Performance Improvement in Heat Exchanger Company using Lean Sustainable Manufacturing Approach

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Abstract

PT XYZ fabricates heat exchangers for power generators and supports government programs related to sustainable development by implementing sustainable manufacturing strategies. The company wants to improve production activities to support their sustainability activities. The purpose of this study is to analyze the results of mapping lean sustainable manufacturing in order to improve the performance of sustainable manufacturing in the company. The initial stage of the research was carried out by measuring sustainability awareness and determining the factors of drivers, barriers, and benefits of sustainability. Next, the current state sustainability value stream mapping (Current-SVSM) was made, which results of manufacturing lead time (MLT) is 1686,626 minutes and process cycle efficiency (PCE) is 54.51%. The next stage is the analysis of the causes of waste using Ishikawa diagram. Sustainability index (SI) indicator was determined and calculated, results 132.3% sustainability index value. The improvements were proposed in the form of regular machine maintenance, application of the Poka-Yoke concept, 5S method and work systems improvement. The results of the Future SVSM are projected to decrease MLT to 1438,881 minutes, increase PCE to 63.89% and decrease SI to 70.7%.

Keywords
waste, sustainability, lean manufacturing, sustainable value stream mapping, sustainability index.

1. Introduction

Lean systems are operations systems that maximize the value added by each of a company's activities by removing waste and delays from them. The goals of a lean system are to eliminate these eight types of waste, produce services and products only as needed, and to continuously improve the value-added benefits of operations (Krajewski, L.J., et al., 2016). A lean manufacturing enterprise is defined as a systematic approach to identifying and eliminating waste or non-value-added activities through continuous improvement by flow of the product at the request of the customer in pursuit of perfection. It can be expressed in industrial/manufacturing firms as the performance-based-process that increases a competitive advantage (Garbie, I., 2016). In today's competitive business world, industries are required to fall in line with small lead times, low costs and high customer service levels for better survival. Due to these industries have become more customers focused. The result is that industries have been putting in significant effort to reduce their lead times. The main focus of industries in the 21 st century has been the customers and industries have become very competitive to satisfy the customers. Organizations that have focused on cycle time as a productivity measure can reduce delivery time and improve quality, thereby creating more satisfied customers (Nallussamy, S. and Ahamed, A., 2017). Research related to the use of lean systems and lean tools has been widely carried out in various industries with the results of increasing production efficiency and output that helps improve company performance. VSM is used to analyze waste that occurs during the production process so that the component industry that is the object of research can further improve quality and service and meet customer requirements to remain competitive with other companies. (Jasti, N.V.K. and Sharma, A., 2014). Subsequent research related to lean manufacturing was carried out in the automotive industry by utilizing lean tools such as 5S, VSM and line balancing by identifying non-value-added activities by analyzing the waste that occurred (Nallussamy, S. and Ahamed, A., 2017. Ngo Anh Phuong and Dr. Ngo Anh Phuong used the expanded VSM related to the concept of sustainable manufacturing. -Ing Thomas Guidat (2018). The study illustrates the performance of sustainable manufacturing using sustainable value stream mapping (SVSM) to identify problems that occur during the production process that hinder sustainability in apparel companies). There are many key performance indicators required to define the sustainability index of a manufacturing plant. Some researchers specify that a lean approach can be one of these indicators, even though the notion is not fully supported by all the peers in researching sustainability index in manufacturing plants. Marhani et al. discussed how lean approaches can help the cause of achieving sustainability (Marhani, M.A., et al., 2013). Abolhassani et al. (2016) analyzed how lean approaches can impact a continuous improvement process in a manufacturing industry.

The Sustainable Development Goals (SDGs) are a global action plan agreed by world leaders, including Indonesia, to end poverty, reduce social inequality and protect the environment. The SDGs contain 17 Goals and 169 Targets that are expected to be achieved later in 2030 include the achievement of three interrelated goals, namely, economic development, social inclusion, and environmental sustainability which are necessary for the welfare of individuals and communities (-, 2015). To implement the Sustainable Development Goals (SDGs) in manufacturing companies, sustainable manufacturing can be implemented. The concept of sustainable manufacturing has 3 important aspects, namely economic aspects, social aspects and environmental aspects. The economic aspect is the company's efforts to continue to grow and still generate large profits. While the social aspect is the company's efforts to provide feedback to local residents. This last aspect is the most important aspect, namely the environment, this aspect is the company's effort not to dispose of waste that is harmful to the environment in order to continue to protect the environment (Heidari A. et al., 2013). To make a sustainable company, it is enough not only to prove that a product has value for customers, but also how the company treats employees, the environment and products that support nature conservation.

Research related to the evaluation of sustainability performance using SVSM is increasingly being used. In the following research, improvements are made to the design of analytical tools based on lean and sustainable manufacturing which are validated by conducting a case study in a furniture company. The analytical tool is able to identify potential problems in the economic, environmental, and social aspects which are the pillars of sustainable manufacturing. If this problem can be reduced, the level of sustainability will increase (Hartini, S. et al., 2018). Latif, H.H., et al.(2017) doing research about sustainability index development for manufacturing industry. The focus is on non-hazardous waste and the indicators of the index are selected with respect to energy efficiency, workers' health and safety and waste reduction potential. A systematic methodology is required to improve energy efficiency, productivity, and a work environment to achieve sustainable manufacturing goals. For that reason, a sustainability index is an important goal. This paper has provided an estimation of sustainability index by incorporating key factors. Sustainable manufacturing has become a new paradigm involving the use of sustainable processes and systems to produce more sustainable products, is currently becoming increasing important. Many studies have been conducted related to research on sustainability and resulted in a system for measuring the performance of sustainable maintenance in several industries. Marie, I.A., et al. (2020) conducted a study to analyze the mapping of lean sustainable maintenance in the company to enhance the sustainable maintenance performance by using lean competitive manufacturing strategy.

