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

A A A Putri
Industrial Engineering Departement, Diponegoro University

S Hartini
Industrial Engineering Departement, Diponegoro University

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A A A Putri[1], S Hartini[1,*] R Purwaningsih[1]

[1]Industrial Engineering Departement, Diponegoro University, Semarang 50275, Indonesia

*Author to whom correspondence should be addressed:
E-mail: srihartini@lecturer.undip.ac.id

Abstract: This study aims to design a sustainable value stream mapping (Sus-VSM) as a basis for improving the sustainability performance of an animal feed production process. The scientific contribution of this study is to generate relevant sustainability performance indicators for an animal feed company, it was performed by conducting a literature study. Efficiency measurement approach was used to assess the performance. To exhibit the applicability of the method, a case study was conducted in one of 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 manufacturing can cause an impact on the environment such as heavy metal polution[1] and greenhouse gas emissions[2]; thus, maintaining a balance between industrial development and environmental issues 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[3,4]. This phenomenon drives development in the manufacturing system from traditional and lean manufacturing to sustainable manufacturing[4]. Value stream mapping (VSM) is commonly used as an analysis tool to diagnose manufacturing system problems and identify opportunities for improvement[5,6]. 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[7,8]. These non-value added activities have to be taken into account for making improvements and redesigning the manufacturing system.[9,10,11]

Despite the benefits gaining from implementing the VSM, it is criticized due to 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 can be used to evaluate the manufacturing system by defining non-value added activities and to provide recommendations to improve the manufacturing performance in terms of economic, environmental, and social aspects[12] However, the Sus-VSM still has several limitations, i.e., in the area of application, in the scope of the study, and in the absence of a single-score as a representative value for sustainability performance[13]. Sustainable value stream mapping to enhance sustainability has been developed in the automotive[14,15], food and beverage[16,17], agro-industry, electronics[12,18], thermoplastic products[19], batik[20] and furniture industries[21]. The environmental and social metrics might be different in each industrial sector[12], 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[12]. It leads to a research challenge in the development and the application of the Sus-VSM.

National Socio-Economic Survey of Indonesia in 2011 stated that Indonesians spent 1.85 percent of their income on meat (62 percent of which is poultry) and 2.88 percent on eggs[22]. Feed mills play an important role in determining the price of livestock products for broilers because 60% of production costs are feed costs[23]. Meanwhile, for laying hens, the cost of feed also reaches 87% of the production cost[24,25]

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 as following. The

company was not succeeded to attain its production target due to lengthy production waiting time (economic issue); an inefficiency in the use of raw materials and energy (environmental issue), and bad working condition due to noise in production areas, use of hazardous chemicals, and bad work postures (social issue). The effectivenes of the overall production is 91%, The effectivenes compares the actual output to the target value[26]. The average production output is 1370 ton per day while the targeted value is 1500 ton per day.

These problems have to be immediately analysed by the Sus-VSM. Implementing the 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 and Green Concepts

The lean manufacturing concept strives to pursue continuous improvements by identifying and eliminating several wastes in the manufacturing system to reduce production cost and time while improving the quality of the products. In recent decades, companies in various sectors that integrated the lean concept into their operations are able to improve their competitiveness[27].

The lean concept has been widely recognized to improve operational performance[28] of a company; however, its competitiveness tends not to last in the long term[29]. It is because the traditional lean concept does not consider environmental issues; thus, it does not anticipate problems related to the environment[30]. On the other side, the green manufacturing concept was developed to minimize the negative impacts of the manufacturing process on the environment[31]. Eventually, the lean and green concepts can be implemented simultaneously. The application of the lean manufacturing methods will trigger the achievement of green manufacturing; vice versa. The lean and green concepts are very potential to be integrated to achieve maximum performance[32]. Companies that implement lean and green together are empirically regarded to have better performance than companies that only implement stand-alone concept: either lean or green manufacturing[33,34].

