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Implementation of Lean Manufacturing Process to Reduce Waste: A Case Study

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Abstract. Excessive waste production is often happening in the inefficient use of resources in manufacturing. There is still some excessive waste found in the electronic components company as a case study. It resulted from the careless use of resources and indirectly weakness their market positioning. The purpose of this paper is to present an implementation of a lean manufacturing process to reduce waste. This study aims to analyze and reduce the waste that occurs using lean manufacturing approaches. The value stream mapping (VSM) and waste relationship matrix (WRM) were applied to describe and to analyze the production flow of waste. Then, a waste assessment questionnaire (WAQ) is used to determine the percentage of waste that occurs. Value Stream Analysis Tools (VALSAT) is used for complete mapping tools. Three methods are considered for determining the feasibility, namely, net present value, internal rate of return, and profitability index. Base on analysis, we choose on the 3rd largest waste to be improved. According to the data analysis, it is found that increasing the number of production machines, carrying out appropriate maintenance activities, increasing training and supervision, and adding work facilities are recommendations for the improved production process. The proposed guidance seems to help the company reduce the seven waste and increase unit production. It is expected that the production process will be more effective and efficient.

1. Introduction

Companies must pay more attention to the condition of their competition with competitors. Essential aspects should be considered in the supply chain management, including product design, material sourcing, and selection, manufacturing processes, final product delivery to consumers, and product management [1]. Quality products at affordable prices and timeliness following the time of absolute demand must be met when the company wants to survive in market competition. The companies should have some activities for increasing product value-added and for eliminating waste as well as improving productivity [2,3]. Manufacturing companies often implement lean manufacturing to optimize their production process due to waste activities that arise [2], [4,5]. Lean manufacturing is the most popular approach to eliminating waste in the manufacturing industry, and it refers to the

manufacturing process without waste [4]. Lean is an ongoing effort to reduce waste and increase the added value of products to provide value to customers (customer value) [5].

The concept of Lean's thinking is oriented to the Toyota Production System (TPS), which determines activities that have value and eliminates non-added value activities so that each step of production adds value to the process [6]. Lean manufacturing is a powerful tool and the most effective way to utilize the resources and reduce the waste production system [7].

Lean manufacturing is defined as a system of continuous improvement that integrates daily work in producing and delivering products, services, and information to identify waste that affects the flow in production, grace period, quality, and cost [8]-[10]. Popular definitions of lean manufacturing and Toyota Production System (TPS) are a complete technique when combined and mature, which will help to reduce and then eliminate the seven types of waste [11]. TPS has applied all aspects of lean manufacturing objectives. This system will make the company more concise and more flexible and more responsive by reducing waste [11]. Waste can be defined as any work activity that does not add value to transforming inputs into outputs along the value stream [12]. The seven types of waste and their explanation are overproduction, defects, unnecessary inventory, inappropriate processing, excessive transportation, waiting, and unnecessary motion [13].

Regarding the implementation of lean manufacturing, companies should implement a methodology that incorporates key factors as integrated management systems [14]-[16], strategy and culture [17], and operations [18], which are focused on improving their performance. This study aims to increase sustainable performance in the company by eliminating waste of activities that do not add value in the process [19, 20, 21] and provides recommendation improvement to the company. Lean production is aimed at creating products with many variations but still has a low cost.

2. Approaches for Implementing Lean Manufacturing Process

The approaches for analysis equipment replacement consist of four stages, i.e., problem identification and collecting data, data analysis using five tools, namely value stream mapping (VSM); waste relationship matrix (WRM); waste assessment questionnaire (WAQ); value stream analysis tools (VALSAT); and failure mode and effects analysis (FMEA). Recommendation for improvement is proposed based on feasibility analysis using three methods as follows: net present value (NPV), internal rate of return (IRR), and profitability index (PI). Figure 1. shows the flowchart of the implementing lean manufacturing process to solve the problem.
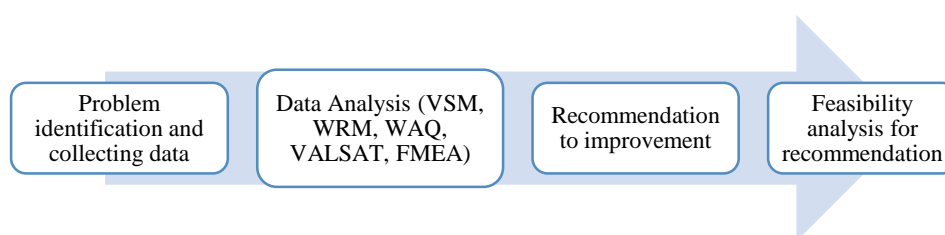

Figure 1. Flowchart methodology

Value stream mapping (VSM) is a map that illustrates all the steps in the work process (including rework) related to the conversion of customer needs into a product and shows how much value is added from each stage to the product [22,23]. The use of VSM as a process for improvement at the system level. Then, waste relationship matrix (WRM) were applied to describe and to analyze the production flow of waste. After the waste relationship matrix (WRM) method is completed, it is followed by a waste assessment questionnaire (WAQ). A waste assessment questionnaire (WAQ) is used to determine the percentage of waste that occurs.   It is a proposed method that articulates the definition of each of the seven types of waste and its impacts [24]. This method is intended not only to help see waste but also to measure the relationship and its effects. Criteria are made to measure each relationship's strength directly so that a waste matrix is created, which classifies each relationship directly [24]. Value Stream Analysis Tools (VALSAT) are utilized for complete mapping tools.