PT XYZ is a manufacturing company that was founded in 1999 and is engaged in the fabrication of heat transfer equipment. The products produced by PT XYZ include Heavy Duty Radiator, Oil Cooler, Air Cooler, Heat Exchange, and Vessel. To meet customer demand and satisfaction, the company is always trying to increase its production so that all consumer demands can be met. PT XYZ supports government programs related to sustainable development by implementing sustainable manufacturing strategies. The company wants to improve production activities to support their sustainability activities. In an effort to sustainable development, the company has implemented one of the sustainable manufacturing strategies, namely by applying the reuse concept, which is the use of leftover raw materials. The current environmental conditions at the company are noise on the production floor of 82 dB, where workers are on the production floor for approximately 7.5 hours of work per day and when overtime hours are applied approximately 11 hours of work per day. The company has received ISO 9001: 2015, ISO 14001: 2015, ISO 45001: 2018, OHSAS 18001: 2007 certification, and SMK3 Certificate from the Ministry of Manpower. But in reality, the company is considered to be still lacking in implementing these rules so that there are still several kinds of shortcomings, especially in the production process. Based on the achievement of production targets in January – July 2019, the company was unable to meet customer demands. The company suspects that there are still inefficiencies that occur during the production process, including product defects that cause consumers to complain to the company resulting in the process being repeated, resulting in a longer production process time, and a lot of wasted energy. The condition of not meeting the number of requests also causes the implementation of an overtime system that affects the level of health and job satisfaction of employees. The implementation of the overtime system has an impact on increasing production costs.

1.1 Objectives
This study aims to analyze the results of mapping lean sustainable manufacturing in order to improve the performance of sustainable manufacturing at PT XYZ.

2. Literature Review
2.1 Lean Manufacturing
Lean manufacturing is defined as a systematic approach to identify and eliminate waste or non-value-added activities through continuous improvement by product flow at the request of customers in pursuit of perfection. Several strategies that can be applied to increase efficiency on the production floor include total quality management (TQM), six sigma, reengineering, agility manufacturing, and lean concepts. And in the end, lean production techniques used through lean tools (eg. value stream mapping) are used to reduce or eliminate waste (Garbie, 2016). Efforts to eliminate waste in the application of lean manufacturing are important, it is necessary to identify waste that occurs from the start. There are seven wastes identified based on the Toyota Production System, namely over production, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting and unnecessary motion (Hines and Taylor, 2000). Manufacturing Lead Time (MLT) is the total time required to manufacture a product item including setup time (S), queue time (Q), operation time (O), and move time. time (M) (Fogarty, 1991). Manufacturing Lead Time calculation formula is as follows.

$$\text{MLT} = \text{VA} + \text{NVA} + \text{NNVA} \qquad (1)$$

Process Cycle efficiency (PCE) is the measurement result for the efficiency of production activities based on the percentage between the processing time and the overall production time. The percentage of Process Cycle Efficiency is obtained by calculating the following formula:

$$\text{PCE} = \frac{VA}{MLT} \times 100\% \qquad (2)$$

2.2 Sustainable Manufacturing
According to Latif, H.H., et al.(2017) the definition of sustainability is being productive while making little to no impact on non-replenishable resources. Meanwhile,sustainable manufacturing can be defined as the process of making a product, which in its application is able to reduce negative environmental impacts, save energy and natural resources, be safe for employees, the community, and consumers as well as economical. Regarding sustainable manufacturing, there are two types of competitive manufacturing strategies that can be carried out by organizations/companies, namely conventional strategies (related to cost, time and quality) and non-conventional strategies. Non-conventional competitive manufacturing strategies play an important role in evaluating manufacturing companies by optimizing the level of complexity, maximizing manufacturing leanness, manufacturing agility, remanufacturing, and recycling. Leanness, agility, remanufacturing, and recycling strategies are considered the domain of an organization/company's operational improvement strategy, and maximizing them will provide the potential for the company to grow (Garbie, 2016).

2.3 Sustainability Awareness
Companies play a large and important role in implementing programs to increase awareness of sustainability, although most of the manufacturing companies have not yet switched to implementing sustainable practices. Sustainability awareness is a step used to find out how well the company understands about sustainability. The tools used to measure sustainable awareness are in the form of a questionnaire to find out the drivers, barriers and benefits of sustainability in the company. Sustainability drivers are factors that support companies to implement the sustainable concept. Barriers of sustainability are factors that hinder companies from implementing the sustainable concept. Benefits of sustainability are used to find out what benefits and benefits will be obtained by the company in implementing the concept of sustainable manufacturing (Garbie, 2016).

2.4 Sustainability Index
The sustainability index is a measurement of the concept that has been carried out by a company, what percentage of the company has implemented the concept of sustainability which consists of several indicators from the three pillars, namely economic, social, and environmental (Garbie, 2016). The following is the calculation for the sustainability index.

$$\frac{S}{Sd_i} = \left(I_{i1}^{Y_{i1}}, I_{i2}^{Y_{i2}}, I_{i3}^{Y_{i3}}, I_{i4}^{Y_{i4}}, I_{i5}^{Y_{i5}}, I_{i6}^{Y_{i6}}\right) \qquad (3)$$

$\frac{S}{SD_i}$ is sustainability main pillar (eg economic / social / environmental).
I_{ij} is ratio of sustainability issues or key indicators in the main pillars.