2.2 The Development of VSM to Sus VSM

VSM is one of the most considered analytical tools in the lean manufacturing[35]. VSM can identify "the seven wastes" that consists of transportation, inventory, unnecessary movements, waiting time, over-production, unnecessary processes, and defects[36].

There are abundant approaches to achieve sustainable production, such as using a renewable energy source (e.g., biomass, wind, water, geothermal biomass energy, and solar cell)[37,38] practicing green human resource management[39], applying waste collection system[40], and utilizing waste to obtain more valuable commodity[41].

There were several efforts to integrate the environmental aspect into the VSM to achieve sustainability. Carbon dioxide emissions minimization was included by Simons and Mason[42] in the implementation of VSM in the agricultural food supply chain. Torres and Gati[16] added water consumption indicator. Kuriger and Chen[43], Keskin et al[44], and Müller et al [45] added energy efficiency to form the so-called energy efficiency-VSM (EE-VSM). Ng et al[46] added carbon-value efficiency. Vinodh et al[14] integrated VSM and LCA with end-of-life scenarios.

The development of VSM to incorporate sustainability was pioneered by Faulkner[12] who developed the Sus-VSM. The metrics in Sus-VSM consist of economic, environmental, and social indicators. There are two criteria must be considered in choosing metrics to be applied in the 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[12].

2.3 The Sus-VSM to Improve Sustainability Performance

Measurement frameworks and schemes have been introduced to measure the performance of sustainable manufacturing which vary in scope and level of detail[21]; for instance, the Global Reporting Initiative[47], which is based on a business perspective. To get a practical direction for the improvement, several scholars have developed sustainability performance at a factory level [48,49,50].

The integration of sustainability in a corporate performance based on empirical evidence has been carried out by several researchers[51,52]. Some researchers proposed the integration of the lean and green concepts to evaluate sustainability performance[53,54,55].

Sus-VSM not only able to analyze non-value-added activities in economic aspects but also environmental aspects[13]. The Sus-VSM as an evaluation tool for sustainability performance was developed by Helleno et al[19]. Model validation was carried out in the cosmetics industry, thermoplastic products, and kitchen utensils. The Sus-VSM as an evaluation tool for sustainability performance has also been developed in the wooden furniture[21] and batik industry[20]. Sustainability indicators were identified according to the literature review[19,20] or chosen by experts[17,21]. Measurement of performance indicators is carried out using an efficiency approach[21]. Once the efficiency level has been measured, the activities with the low-efficiency level can be identified. The activities with a low level of efficiency are considered as signals for management to improve the company performance[19,21]. The advantage of using the Sus-VSM is that the management can identify the level of inefficiency based on activity in every process.

A current state of the Sus-VSM (current state-Sus-VSM) can measure sustainability performance of the current condition. Based on the current state-Sus-VSM, methods to improve the sustainability performance can be suggested. On the other hand, a future state of the Sus-VSM (future state-Sus-VSM) is developed to estimate the level of efficiency that could be achieved if the proposed method was applied[7].

2.4 Animal Feed Production Process

The animal feed company production process starts from the raw material intake. The process is then continued by milling, mixing, pelleting, and packaging processes, as described in Figure 1. In the first process, raw materials are weighed according to a certain formula. Some materials (e.g., corn) are milled in a hammer mill machine. After the milling process, dry materials are mixed with liquids materials (including vitamins and medicines) in the mixer machine. Next, the feed is formed into a certain size of pellets using a pelleting machine. Pelleting and mixing are key processes in the feed production because they ensure the number of nutrients

