additional costs. Judging from the percentage efficiency level of waste that has a number below 65%, it shows that the waste produced is still not treated properly. The indicators of noise level, lighting level, and room temperature are included in the critical category because the value obtained at the time of measurement using the tool exceeds the threshold value and standards set in Regulation of the Minister of Manpower of the Republic of Indonesia Number 5 of 2018 concerning Occupational Safety and Health of the Work Environment. Meanwhile, the employee safety level indicator itself is also included in the critical category because it is below 65%, which is 50%. The cause of the low efficiency value of employee safety is the level of employee concern for safety, which still tends to be weak. In addition, personal protective equipment such as boots is not used, as are proper gloves, and many workers only wear short sleeves. As for activities that are considered dangerous, there are three production processes: grinding, melting, and making dough. So improvements are needed in order to improve and maintain the safety of employees at the company.

5.2 Sustainable Value Stream Mapping Before the Improvement Plan

The following is sustainable value stream mapping with the value of efficiency calculations on each assessment indicator, which can be seen in Figure 2.

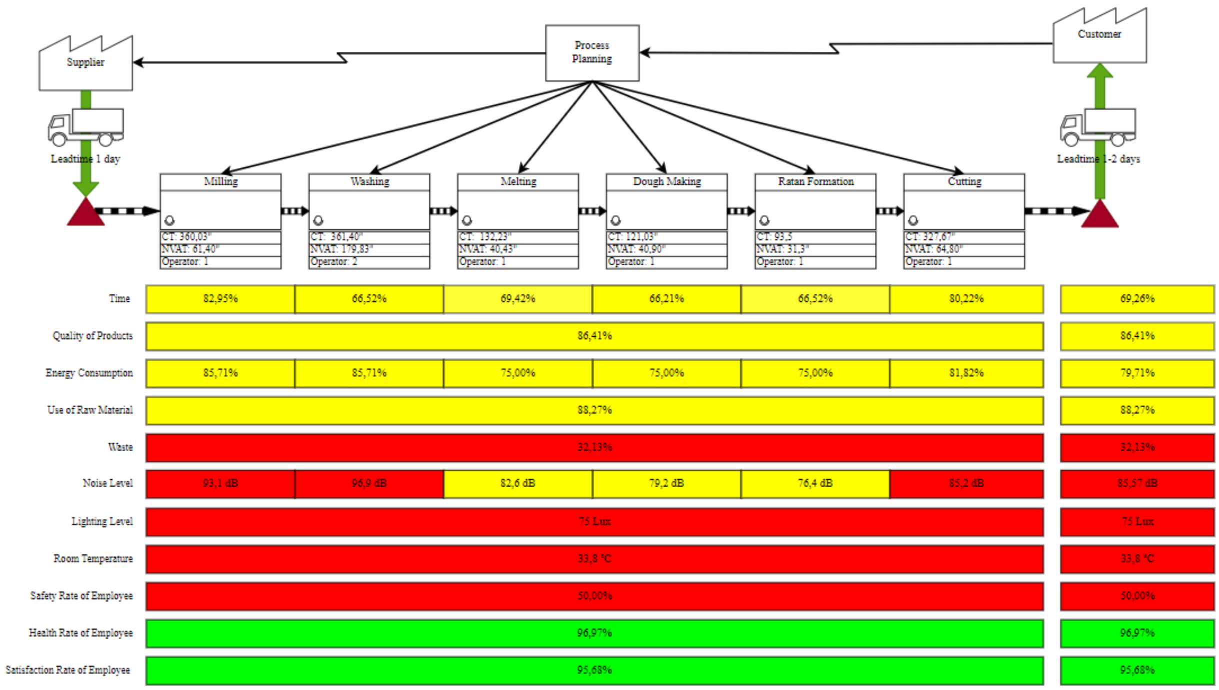

Figure 1. Sustainable Value Stream Mapping Before the Improvement Plan

From the Sustainable Value Stream Mapping above, it can be seen that of the eleven indicators used for the assessment, there are two (two) assessment indicators that fall into the very good category, namely the level of employee health and the level of employee satisfaction with each final value, which can be seen in Figure 2 in the box on the right, which is green, which is 96.97% and 95.68%, respectively. This level of efficiency can be said to be very good because the efficiency value of the two indicators is more than 95%. Furthermore, there are four indicators included in the moderate category, which can be seen in Figure 2 in the yellow right box, which include indicators of time, product quality, energy consumption, and use of raw materials. where for each efficiency value of several indicators sequentially, namely 69.26%, 86.41%, 79.71%, and 88.27%. This efficiency value is included in the moderate category because it can be seen in Table 4 of the range of efficiency values that fall into the moderate category, from 65% to 90%. Furthermore, there are five indicators included in the crisis category, namely waste, noise level, lighting level, room temperature, and work safety level. It can be seen in Figure 2 in the box on the right, which is red with each value sequentially, namely 32.13%, 85.57 dB, 75 Lux, 33.8°C, and 50.00%. For this efficiency level, it falls into the critical category because, judging from Table 4, the efficiency level is below 