2.5 Lean Sustainable Manufacturing

Sustainable manufacturing is a production process that minimizes negative environmental impacts, saves energy and natural resources, is safe for employees, communities, and consumers and is economically healthy. By using a lean manufacturing approach, the company can analyze the waste that occurs during the production process. The difference in using a lean manufacturing approach with sustainable manufacturing is that lean manufacturing only looks at waste in outline, namely those contained in seven wastes, cycle time, setup time, while in sustainable manufacturing sees waste or existing problems from the 3 sustainable pillars, namely economic, social , and the environment.
Value Stream Mapping (VSM) is used as an initial tool in lean manufacturing mapping which shows a picture of all activities or activities carried out by a company. Based on the VSM results, a waste analysis can be carried out, where if the waste has been found, the waste must be eliminated. The purpose of VSM is for process improvement in a system (Lonnie, 2010). Sustainable Value Stream Mapping (SVSM) extends traditional value stream mapping by combining three aspects, namely environmental aspects for evaluating environmental sustainability and social aspects for evaluating community sustainability at the production line level. The addition of this aspect allows all three aspects of sustainability to be evaluated for the production line, and for potential improvements to sustainability performance to be identified (Faulkner, 2014).
A sustainability index should be designed in such a way that it becomes applicable to all industry. The index should be chosen carefully so that it truly reflects the sustainability of a manufacturing organization. The most important aspect of the research is to integrate energy, waste and workers' safety into one sustainability index. Pairwise comparison is a method where each candidate is matched with each of the other candidates. (Latif, H.H., et al., 2017)
There is a framework for evaluating the sustainability performance of manufacturing process at factory level. First, the Delphi method is used for the selection of relevant indicators. Then SVSM is used for the assessment of indicators using the efficiency approach and the AHP method is used to determine the indicator weights. MSI was developed as control tool to monitor the whole manufacturing sustainability performance. MSI can be controlled periodically after improvements have been made to indicators that have not been efficient. (Huang, A. and Badurdeen, F. 2018)

3. Methods

The flowchart image in figure 1 below is a general problem solving stage. For the detailed stages of data processing activities carried out can be seen in Figure 2 below.