needed. Pellets must be cooled and dried; and then go to the packing process in 50 kg-bags for one pack.
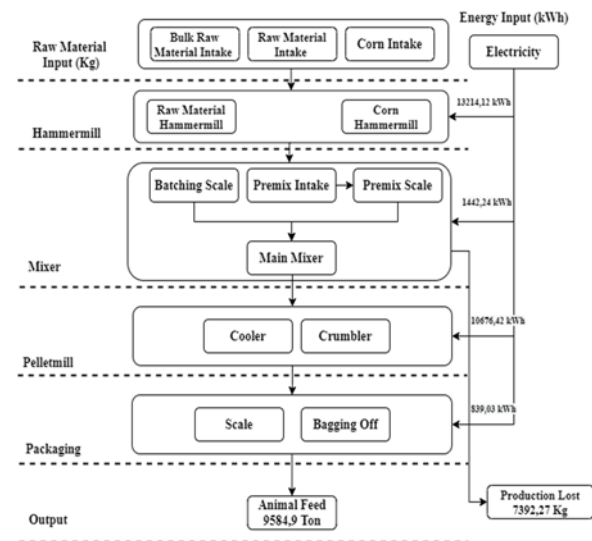

Fig. 1 Animal Feed Production Process

3. Research Method

3.1 Theoretical framework

This research consist of three stage of study, The source of the quantitative data used in this research is from the company document. The author also observed the condition in the work area to obtain data that are related to the social indicator. The figure below explain the theoretical framework used in this research.
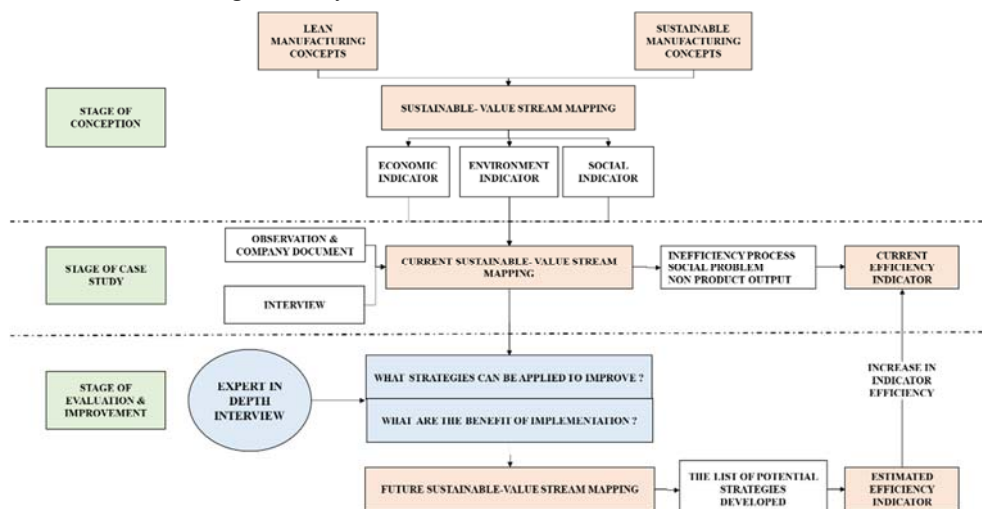

Fig. 2 Theoretical framework

3.2 Indicators Measurement

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[12] and Hartini[56], The indicators and selected metrics are shown in Table 1. Performance measurement is carried out in all of the production process stages.

The sustainability performance is measured by employing an efficiency approach, represented by selected indicators of three aspects (i.e., economic, social, and environmental aspects). The ergonomic assessment of the work environment is measured by the physical load index (PLI)[57]. The sustainability performance categorization is based on the average of the 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.[21] The average efficiency value will be visualized in the Sus-VSM.

The Sus-VSM is developed in two ways, i.e., the current state-Sus-VSM and the future state-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. The future state-Sus-VSM 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 are grouped into the social, economic, and environmental aspects. The economic aspect consists of time efficiency, cost efficiency, and quality. The time efficiency is calculated based on the ratio between the total value-added time to the total production time. The time efficiency of the production process is shown in Table 2. The 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. The cost efficiency of the animal feed production process is shown in Table 3.

The quality efficiency is measured by dividing the good products by the total of products; the result was 99.92%.