65%. Meanwhile, the noise level, lighting level, and room temperature can be said to be critical by looking at Table 5. Some of these indicators are said to be critical if the test value exceeds the threshold value or standardization set by the company. Therefore, for indicators that are included in the critical category, improvements are needed to be able to increase the efficiency of the five indicators namely waste, noice level, lightning level, room temperature, safety rate of employee.

5.3 Improvement Plan

After knowing the indicators that need to be improved, the final stage of this research is to provide suggestions for improvements to be able to increase the effectiveness and efficiency of the plastic pellet company. There are 5 indicators that need improvement, which include waste, noice levels, lighting levels, room temperature, and employee safety levels. In order to reduce waste that is only thrown in the field and increase the costs that companies have to incur, the suggestion for improvement for the waste indicator itself is to recycle the waste in the form of sludge into a planting medium. In the process of making planting media, there are several tools and materials needed, namely plastic cups, rulers, scales, waste sludge, compost, peanuts, and green beans. To do this, several steps must be carried out, namely as follows:

1. Prepare plastic washing waste in the form of mud and dry it in the sun. This drying is done to reduce the water content in the mud. For documentation of the process of making planting media in this process, see Figure 2.

Figure 2. Waste Sludge Drying Process

2. Next, mix the mud with compost using a ratio of 25:75 (Dong et al. 2013). After mixing the planting medium, let it sit for two days.

Figure 3. Planting Media Mixing Process

3. Then, put the planting medium into a used plastic cup and plant the green bean seeds and peanut seeds. Then observe the height of the two plants to determine the effect of adding mud to the planting medium.

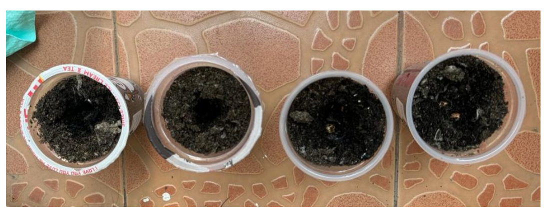

Figure 4. Planting Green Beans and Peanuts

After conducting interviews with the factory, it was discovered that in the waste disposal process, the company spent approximately IDR 300,000.00 per truck. Therefore, this plan can help companies reduce expenditure on waste disposal. Where to make this waste sludge into a planting medium, costs are required for the compost used, which can be obtained at a price of IDR 10,000.00 per sack (12 kg). If the company sells the planting media for IDR 15,000.00, it will make a profit of 50% of the capital spent.

The indicator that falls into the critical category is noise level, and this noise level can affect workers if they are continuously in areas with high noise levels. A corrective suggestion for this indicator is to give these workers ear protector. There are two types of ear protection devices that can be used, namely earplugs and earmuffs, which can be seen in Figure 5.