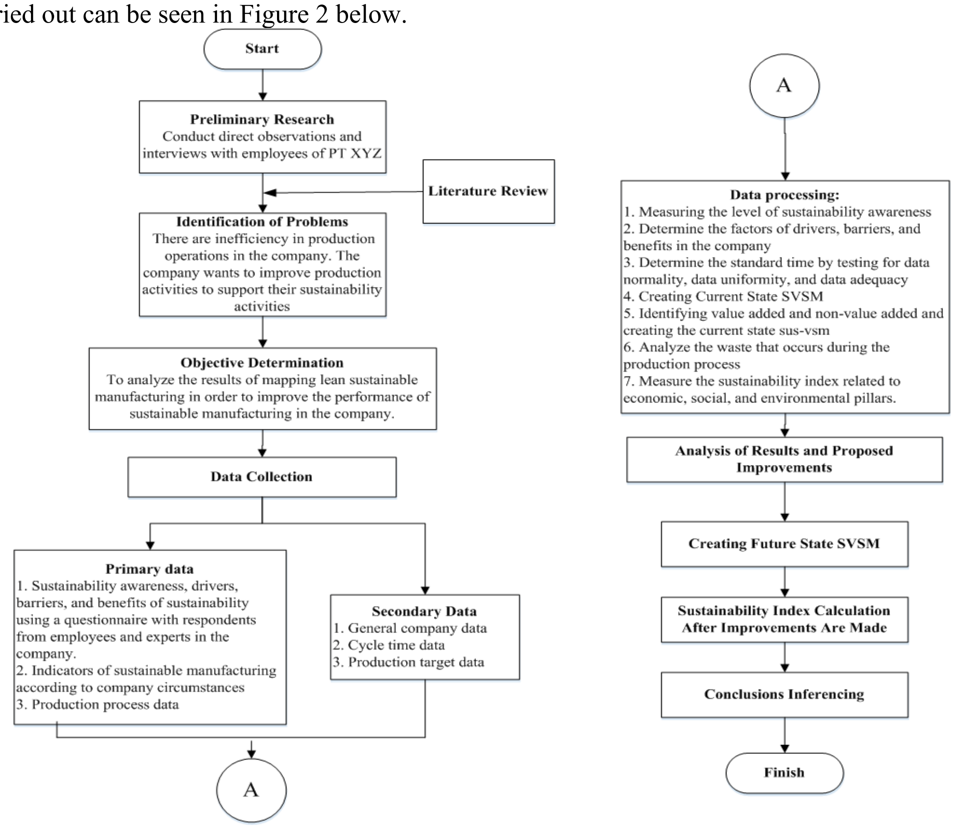

Figure 1. Flowchart of research methodology

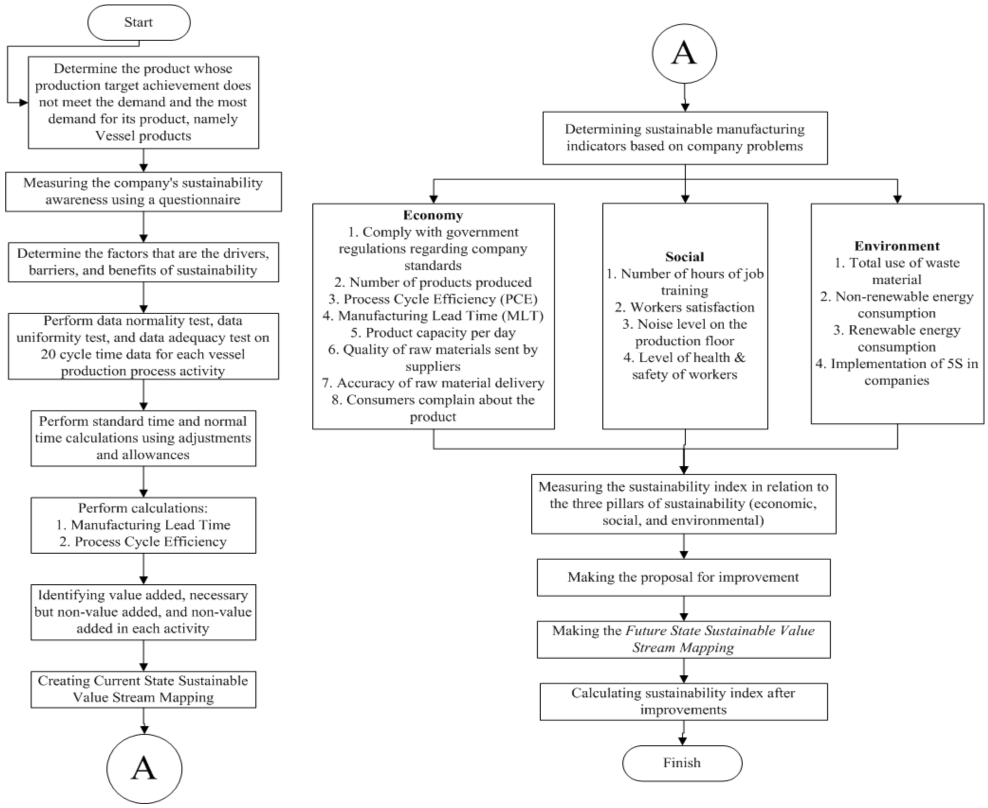

Figure 2. *Flowchart* of data processing

4. Data Collection
4.1 About PT XYZ

PT XYZ is a company engaged in the design & fabrication of heat exchangers (heat exchangers) for power generating machines at state power companies and private industries. The company was founded in 1999 and carries out manufacturing activities on an area of ± 18.000m². The company strives to realize the implementation of sustainable development by choosing the use of environmentally friendly materials. This is marked by the ISO 14001:2015 certification from the AQM certification body related to the company's environmental management system. In the production process, the company has implemented a reuse process where if there are leftover raw materials that can be reused, a reuse process will be carried out which is useful for reducing waste production that can affect the environment around the company.

4.2 About Vessel Product

Vessel product is one of the products with a large enough demand that has been produced by the company. The following is a picture of the Vessel product (Figure 3).

Figure 3. Vessel product

Vessel products consist of two components, namely shell and head. The raw material used for the manufacture of vessel products from its two components is a steel plate with a thickness of 6 mm. Before the raw materials are used for the production process, an inspection process is carried out to determine whether the materials used have defects. If the raw material has no defects, it can be used directly for the production process. The product diameter of the vessel is 750 mm with a length of 1220 mm. The two components are manufactured through a forming process using an automatic punching machine. Next is the inspection process to check whether the diameter is in accordance with customer demand or not. After the forming process is carried out, the two components of the vessel product will be assembled by a welding process using a welding machine and an inspection process is carried out. After the welding process is carried out, the hydrotest process is then carried out to determine whether there is a leak on the sides with the help of an automatic tub machine. After the hydrotest process is carried out, the painting process will be carried out and inspection will be carried out. After that, the packaging process is carried out and the product will be sent to the customer.

4.3 Cycle Time

The cycle time of each activity is obtained from data collected from the company totaling 20 data for each activity. Furthermore, from the 20 cycle time data, normality test, uniformity test and data adequacy test were carried out. Next is the normal time calculation by adding an adjustment factor based on the Westinghouse approach which considers the operator's work speed based on four factors, namely skills, effort, working conditions, and consistency. After that, the standard time is calculated by adding the allowance factor.

4.4 Sustainability Awareness

Sustainability awareness is a stage that produces a critical assessment related to the implementation of the concept of sustainability in the company. In this study, a questionnaire was used to obtain sustainability awareness with groups of questions on general sustainability, drivers of sustainability, barriers to sustainability, and benefits of sustainability. Employees who fill out the sustainability awareness questionnaire are experts who understand the state of the company. The results obtained based on respondents' answers are that employees already understand the sustainable concept even though there are still obstacles so that motivation is needed to be able to carry out the sustainable concept in the company. For the group of questions related to sustainability drivers, it was found that the most motivating factor for companies from first to third rank was building a company image so that the opportunity to get international consumers was greater, increasing market competitiveness, and increasing environmental awareness that could motivate companies to reduce the use of materials that are not used. adversely affect the environment.

The results of the questionnaire answers for groups of questions related to sustainability barriers show that the inhibiting factors for implementing the concept of sustainability in companies are the lack of tools, lack of infrastructure such as processing waste products, as well as lack of data and standardization. This makes it difficult for the company to achieve the target of achieving the value of the sustainability indicator. Benefits of sustainability are the benefits that will be obtained if the concept of sustainability has been applied to the company. From the answers to the questionnaire, it is known that the benefits that the company will get when implementing the concept of sustainability are that it can reduce waste which results in production targets being not achieved, using more efficient resources, and reducing production costs.

5. Results and Discussion

5.1 Creating Current State Sustainable Value Stream Mapping (Current SVSM)

The initial stage in designing the current state sustainable value stream mapping is to observe the activities that occur during the vessel production process along with the cycle time of each activity during the production process. After this is done, then a mapping is carried out on the vessel production process so that it can be seen what waste is present during the vessel production process. This is shown in table 1.