The environmental aspect consists of material consumption, energy consumption, and water consumption. The efficiency of material consumption is shown in Table 4. The 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 the animal feed. The energy consumption efficiency is shown in Table 5. The water consumption only occurs in the mixing process, from 560 litres of water consumed, only 502 litres is used, and 93 litres is wasted; thus, the water consumption efficiency is around 90%.

The social aspect consists of PLI, noise level, and work risk. The PLI values range from 0 (zero) to 56.17. The highest relative contributions to the PLI are in the raw material intake process and packaging process. Noise levels are calculated to make sure the employees work in a safe environment. 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 [12]. 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 1. Selected Metrics

Dimension	Selected Indicators	The related-Metrics	Equation	References
Economy	Time (TE)	VAT: Value Added Time NVAT: Non-Value-Added Time TT: Total Time	$TE = VAT/TT$ $VAT = \sum_{i=1}^{n}(VAT_i)$ $NVAT = \sum_{i=1}^{n}(NVAT_i)$ $TT = VAT + NVAT$	[12] [56] [18] [12] [56] [18]
	Cost (CE)	VAC: Value Added Cost NVAC: Non Value Added Cost TC: Total Cost	$CE = VAC/TC$ $VAC = \sum_{i=1}^{n}(VAC_i)$ $NVAC = \sum_{i=1}^{n}(NVAC_i)$ $TC = VAC + NVAC$	[56] [18] [56] [18]
	Quality (QE)	ND: Number of Defects TM: Total Material QE: Quality Efficiency	$QE = 1 - ND/TM$	[56] [18]
Environmental	Energy Consumption (EE)	VAE: Value Added Energy NVAE: Non Value Added Energy TE: Total Energy	$EE - VAE/TE$ $VAE = \sum_{i=1}^{n}(VAEi)$ $NVAE = \sum_{i=1}^{n}(NVAEi)$ $TE = VAE + NVAE$	[12] [56] [18]
	Water Consumption (WE)	VAW: Value Added Water NVAW: Non-Value Added Water TW: Total Water	$WE = VAW/TW$ $VAW = \sum_{i=1}^{n}(VAWi)$ $NVAW = \sum_{i=1}^{n}(NVAWi)$ $TW = VAW + NVAW$	[12] [56] [18]
	Material Consumption (ME)	VAM: Value Added Material NVAM: Non Value Added Material TM: Total Material	$ME = VAM/TM$ $VAM = \sum_{i=1}^{n}(VAMi)$ $NVAM = \sum_{i=1}^{n}(NVAMi)$ $TM = VAM + NVAM$	[12] [15] [18]

Table 1. Selected Metrics

Dimension	Selected Indicators	The related-Metrics	Equation	References
Social	Physical Load Index (PLI)	RC: Relative Contribution	$RC = \frac{PLISi}{\sum_{i=1}^{n}(PLISi)} \times 100$	[57]
	Work Risk (RE)	NR: Number of activity with risk Nac: Number of activity	$RE = 1 - NR/Nac$	[12]
	Noise	ND: Noise Dosage MET: Maximum Exposure Time AT: Actual Time	$ND = (AT/MET) \times 100\%$	[12]

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 state-Sus-VSM was generated, which is shown in Figure 3. This current state- Sus-VSM is integrated with the sustainability performance assessment for the economic, environmental, and social indicators. The efficiency of each metric is given on the right side of Figure 3 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 aspect 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; i.e., energy

efficiency in the material mixing (82.78%), pelleting (76.69%), and packaging process (84.72%).

Several social aspect 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 safe conditions.

The noise levels in the material preparation area and in the packaging area are at borderline levels. Noises come from the elevator machine, the packaging machine, and the pelleting machine. The noise levels in the areas of milling and mixing are above the allowable noise level, which are 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 in 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. In order to lower the pallet, the workers have to use sharp knives. The risk appears if the knives are 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 Recommendation for improvement

The performance of the economic aspect is in the excellent category, unless the time efficiency. The production process has a total non-value-added time of 114 hours (the total manufacturing lead time is 669 hours). These non-value-added times include a waiting time of 64 hours, change overtime of 33 hours, and downtime of 17 hours. The 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 activity. The waiting time reduces cost performance because the company has to pay unproductive machines and workers. The recommendation for improvement is to apply regular preventive maintenance to reduce the breakdown time.