Figure 5. Earplugs and Earmuff

According to Farhad et al., using earplugs and earmuffs can reduce noice by up to 18 dB. So, using this tool can protect workers' ears so as to reduce the risk that can arise due to noice. For lighting level indicators, companies can change the lamps used to be brighter so that the lighting level can be in accordance with predetermined standards. For room temperature indicators, this can be done by increasing the number of exhaust fan on the roofs of the production area and adding ventilation around the production area. And for indicators of the level of work safety, the company can conduct counseling on the importance of security and safety at work and facilitate personal protective equipment such as gloves, boots, and long-sleeved clothes to minimize exposure to the plastic melt dough, which can be seen in Figure 6.

Figure 6. Personal Protective Equipment

6. Conclusion

After carrying out efficiency measurements and calculations for eleven indicators, it was found that five assessment indicators fell into the critical category, namely waste, noise level, lighting level, room temperature, and employee safety level. For the first indicator, namely waste, with an efficiency rate of 32.13%, this indicator includes the environmental aspect. Furthermore, there is a mean noise level indicator with a noise level of 85.57 dB. For the lighting level indicator, namely with a lighting level of 75 Lux, the value is still below the predetermined standard of 100 Lux for room temperature indicators after measurements are taken for a temperature of 33.8°C. This value also exceeds the temperature standard set by government regulations. And for work safety indicators, they have a low efficiency rate of 50.00%. These results are depicted through the Sustainable Value Stream Mapping chart using traffic lights, which can be seen in Figure 1. Therefore, improvements were made to these five indicators, namely using waste as a planting medium, using earplugs and earmuffs to reduce noise, replacing lamps with higher lighting levels, adding several ventilation and exhaust fans, and using Personal Protection Equipment in production areas. and provide warnings and sanctions for employees who do not comply with regulations. This improvement suggestion aims to improve the effectiveness and efficiency of the production process at the PE-type plastic pellet company.

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Biographies

Chika Gabriela Keren, born in Palembang, Sumatera Selatan, Indonesia, is a student in the Department of Industrial Engineering at Taurmanagara University. She is active in campus activities such as the work program at IMADUTA. Besidethat, I do some activities that I love, such as reading a book, playing the piano, swimming, and listening to music.

Lithrone Laricha Salomon has been a lecturer at the Industrial Engineering Department of Universitas Tarumanagara since 2006. She graduated from Universitas Tarumanagara with a bachelor's degree in mechanical engineering. She She continued her studies and got her Master's Degree from the Industrial Engineering Program at Universitas Indonesia. She teaches a subject related to quality management systems, such as total quality management, quality control, and design.of experimentation and industrial statistics. Besides teaching, she also did some research, carrying out a number ofcommunity service activities in many places around Indonesia. She has written more than 40 publications onInternational and national proceedings and journals since 2007.

Wilson Kosasih was born in Medan, North Sumatra, Indonesia, is a lecturer in the Department of IndustrialEngineering at the Faculty of Engineering, Universitas Tarumanagara Since 2005, she has conducted teaching and research and hasserved as Industrial Engineering Undergraduate Chairman since 2018 until now. He completed his undergraduateMechanical Engineering Education at Universitas Tarumanagara: obtained a Master Degree in Industrial Engineeringat the Universitas Indonesia and is currently taking a doctoral program at the Institut Teknologi Sepuluh Nopember.with a concentration in industrial management. Holders of professional certification in the field of supply chain andlogistics, Certified Supply Chain Manager (CSCM), and Certified Professional in Logistics Management (CPLM) fromISCEA, USA; certification for Professional Engineer (IPM) from PII; and ASEAN Engineer certification from AFEO.He worked for a multinational company in the FMCG field before becoming a full-time lecturer in 2009. He has professional experience and consultant in the field of productivity and quality engineering. Since becoming a lecturer,he has been active in research, scientific publications and community service by obtaining grants from within and outside Untar, such as from the Ministry of Research, Technology, and Higher Education. His research fields are lean.Manufacturing, quality engineering, and supply chain management. In addition, he is also active in professionalorganizations, currently as a member of the Professional Competency Assessment Board for Industrial Engineering.Engineers at BKTI PII, as well as an External Assessor for Electronic-Based Government Systems, Ministry of StateApparatus Empowerment and Bureaucratic Reform of the Republic of Indonesia