Manufacturing Lead Time = VA + NNVA + NVA = 919.43 + 719.17 + 48.0265 = 1686.626 minutes

$$\text{PCE} = \frac{VA}{MLT} \times 100\% = \frac{919.43}{1686.626} \times 100\% = 54.513\%$$

Based on the calculation results above, it is obtained that the percentage value of the process cycle efficiency of vessel production is 54.513%. The calculation of manufacturing lead time is 1686,626 minutes. With 7.5 working hours, the daily production capacity is 0.267. The following is a current sustainable value stream mapping (Current Sus-VSM / Current SVSM) for the vessel production process which can be seen in Figure 4.

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Table 1 *VA*, *NNVA*, *NVA analysis and* waste identification for vessel activity mapping

Work Station	Activity	Process	Type of Activity					Standard Time (Minutes)	Value			Waste						
			O	T	I	S	D		VA	NNVA	NVA	W 1	W 2	W 3	W 4	W 5	W 6	W 7
GBB	1	Steel plate raw material inspection			√			17.90		17,90						√		
	2	Transfer of steel plate raw materials to forklift		√				8.78			8,78					√		
Component	1	Transfer of steel plate raw materials to component work stations		√				14,19		14,19					√			
	2	Forming machine setup	√					14,38		14,38								√
	3	Head component forming process	√					160,09	160,09									√
	4	Inspection of the results of the head component forming process			√			66,95		66,95			√					
	5	Shell component forming process	√					159,80	159,80									√
	6	Inspection of the results of the shell component forming process			√			81,29		81,29			√					
	7	Transfer of the results of the component forming process head to forklift		√				9,04			9,04							√
	8	Transfer of the result of the component forming process shell to forklift		√				8,95			8,95							√
Welding	1	Transfer of the results of the head component forming process to the welding machine		√				9,51		9,51								√
	2	Transfer of the result of the component forming process shell to welding machine		√				9,86		9,86								√
	3	Welding machine setup	√					15,88		15,88								√
	4	Welding Process	√					210,01	210,01									√
	5	Inspection of welding process results			√			68,71		68,71			√					
	6	Transfer of the results of the welding process to the forklift		√				10,63			10,63							√
Solder	1	Transfer of the results of the welding process to the soldering station for the hydrotest process		√				11,93		11,93					√			
	2	Pouring water into the results of the welding process	√					10,56		10,56						√		
	3	Automatic test tub machine setup	√					9,27		9,27								√
	4	Hydrotest process	√					209,92	209,92									√
	5	Inspection of the results of the hydrotest process			√			46,41		46,41			√					
	6	Transferring the results of the hydrotest process to a forklift		√				10,63			10,63							√
Finishing & Painting	1	Transfer of the results of the hydrotest process to the station finishing & painting work		√				10,16		10,16					√			
	2	Painting process using a spray gun		√				179,62	179,62									√
	3	Product drying after processing painting					√	82,43		82,43						√		
	4	Finished goods inspection			√			67,53		67,53								√
	5	Packing	√					182,21		182,21								√