The performance of the environmental aspect is in the excellent category. The materials might lose when they are in the mixing machine. This is because of pipe leaks while materials were transferred from one machine to the next machine. The facility is old enough, and it is a problem for the company to replace the pipe.

The social aspect 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 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.
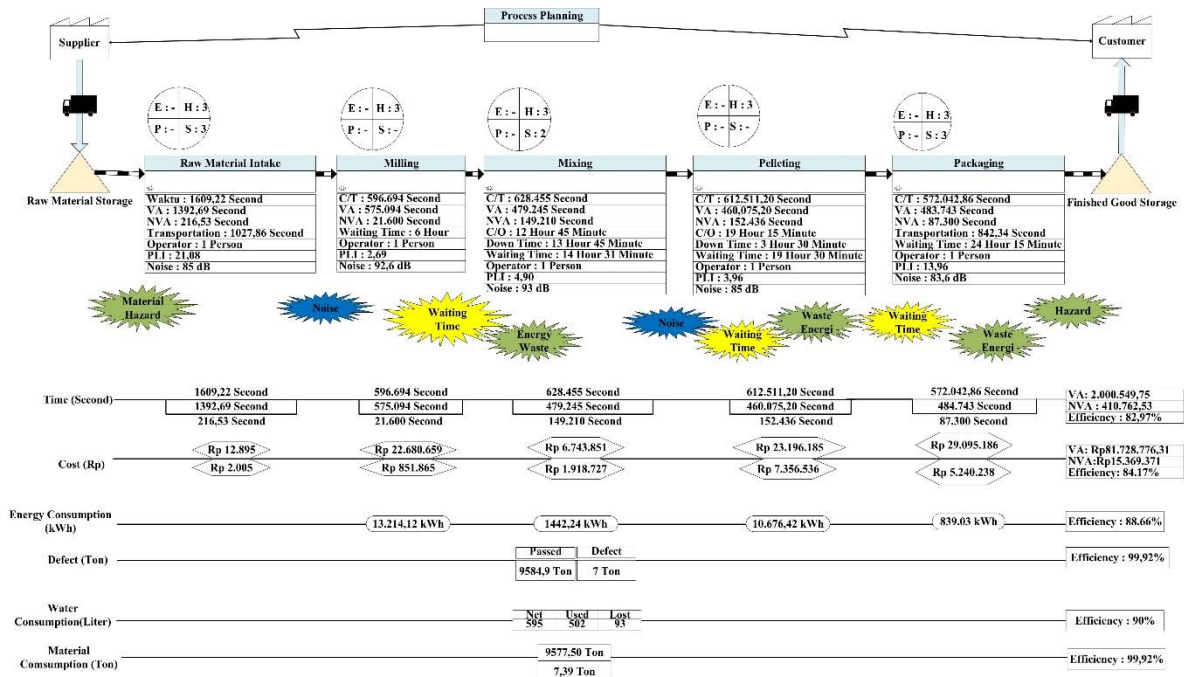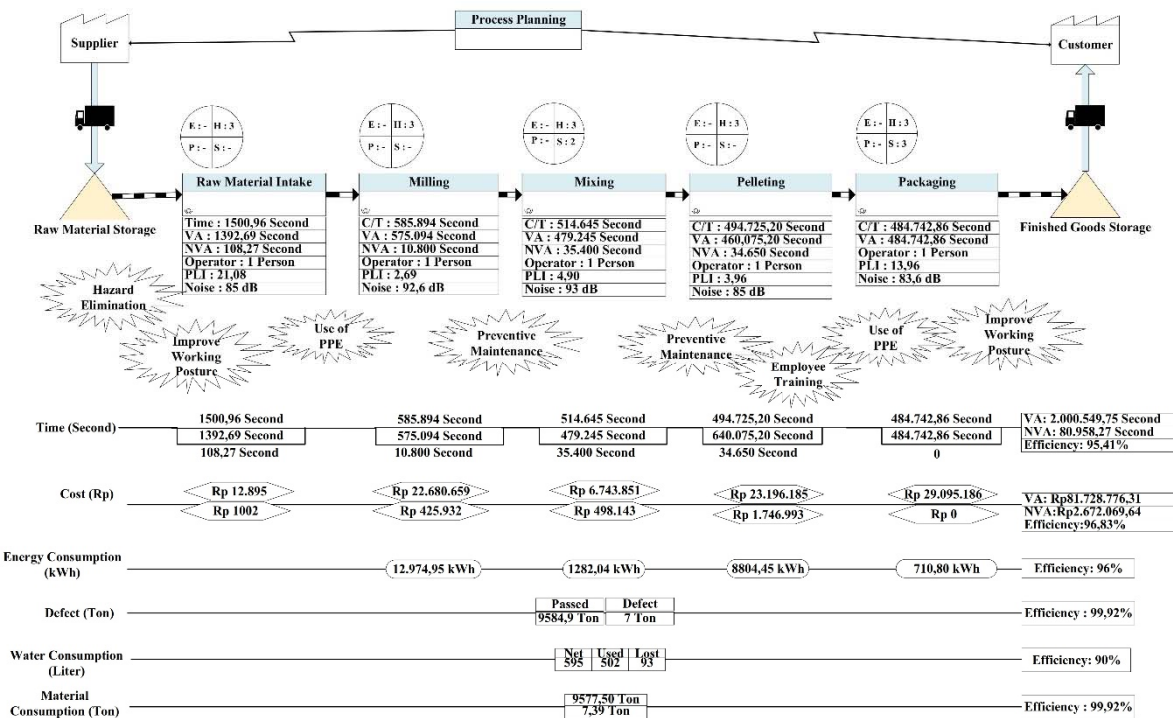
Figure 3. Current Sustainable Value Stream Mapping

