Sustainable VSM Design to Improve Sustainability Performance

by Ade Aisyah Putri

Sustainable Value Stream Mapping Design to Improve Sustainability Performance of Animal Feed Production Process

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Abstract: This study aims to design a Sustainable-Value Stream Mapping as a basis for improving the sustainability performance of the animal feed production process. The scientific contribution of this study is generating relevant sustainability performance indicators for an animal feed company by performing a literature study and validating it by in-depth interviews with the company's top management. Performance assessment of the selected indicators uses an efficiency measurement approach. The case study was conducted in the largest animal feed companies in Indonesia. Finally, the recommended Sus-VSM was proposed to improve the performance of the company as well as to estimate its future performance.

Keywords: sustainability performance indicators, sustainable-value stream mapping, animal feed production process, engineering

1. Introduction

Industrial development can cause impact for the environment such as heavy metal polution, maintaining balance between industrial development and environmental pollutions is needed to achieve sustainability.[1)] An increase in consumers' environmental awareness encourages companies to utilize methods that not only focus on minimizing costs but also consider the implications of the production process to the environment and society.[2,3)] This phenomenon drives development in the manufacturing system from traditional and lean manufacturing to sustainable manufacturing.[3)] Value stream mapping (VSM) is commonly used as an effective system analysis tool to diagnose manufacturing system problems and identify opportunities for improvement.[4)5)] The VSM portrays materials, the flow of information, as well as decision making which are needed to identify value-added activities and non-value-added activities.[6)7)] These non-value-added activities have to be taken into account for making improvements and redesigning the manufacturing system.[8,9,10)]

Despite the benefits of gaining from implementing VSM, it is criticized since it does not consider activities regarding environmental and social issues. To overcome this drawback, a sustainable VSM (Sus-VSM) was developed by adding environmental and social indicators. It shows that Sus-VSM is able to evaluate the manufacturing system by defining non-value-added activities as well as to provide recommendations for improving the performance in terms of economic, environmental, and social aspects (the three pillars of sustainability).[11)] However, Sus-VSM still has several limitations, i.e., in the area of application, in the scope of the study, and the absence of a single-score as a representative value for sustainability performance.[12)] Sus-VSM has been implemented in several sectors, i.e., in the electronics industry, [11)] the automotive industry,[13)] the cosmetics and thermoplastics industry, [14)] the furniture industry,[15)] and the beverage industry.[16)] The environmental and social metrics might be different in each industrial sector,[11)] since it has differences in the production process and material requirements; hence, it is recommended to use different metrics in determining the indicators of the performance. It leads to a research challenge in the development of Sus-VSM in other sectors.

This research aims to develop and evaluate the Sus-VSM of a company that produces animal feed in Central Java Province, Indonesia. The company has to deal with several issues in economic, environmental, and social aspects that affect its performance: the company was not succeeded to attain its production target due to lengthly production waiting time (economic issue); there is an inefficiency issue in the use of raw materials and energy (environmental issue); as well as the issue of the bad working condition due to noise in production areas, the use of hazardous chemicals, and bad work postures (social issue). These problems have to be immediately analyzed by Sus-VSM. Implementing Sus-VSM in the animal feed company is of interest to identify activities that hinder its sustainability performance. Finally, this research also provides some recommendations to improve the sustainability performance of the animal feed company according to the Sus-VSM result.

2. Literature review

2.1 Lean manufacturing

Lean manufacturing concept strives to manage continuous improvements by identifying and eliminating several wastes in the manufacturing system in order to reduce costs and production time as well as to improve the quality of the products. In recent decades, companies in various sectors that integrated lean management into their operations are able to improve their competitiveness.[17] In addition, the lean concept has been recognized to improve operational performance,[18] yet the competitiveness tends not to last in the long term.[19]

The lean concept identifies seven types of waste that consist of transportation, inventory, unnecessary movements, waiting time, over-production, unnecessary processes, and defects.[20] The types of waste most frequently found are waste in inventory (60%), followed by waiting time (51%), defects (41.5%), transportation (29%), unnecessary movements (27.5%), unnecessary processes (21%), and over-production (21%). Several methods which are company-specific were developed to reduce these types of waste. Kanban, kaizen, and value stream mapping (VSM) are key methods in the implementation of lean manufacturing; furthermore, the VSM is the most considered method in the process of implementing lean manufacturing.[21]