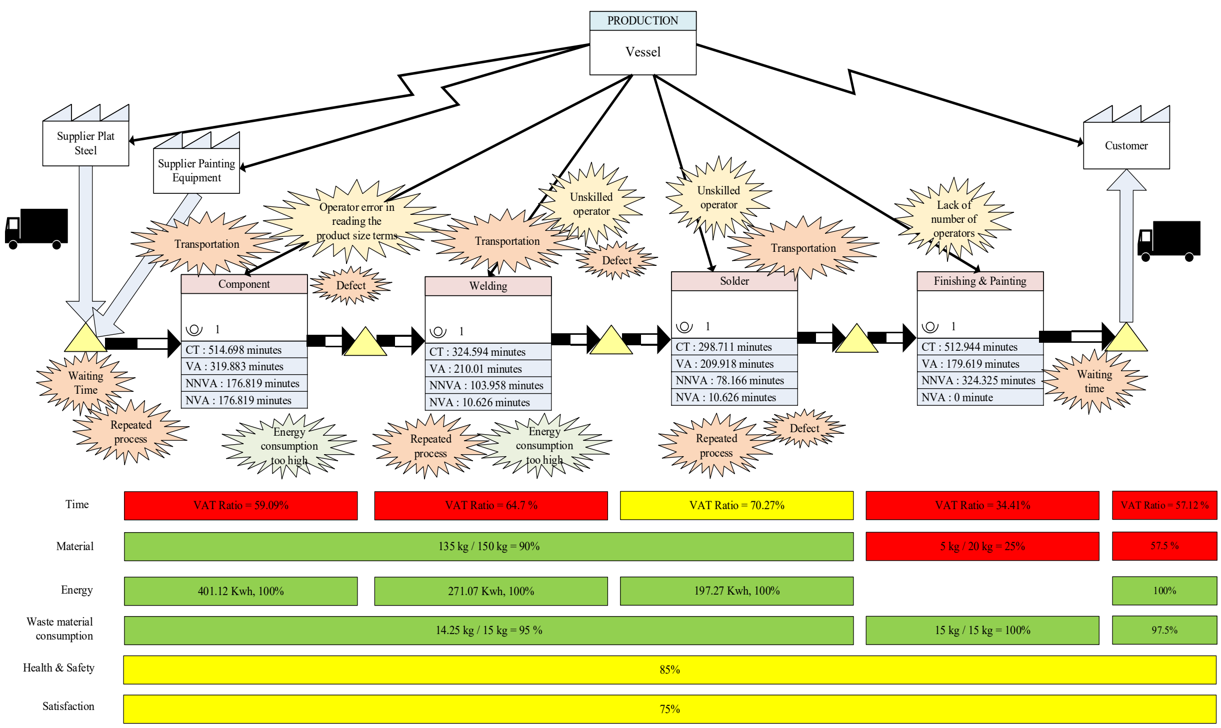

Figure 4. *Current state of vessel production SVSM*

To find out the mapping of the vessel production process, sustainable value stream mapping (SVSM) tools are used. The difference between using value stream mapping (VSM) and sustainable value stream mapping (SVSM) is that in SVSM there are additional environmental aspects for evaluating environmental sustainability and social aspects for evaluating community sustainability at the production line level (Hartini, S., 2018). Additional environmental aspects include the use of energy and the use of waste materials. The social aspect includes the level of health & safety of the employees and the level of workers' satisfaction. Figure 4 shows the current state of SVSM for the vessel production process. In the picture there is a traffic light system with red color which means critical explaining the range from 0 – 65%, yellow which means moderate with a range of 65 – 90%, and green which means excellent with a range of 90 – 100%. Kaizen burst is found in the SVSM which explains the problems found in the work station areas during the production process. The colors of the kaizen burst are divided into three, namely orange (economic), yellow (social), and green (environmental).

There are several problems that occur during the vessel production process from existing work stations. If observed from the inspection to the soldering station, there is waste waiting, defects, transportation, and the process is repeated. Waste waiting is found in raw material inspections caused by operators who have difficulty finding tools for raw material inspections. Waste defects are caused by machine maintenance that is not carried out regularly so that there are problematic components and operator errors in doing their work. Waste transportation is caused by the obstruction of the path of moving goods to other work station areas by goods or tools on the production floor and transportation methods that are too long so that it takes time. The process is repeated due to machine problems and operator errors in doing their work. In the soldering station area, waste waiting is caused by the waiting time for the product drying process that utilizes sunlight, which if the weather is not hot, the drying process will take longer.

In the vessel production process, there is a waste of energy use due to excessive use of machines. Excessive use of the machine is caused by the occurrence of machine down time due to component damage. The company has not implemented preventive maintenance so that engine maintenance activities are not carried out regularly. The company does not yet have a schedule for engine component replacement and engine inspection. Next, the company has not made good use of stainless-steel material waste. Furthermore, the level of health & safety of workers is 85% because in the production process there are still production operators who do not use personal protective equipment and are not aware of occupational health and safety. In the picture there is also a level of worker satisfaction which is worth 75% due to the implementation of the system. overtime.

From the results of the identification of waste above, there are 4 types of waste, namely, defect, transportation, waiting, and inappropriate processing. Ishikawa diagram is used to identify the causes of waste.

5.2 Calculation of Sustainability Index

5.2.1 Determining Sustainability Index Indicator

After observing and interviewing several selected company staff, several sustainability index indicators can be determined based on economic, environmental, and social pillars that will be used to measure the sustainability index value so that the level of sustainable manufacturing at PT XYZ can be determined. The information on the selected indicators for the measurement of the sustainable index at PT XYZ can be seen at table 2 and table 4.

5.2.2 Calculation of Pairwise Comparison Matrix

The next step is to calculate the weights using a pairwise comparison approach for the three sustainability aspects, namely the economic, social, and environmental aspects. The weight calculation is carried out in order to determine the level of importance between aspects and which aspects affect the most according to the company's circumstances. The first step in this weighting is to conduct interviews with experts so that the level of importance between aspects is known. The results of the calculation of the weight of the criteria for the three aspects can be seen in table 2 and table 4 (vector eigen column).

5.2.3 Calculation of Sustainability Index

In the previous process, the target and existing values for each indicator were obtained, then the sustainability index was calculated for each indicator that had been selected according to the company's conditions. The following are the results of the calculation of the sustainability index at PT XYZ which are shown in table 2.

The calculations that will be carried out to calculate the value of the sustainability index for the first indicator on the economic aspect are as follows:

$Value\ of\ change = Target - Existing = 90 - 75 = 15$

$Percentage = \frac{Value\ of\ Change}{Existing} = \frac{15}{75} \times 100\% = 20\%$

$Yij = \text{Log}(value\ of\ change) = \text{Log}(15) = 1.18$

$Iij = \frac{Besar\ Nilai\ Target}{Besar\ Nilai\ Existing} = \frac{90}{75} = 1.2$

$Iij\text{\^{}}Yij = (Log(Value\ of\ Change))^{\left(\frac{Besar\ Nilai\ Target}{Besar\ Nilai\ Existing}\right)} = 1.24$

Table 2. Calculation of sustainability index (SI)

Indicator		Performance measure	Existing	Target	Value of change	Percentage	Yij	Iij	Iij^Yij	S/Sdei		Eigen Vector	Sustainability Index	
Economy	Government regulation	%	75	90	15	20%	1,18	1,2	1,24	0,71	71%	0,73	1,321	132%
	Number of products produced	pcs	139	162	23	17%	1,36	1,17	1,24					
	Process Cycle Efficiency (PCE)	%	54,51	58,6	409	8%	61	1,08	1,05					
	Manufacturing Lead Time (MLT)	Minutes	1.686,626	154,925	-137,376	8%	2,14	0,92	0,84					
	Production capacity (day)	pcs	0,267	0,43	0,163	61%	-0,79	1,61	0,69					
	Quality of raw materials sent by suppliers	%	90	100	10	11%	1	1,11	1,11					
	Raw material delivery accuracy	%	90	100	10	11%	1	1,11	1,11					
	Consumers complain about the production	%	10	5	-5	50%	0,7	0,5	0,62					
Social	Employee training	Hour	8	8	0	-	-	-	-	0,92	92%	0,19		
	Workers Satisfaction	%	75	80	5	7%	1,7	1,07	1,05					
	Noise level	dB	82	70	-12	15%	1,08	0,85	0,84					
	Health & safety level	%	85	90	5	6%	0,7	1,06	1,04					
Environment	Waste material consumption	%	97,5	100	25	3%	0,4	1,03	1,01	7,85	785%	0,08		
	Non-renewable energy consumption	Kwh	869,46	720,56	-148,9	17%	2,17	0,83	0,67					
	Renewable Energy Consumption	%	20	60	40	200%	1,6	3	5,8					
	5S implementation	%	50	80	30	60%	1,48	1,6	2					

Based on the calculation of the sustainability index, the results obtained for the economic aspect is 71%, the social aspect is 92%, and the environmental aspect is 785%. The overall SI indicator is 131.3%. The larger the SI value, the more attention it needs to make improvements. PT XYZ needs to make improvements for a sustainable company.