Figure 4. Future Sustainable Value Stream Mapping

4.4 Future sustainable value stream mapping

The future state-Sus-VSM is proposed with some previously mentioned recommendations 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 state-Sus-VSM aims to both provide recommendations and estimate the efficiency result of the improvement. Figure 4 is the future state-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 also occurs 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.[58] For the next research, the sustainability performance might be measured by other methods, such as the product-service system, which is a more macro analysis that measures the industry sustainability index by measuring the environment, economic and socio-cultural aspects[59,60].

5. Conclusion

5.1. Finding

The Sus-VSM has been demonstrated to analyse the production process of the animal feed company by identifying value added activities and non-value-added activities. This study has generated relevant indicators for the animal feed company that are depicted in the aspect of economic (time efficiency, cost efficiency, product quality), environmental (energy consumption, water consumption, material consumption), and social (PLI, hazard, and noise level). The result shows 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 decrease the waiting time and to improve the work environment.

5.2. Managerial Implication

The assessment of the sustainability performance that is integrated into the Sus-VSM provides a picture that could represent the company's performance for each indicator throughout the production process. If the assessment is carried out regularly, it will help the company in monitoring the development of the company's performance. The development of the Sus-VSM could provide evaluation tools and directions for the company to create sustainable improvements. The model developed in this study is able to identify inefficient activities. Therefore, the company could get a hint to choose indicators that are more prioritized for the improvement. It is an important consideration when the company is constrained by a limited budget.

5.3. Limitation and Future Research Direction

The conceptual method for assessing the sustainability performance of the animal feed production process still utilises indicators based on literature review and have been validated by one company as the object of this study. To make a generalization of the indicators being used, more respondents and more case studies are needed. In addition, sensitivity analysis could be carried out so that the most influence indicators are identified. Furthermore, the proposed approach can also be used in other sectors by

adjusting indicators that are relevant to the sector being studied.

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