The traditional lean concept does not consider environmental issues; thus, it does not anticipate problems related to the environment.[22] On the other hand, the green manufacturing concept was developed to minimize the negative impacts of the manufacturing process to the environment.[23] Eventually, lean and green concepts can be implemented simultaneously. Companies that implement lean and green together are empirically recognized to have better performance than only implement stand-alone concept: either lean or green manufacturing.[24,25] The application of lean manufacturing methods will trigger the achievement of green manufacturing; vice versa. For instance, implementing the lean concept to reduce product defects can improve the quality and reduce production costs; while in the meantime carrying out the green manufacturing objective as it can reduce the wastes to the environment. The concept of reuse of packaging or returnable packaging in green manufacturing can increase the efficiency in the materials used as well as to reduce costs as one of the goals of lean manufacturing.

Lean and green concepts are very potential to be integrated to achieve maximum performance.[26] Researchers have developed and empirically examined lean and green frameworks for production systems.[27,28,29] Previous studies indicated that the integration of lean and green can improve operational, economic, and environmental performance.[30]

2.2 Sustainable manufacturing

Sustainable manufacturing is well-defined as manufacturing whose processes are minimizing negative impacts on the environment, minimizing the use of energy and natural resources, providing safety for its employees, communities, and consumers, as well as being economically beneficial.[23][31] Utilizing waste to obtain more valuable commodity is one way to achieve sustainable manufacturing.[32] Sustainable manufacturing has to take environmental issues into consideration (the green manufacturing concept) and the economic aspect as well (the lean manufacturing concept). Ultimately, to integrate the three pillars of sustainability, the concepts of lean and green manufacturing have to be complemented by the social aspects.

Measurement frameworks and schemes have been introduced to measure the performance of sustainable manufacturing which vary in scope and level of detail. These various metrics were used to assess the production processes from economic, environmental, and social perspectives. The metrics are grouped into six clusters, i.e., environmental impact, energy consumption, cost, operator safety, personal health, and waste management,[33] while there are 77 indicators involved.[34] Not all of those indicators are relevant for a certain industrial sector, especially in the social and environmental performance indicators. Metrics for measuring social and environmental performance which are generated from a metal industry, a discrete manufacturing, must be different from, let say, a food industry, a chemical process manufacturing. The production line in the food industry requires a set of metrics to evaluate food hygiene and safety conditions which are not considered yet. Therefore, it is important to discover appropriate metrics to be applied to a certain industrial sector.

2.3 Sustainable value stream mapping

The development of VSM to incorporate sustainability was commenced by Simons (2003) [35] and then enhanced by Faulkner (2014) [11] who developed the Sus-VSM. The metrics in Sus-VSM consist of economic, environmental, and social indicators. Environmental indicators consist of water, material, and energy consumption, while social indicators consist of the work environment and physical condition of the workforce. There are two criteria that must be considered in choosing the metric to be applied in Sus-VSM: the first is the usefulness of the metric and the second is the clarity as a visual tool. Note that metrics duplication must be avoided by minimizing the number of metrics after selecting the core metrics that provide the greatest benefit.[11]

3. Research Method

3.1 The indicators

The animal feed company production process stages start from the raw material intake. The process is then continued by milling, mixing, pelleting, and packing process as described in Figure 1. In the first proses, a bulk of ingredients, such as soybean meal, and some micro-ingredients, such as vitamins or medications, are prepared in a certain weight according to the feed ratio. The feed ingredients, i.e., coarse cereal grains, such as corn, require a grinding process in hammer mills. After the grinding process, dry meal particles are blended with liquids ingredients, such as added fat or other ingredients, in a mixer. Next, the feed mash is conveyed to pelleting mills and forced through holes in a metal die plate to form compacted pellets before pellets are cut off to a certain size. Pelleting is a crucial process in feed production since high-quality pelleted products would ensure the proper amount of nutrition that will be consumed. Pellets must be cooled and dried and then go to the packing process in 50 kg-bags for one pack.

The economic indicators for the production process consist of production time, production costs, and product quality. The environmental indicators consist of consumption of material, energy, and water; while the social indicators measure the noise level, work physical load index, and work safety risk. The indicators are measured based on Faulkner (2014), [11] Hartini (2018), [15] Brown (2014).[36] The indicators and selected metrics are shown in Table 1. Performance measurement is carried out in all of the production process stages.