5.3 Proposed Improvements

Based on the results of the SVSM mapping of vessel products and the calculation of the sustainability index, the proposed improvements to PT XYZ are as follows : Implementation of Preventive maintenance and training for operators ; Application of 5S and the addition of a rack or table with wheels for placing tools ; Incorporating the process of pouring water into the results of the welding process with the activity of setting up an automatic tub machine ; Combined head and shell component inspection process ; Combining the process of moving the head and shell components ; and Adding operators in the packing process.

5.4 Future State Sustainable Value Stream Mapping

Based on the improvement in combining inspection activities, moving goods, and adding operators to the proposed packing process, there was a decrease in the number of vessel production process activities from 27 activities to 19 activities. This is expected to reduce waste that occurs during the production process. For repair activities and identification of non-value-added, necessary but non-value added, and value added activity can be seen in the table 3. By making improvements according to the proposal, the projected completion time of activities is obtained with the results of value-added time of 919.43 minutes, necessary but non-value-added time of 480.47 minutes, non-value-added time of 38.98 minutes, manufacturing lead time of 1438,881 minutes, and process cycle efficiency of 63.89%. Figure 5 shows the sustainable value stream mapping (SVSM) after the repair. Waste defects, operator errors in reading product size provisions and operators who are less skilled in their work can be minimized by making suggestions for regular machine maintenance and holding training to minimize operator errors in their work as well as to increase operator skills in their work. Waste transportation and waiting can be eliminated by making suggestions for improving the application of 5S on the production floor so that the movement of goods is not hindered and proposals for adding tools racks to arrange tools needed in the production process.

The picture also shows that the VAT ratio has increased from 57.12% to 65.18%. The VAT ratio is the quotient between the VA value and the sum of the VA, NNVA, and NVA values. This is due to a combination of activities to reduce inappropriate processing waste that has been carried out in the proposed improvement. Energy reduction has decreased at component and welding work stations, namely at component work stations at 366.56 Kwh and at welding work stations at 155.42 Kwh. This can be realized properly if the company implements the proposed machine maintenance improvement on a regular basis so that the use of the machine is more optimal and the process carried out using the machine is not repeated. The use of waste material has also increased from 97.5% to 100% because the remaining material at the component, welding, and solder work stations can still be reused to the maximum and no material is wasted. The level of health & safety has increased to 95% due to the proposed improvement by providing counseling on the importance of using personal protective equipment. The level of workers satisfaction has increased to 85% if the company makes a new policy, namely the overtime system by increasing rest hours so that employees are also more optimal in their work and have a positive impact on the company.

Table 3. VA, NNVA, and NVA mapping for vessel production activities after improvement

Work Station	Activity	Process	Standard Time (Minutes)	Value		
				VA	NNVA	NVA
GBB	1	Steel plate raw material inspection	17,901194		17,901	
	2	Transfer of steel plate raw materials to forklift	8,77737			8,7774
Component	1	Forming machine setup	14,381785		14,382	
	2	Head component forming process	160,087	160,09		
	3	Shell component forming process	159,796	159,8		
	4	Inspection of the results of the shell and head component forming process	66,954996		66,955	
	5	Transfer of the results of the component forming process head and sheel to forklift	8,954244			8,9542
Welding	1	Welding machine setup	15,8848		15,885	
	2	Welding Process	210,01	210,01		
	3	Inspection of welding process results	68,71095		68,711	
	4	Transfer of the results of the welding process to the soldering station	10,6262			10,626
Solder	1	Pouring water and machine setup automatic test tank	9,2708		9,2708	
	2	Hydrotest process	209,918	209,92		
	3	Inspection of the results of the hydrotest process	46,408064		46,408	
	4	Transferring the results of the hydrotest process to the finishing & painting work station	10,6262			10,626
Finishing & Painting	1	Painting process using a spray gun	179,619265	179,62		
	2	Product drying after the painting process	82,4252		82,425	
	3	Finished goods inspection	67,528625		67,529	
	4	Packing process	91		91	

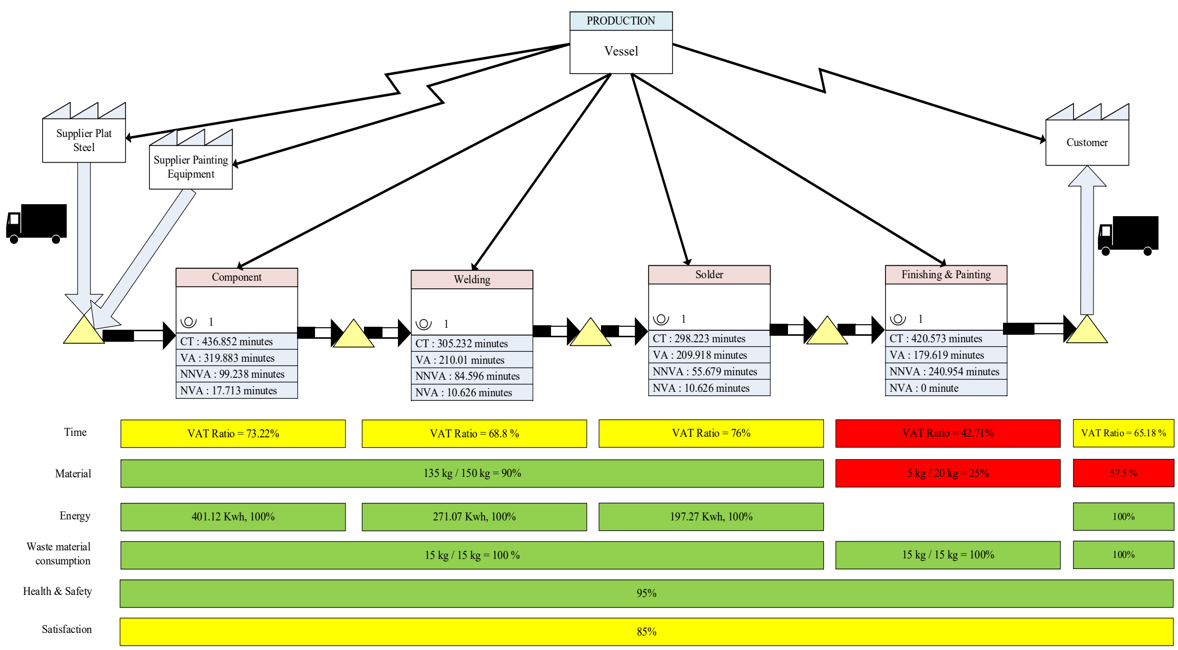

Figure 5. *Future state of vessel production SVSM*

5.5. Calculation of *Sustainability Index* After Improvement

The calculation of this sustainability index is the result of the company's calculations to make improvements with the proposals made. After improving the value of the sustainability index, which was initially valued at 132.3%, it is projected to decrease to 70.7%. The result can be seen at table 4

Table 4. Sustainability index calculation after improvement.

Indicator		Performance measure	Existing	Target	Improvement	Value of change	Percentage	Yij	Iij	Iij^Yij	S/Sdei		Eigen Vector	Sustainability Index	
Economy	Government regulation	%	90	90	Implementing ISO with more maximum	0	-	-	-	-	0,61	61%	0,73	0,734	73%
	Number of products produced	pcs	159	162	Combine activities during the production process	3	2%	0,48	1,02	1,01					
	Process Cycle Efficiency (PCE)	%	63,89	58,6		-5,2	8%	0,72	0,92	0,94					
	Manufacturing Lead Time (MLT)	Minutes	1.438,881	154,925		-1.283,956	8%	2,04	0,93	0,86					
	Production capacity (day)	pcs	0,313	0,43		0,117	37%	-0,93	1,37	0,75					
	Quality of raw materials sent by suppliers	%	100	100	Communicate with suppliers about the results of their shipments	0	-	-	-	-					
	Raw material delivery accuracy	%	100	100		0	-	-	-	-					
	Consumers complain about the production	%	5	5	Stricter the inspection process of finished goods	0	-	-	-	-					
Social	Employee training	Hour	8	8	-	0	-	-	-	-	0,85	85%	0,19		
	Workers Satisfaction	%	85	80	Create some new policies for employees	-5	6%	0,7	0,94	0,96					
	Noise level	dB	73	70	Employees must using earplugs	-3	4%	0,48	0,85	0,92					
	Health & safety level	%	95	90	Provide education to employees on the importance of using PPE	-5	5%	0,7	0,95	0,96					
Environment	Waste material consumption	%	100	100	Using waste materials from the production process more optimally	0	-	-	-	-	1,59	159%	0,08		
	Non-renewable energy consumption	Kwh	719,25	720,56	Regular machine maintenance	1,31	17%	0,12	0,83	0,98					
	Renewable Energy Consumption	%	40	60	Using solar panels	20	50%	1,3	1,5	1,69					
	5S implementation	%	85	80	Organize tools and work areas	-5	6%	0,7	0,94	0,96					

The decrease in the value of the sustainability index by 61.6% was due to improvements in the environmental aspects of the indicators with the implementation of 5S in the company. With the application of the proposed improvement, the company can overcome the main problem, namely the occurrence of waste in the production process which often causes the production target not to be achieved. With the implementation of the improvements that have been proposed, the company will also become an increasingly lean company and thus support the company's desire to become a sustainable company.

6. Conclusion

Almost all employees at PT XYZ already understand the concept of sustainable manufacturing. The driving factor for implementing the concept of sustainability (sustainability drivers) in companies is the need to build a company image, while the inhibiting factor (sustainability barriers) is due to a lack of understanding of the tools that can be used by companies to implement the concept of sustainability in companies. The company understands that by applying the concept of sustainability (benefits of sustainability) it can reduce waste. Based on the making of the Current State SVSM, it is known that the inefficiency in the vessel production process is caused by waste defects, waiting, transportation, and inappropriate processing. From the waste, an analysis was carried out to determine the root cause of the problem using the Ishikawa diagram.

The calculation result of the manufacturing lead time of the vessel production process is 1686,626 minutes and the process cycle efficiency is 54.51%. The results of the calculation of the sustainability index based on the selected indicators for the initial conditions are 132.3%. To minimize the waste that occurs, improvements are proposed in the form of regular machine maintenance activities so that the process is not repeated and reduces energy use, holding training for operators, applying the 5S method in structuring tools for the purposes of the production process, and combining several production activities. After the proposed improvements, there was a decrease in the manufacturing lead time to 1438,881 minutes and an increase in process cycle efficiency to 63.89% and the sustainability index decreased to 70.7%.

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