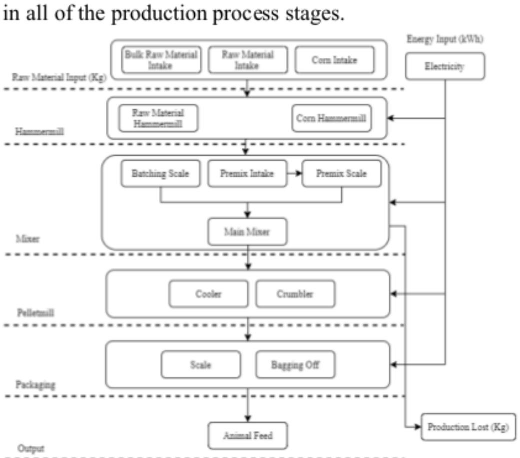

Fig. 1: Animal Feed Production Process

3.1 Indicator Measurement

Sustainability performance is measured by employing an efficiency approach represented by selected indicators of economic, environmental, and social dimensions.[37] The ergonomic assessment of the work environment is measured by the physical load index (PLI). The approach to evaluating physical work indicators was adapted from Hollmann (1999). [38] The sustainability performance categorization is based on the average of efficiency indicators. If the average is in the range of 0-60%, then the performance is categorized as critical. If the average is in a range of 61% -89%, the performance is categorized as moderate; and if the average is in a range of 90%-100%, the performance is categorized as excellent.[39] The average efficiency value will be visualized in the Sus-VSM.

Sus-VSM is developed in two ways, i.e., the current Sus-VSM and the future Sus-VSM. The former describes the current production activities and the results of sustainability performance measurement for the current condition, along with visualization of inefficient activities; while the latter portrays the production activities which are needed to be improved along with the recommendation for improvement as well as the estimate of sustainability performance after the proposed recommendation has been performed.

4. Result and discussion

4.1 Efficiency calculation

The indicators were grouped into the economic, environmental, and social dimensions. The economic dimension consists of time efficiency, cost efficiency, and quality. Time efficiency is calculated based on the ratio between the total of value-added time to the total of production time. Time efficiency of the production process is shown in Table 2. Cost efficiency is measured by defining the amount of time that has an impact on the employee salary and machinery process time that has an impact on the electricity costs which produces desire products. Cost efficiency of the animal feed production process is shown in Table 3. Quality efficiency is measured by dividing the good products by total of products; the result was 99.92%.

The environmental dimension consists of material consumption, energy consumption, and water consumption. Material consumption efficiency is shown in Table 4. Energy efficiency is determined based on the power required by the machine per unit time multiplied by the time required to produce 9,584.9 tons of animal feed. The energy consumption efficiency is shown in Table 5. Water consumption only occurs in the mixing process, from 560 liters of water consumed, only 502 liters are used, and 93 liters are wasted. Thus, water consumption efficiency is around 90%. The social dimension consists of PLI, noise level, and work risk. The PLI values range from 0-56.17. The highest relative contributions to PLI are in the raw material intake process and packaging process. Noise levels are calculated to ensure that employees work in a safe and healthy environment.

Table 1. Selected Metrics

Dimension	Selected Indicators	The related-Metrics	Equation	References
	Time (TE)	VAT: Value Added Time	TE = VAT/TT	[11] [15] [36]
		NVAT: Non-Value-Added Time	VAT=$\sum_{i=1}^{n}(VAT_i)$	
		TT: Total Time	NVAT=$\sum_{i=1}^{n}(NVAT_i)$	[11] [15] [36]
			TT=VAT+NVAT	
	Cost (CE)	VAC: Value Added Cost	CE = VAC/TC	[15] [36]
Economy		NVAC: Non Value Added Cost	VAC=$\sum_{i=1}^{n}(VAC_i)$	
		TC: Total Cost	NVAC=$\sum_{i=1}^{n}(NVAC_i)$	[15] [36]
			TC=VAC+NVAC	
		ND: Number of Defects		
	Quality (QE)	TM: Total Material	QE=1-ND/TM	[15] [36]
		QE: Quality Efficiency		
		VAE: Value Added Energy	EE – VAE/TE	
		NVAE: Non Value Added Energy	VAE=$\sum_{i=1}^{n}(VAEi)$	
	Energy Consumption (EE)	TE: Total Energy	NVAE=$\sum_{i=1}^{n}(NVAEi)$	[11] [15] [36]
			TE=VAE+NVAE	
		VAW: Value Added Water	WE = VAW/TW	
	Water	NVAW: Non-Value Added Water	VAW=$\sum_{i=1}^{n}(VAWi)$	
Environmental	Consumption (WE)	TW: Total Water	NVAW=$\sum_{i=1}^{n}(NVAWi)$	[11] [15] [36]
			TW=VAW+NVAW	
		VAM: Value Added Material	ME = VAM/TM	
	Material Consumption (ME)	NVAM: Non Value Added Material	VAM=$\sum_{i=1}^{n}(VAMi)$	[11] [15] [36]
		TM: Total Material	NVAM=$\sum_{i=1}^{n}(NVAMi)$	
			TM=VAM+NVAM	
	Physical Load Index (PLI)	RC: Relative Contribution	RC=$\frac{PLISi}{\sum_{i=1}^{n}(PLISi)}$ x100	[38]
		NR: Number of activity with risk		[11]
Social	Work Risk (RE)	Nac: Number of activity	RE = 1 – NR/Nac	
		ND: Noise Dosage		[11]
	Noise	MET: Maximum Exposure Time	ND=$\frac{AT}{MET}$x100%	
		AT: Actual Time		

The allowed noise levels are maximum 8-hour exposure and maximum 85-dB. The milling and mixing machines produce noise beyond the safety limit for hearing health. The work risk indicator is measured by conducting interviews with the safety department coordinators and the production manager to find out the number of accidents and the category of the hazard of each workstation. Indicators of the level of work risk are obtained from Faulkner (2014). Work risk levels of all stages are categorized as moderate level on hazardous chemical substances and moderate level on the operated high-speed machine.

Table 2. Time efficiency

Process	Value Added Time (Second)	Non-Value-Added Time (Second)	Efficiency (%)
Raw Material Intake	1,392.69	216.53	86.54%
Milling	575,094.00	21,600.00	96.38%
Mixing	479,245.00	149,210.00	76.26%
Pelleting	460,075.20	152,436.00	75.11%
Packaging	484,743.00	87,300.00	84.74%

Table 3. Cost efficiency

Process	Cost	Value-Added Cost (Rp)	Non-Value-Added Cost (Rp)	Efficiency (%)
Raw Material Intake	Employee Salary	12,895.29	2,004.91	86.54%
Milling	Employee Salary	3,993,708.33	150,000.00	96.38%
	Electricity	18,686,949.60	701,865.58	
Mixing	Employee Salary	4,992,135.42	1,554,271.83	77.85%
	Electricity	1,751,716.96	364,455.76	
Pelleting	Employee Salary	11,182,383.33	3,705,042.67	75.92%
	Electricity	12,013,802.49	3,651,494.55	
Packaging	Employee Salary	28,052,249.01	5,052,083.33	84.74%
	Electricity	1,042,936.90	188,155.18	

Table 4. Material consumption efficiency

Period	Total Production (Ton)	Production Lost (Kg)	Efficiency (%)
1	1,405.10	913.31	99.94%
2	1,491.45	1,476.53	99.90%
3	1,267.45	1,242.10	99.90%
4	1,335.00	1,241.55	99.91%
5	114.20	733.56	99.94%
6	1,509.20	1,041.34	99.93%
7	1,430.50	743.86	99.95%

Table 5. Energy consumption efficiency

Machines	Value-Added Energy (kWh)	Non-Value-Added Energy (kWh)	Efficiency (%)
Milling	12,735.78	478.34	96.38%
Mixing	1,193.85	248.39	82.78%
Pelleting	8,187.80	2,488.61	76.69%
Bagging Machine	710.80	128.23	84.72%

4.2 Current sustainable value stream mapping

According to the measurement results of the efficiency indicators, the current Sus-VSM is generated, which is shown in Figure 2. This current Sus-VSM is integrated with sustainability performance assessment for the economic, environmental, and social indicators. The efficiency of each metric is given on the right side of Figure 2.

The raw material intake process which has four activities is classified as moderate, while the milling process which has two activities, i.e., time efficiency and cost efficiency, is classified as excellent (around 96.38%). The mixing process efficiency is classified as moderate. The pelleting process which consists of five activities is classified as moderate. Finally, the packaging process which has three activities is classified as moderate.

The environmental dimension has good sustainability performance. Several environmental indicators fall into the excellent category. These indicators include energy efficiency in the milling process (96.38%), the efficiency of material consumption in the mixing process (99.92%), and the efficiency of water consumption in the mixing process (90%). Some of the indicators that fall into the moderate category are needed to be improved; there are energy efficiency in the material mixing process (82.78%), pelleting (76.69%), and packaging (84.72%).

Several social dimension indicators are required to be improved. The highest PLI value is material handling (21.08) with the activities of lifting and manual handling. Even though the forklift facilities have been used for shipping pallets, taking 50 kg of sacks and pouring the contents of the sacks into the bin are still performed manually. The packaging process has the second-largest PLI value (13.96) with activities of filling feed into sacks and sewing sacks in a standing posture. The PLI values for other processes are categorized as a safe condition.

The noise level in the material preparation area and in the packaging area is at a borderline level. The noise comes from the elevator machine, the packaging machine, and the pelleting machine. The noise level in the areas of milling and mixing is above the allowable noise level, caused by the hammer mill and mixing machine.

An occupational risk assessment was conducted by interviews with the safety department coordinators and the production manager. According to the production manager, the hazardous chemicals material handling process is classified as a medium-scale risk because there is a lot of dust materials in the form of flour at the storage area. The milling process which uses hazardous chemicals is categorized as a moderate risk level because the operators are exposed to chemicals and corn dust during the production. In the material preparation process, there is a risk of workers being hit by a forklift because to lower the pallet, a sharp knife is used. It contains a risk if the knife is exposed to the workers. The mixing process which uses a high-speed machine has a small risk level even though the operators perform setting or maintaining the machine.

4.3 Reccomendations for improvement

The performance of the economic dimension is in the excellent category, unless the time efficiency. The production process has a total non-value-added time of 114 hours from a manufacturing lead time of 669 hours. These non-value-added times include waiting time of 64 hours, change overtime of 33 hours, and downtime of 17 hours. Waiting time is a major waste in the production process, which is occurred due to checking bin activities on milling and mixing machines, cleaning activities, changing formulas on mixing machines, waiting for materials, and maintenance. The waiting time reduces cost performance because the company paid unproductive machines and workers. The recommendation for improvement is to apply regular preventive maintenance to reduce the breakdown time.

The performance of the environmental dimension is in the excellent category (the performance of the material consumption indicator is 99%). The lost material occurs in material settling in the mixing machine due to pipe leaks while materials were transferred from one machine to the next machine. The facility is old, and it is a problem for the company to replace the pipe.

The social dimension is in the moderate category which is caused by the high-risk level for the workers to be exposed to noise and dust. The recommendations for improvement include the elimination of hazards in the area of material storage and preparation, the use of personal protective equipment in all work areas, and practicing a good work posture, especially in the material handling and packaging. An additional workforce is required in the mixer area for material pouring activity.

Training for operators is also needed to strengthen work procedures and to provide guidance to overcome machine problems and work hazards. New operators also need intensive training to increase their expertise in operating production machines.

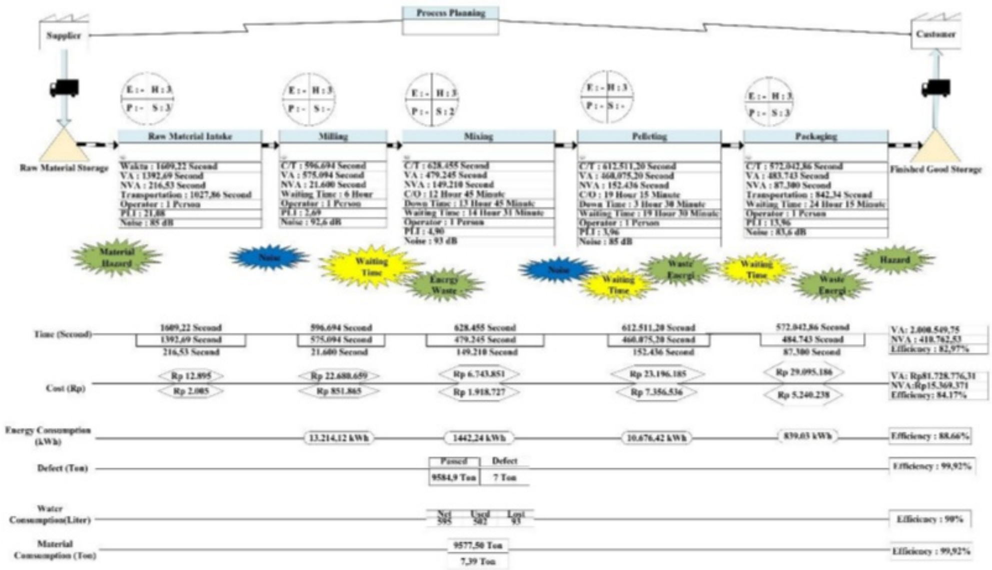

Figure 2. Current Sustainable Value Stream Mapping

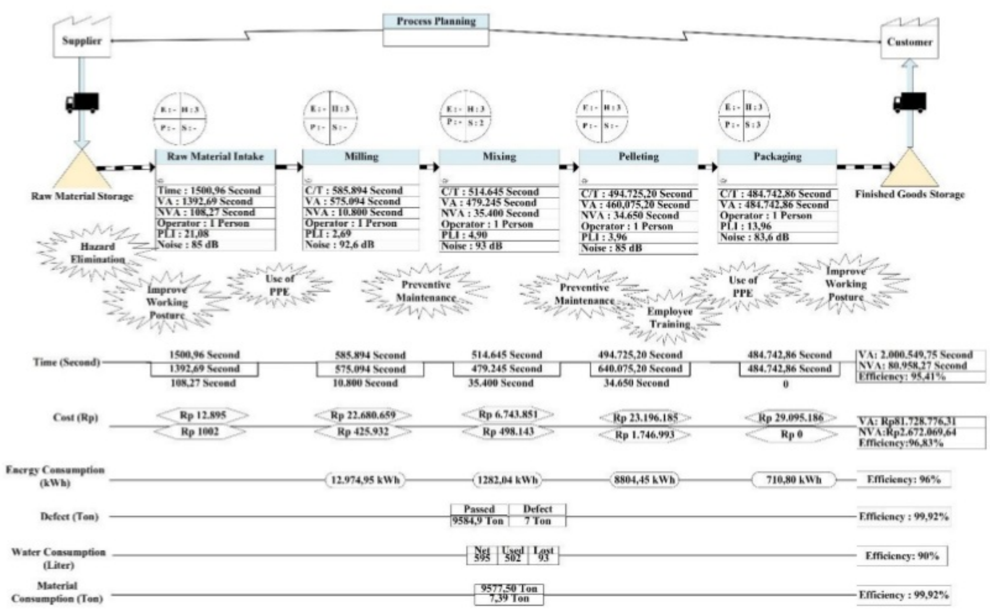

Figure 3. Future Sustainable Value Stream Mapping

4.4 Future sustainable value stream mapping

The future Sus-VSM is proposed with some aforementioned recommendations for improvement to increase the sustainability performance. Reducing waste such as waiting time and reducing the risk of injuries to workers are proposed. Training for workers is also proposed to make the workers be discipline and improve their skills. The future Sus-VSM aims to both provide recommendations and estimate the efficiency result of the improvement. Figure 3 shows the future Sus-VSM of the production process. Efforts to increase the efficiency in the production process aim to reduce production costs and increase competitiveness.

Comparing to the poultry industry, inefficiency not only occurs in the production process but also in the distribution of the products to the consumers. The inefficiency in the distribution makes prices at the retail level be higher. The inefficiency in the distribution process is found in the livestock distribution.[40] For the next research, the sustainability performance might be measured by other methods, such as the product-service system, a more macro analysis that measures the industry sustainability index by measuring the environment, economic and socio-cultural dimension.[41,42]

5. Conclusion

The Sus-VSM has been proven to be able to analyze the production process of the animal feed company by identifying value-added activities and non-value-added activities. This study has found indicators that are relevant to animal feed companies in the dimension of economic (time efficiency, cost efficiency, product quality), environmental (energy consumption, water consumption, material consumption), and social (PLI, hazard, and noise level). The managerial contribution of this study lies in its ability to assess the performance of each relevant indicator and identify indicators in the excellent, moderate, and bad categories. The measurement results based on the case study show that the performance of the economic and environmental dimensions is categorized as excellent, but the social dimension is categorized as moderate due to bad working conditions. Recommendations for improving the sustainability performance in the production process based on the current Sus-VSM are to reduce the waiting time and to improve the work environment.

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