Failure Mode and Effects Analysis (FMEA) is one method of failure analysis / potential failure that is applied in product development, system engineering, and operational management. FMEA is carried out to analyze the potential for errors or failures in the system or process, and the identified potentials will be classified according to the magnitude of the potential failures and their effect on the process.

3.   Result and Discussion

3.1 Value Stream Mapping (VSM)

Value Stream Mapping (VSM) is made to describe all activities that give and do not add value in material flow. This tool is an adaptation of the Toyota production system to help identify waste in the production system. There are two types of Value Stream Mapping, i.e., current state value stream mapping (CSVSM) to represent the current condition and future state value stream mapping (FSVSM) to describe the proposed improvement. Figure 2 shows the result of CSVSM.
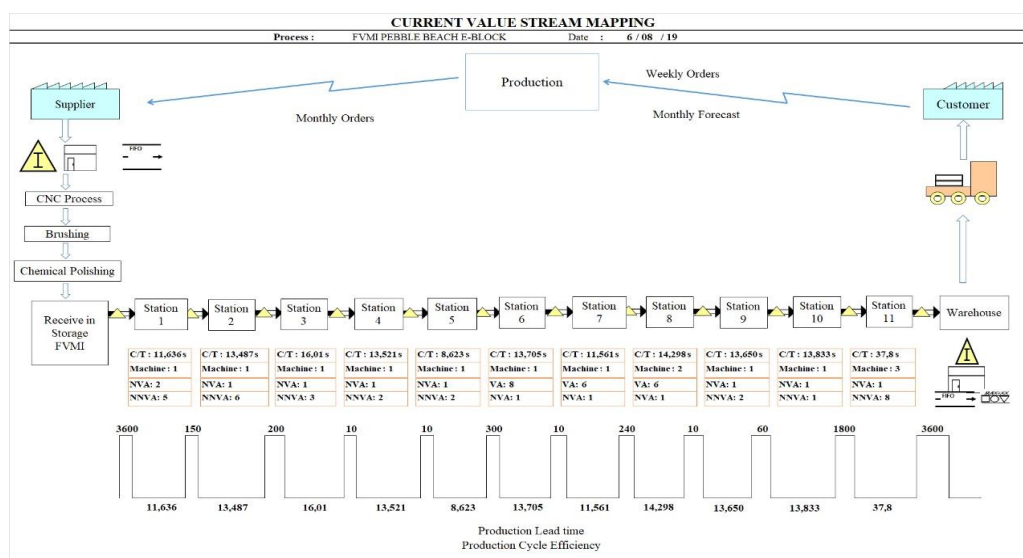
Figure 2. Current state value stream mapping (CSVSM)

To analyze the CVSM results in more detail, several performance indicators are used to measure the level of performance in the field. For more details CVSM analysis can be seen in Table 1.

Table 1. Analysis of CSVSM

No	Performance Indicators	CVSM	Detail Analysis
1	High production cycle time	Cycle Time of all workstations is greater than takt time	- Production time in the field runs slower than the standard time set on request - This process is carried out by humans and is not assisted by an automatic machine. - Daily production target is not reached - The production process is not appropriate, so improvements are needed.
2	Uptime (98%)	The company's standard is maximum production rejects 3%.	- The reject standard has been set by the management after calculating the various losses.
3	Time Effectiveness	Total Cycle Time : 168.124 Total Lead Time : 10,158.124	This time ratio is huge. This is because the bottle neck and waiting time are so long that most of the time is used to wait for the next process. Improvements need to be made in order to reduce waiting time in order to reduce lead time.
4	Material and process flow	The amount of WIP material is too much	- WIP is too much because of the waiting time to go to the next process. Therefore it is necessary to make improvements.

3.2 Waste Relationship Matrix (WRM)

The value and the results of the conversion of interrelation between waste are obtained based on the company's weighting assessment of waste. The results of the questionnaire assessment scores are then grouped according to the level of interrelation between waste. Furthermore, the results of the questionnaire assessment were made into a Waste Relationship Matrix (WRM). The relationship in each type of waste is symbolized by **O** (overproduction), **I** (inventory), **D** (defect), **M** (motion), **T** (transportation), **P** (process), and **W** (waiting).

Table 2. Waste Matrix Value

F/T	O	I	D	M	T	P	W	Skor	%
O	10	0	0	0	0	0	0	10	4.808
I	0	10	4	6	6	0	0	26	12.5
D	0	10	10	4	6	0	6	36	17.31
M	0	6	6	10	0	2	8	32	15.38
T	0	8	4	6	10	0	8	36	17.31
P	0	6	6	2	0	10	8	32	15.38
W	0	8	10	4	4	0	10	36	17.31
Scor	10	48	40	32	26	12	40	208	100
%	4.81	23.08	19.23	15.38	12.50	5.77	19.23	100	X

3.3 Waste Assessment Questionaire (WAQ)

The WAQ method approach is a continuation of the WRM method to assess the seven types of waste further. The application of the WAQ method refers to the research results [24]. The steps for applying the WAQ method areas showed at Tabel 3. Figure 3 shows the final graphs in the final value (Yj final) ranking from Table 3.

Table 3. WAQ calculation results

	O	I	D	M	T	P	W
Skor (Yi)	0.62	0.6358	0.667	0.7294	0.6158	0.743	0.717
Pi factor	23.1	288.46	332.8	236.69	216.35	88.76	332.8
(Yi final)	14.3	183.4	222.1	172.64	133.22	65.92	238.5
Result (%)	1%	18%	22%	17%	13%	6%	23%
Ranking	7	3	2	4	5	6	1
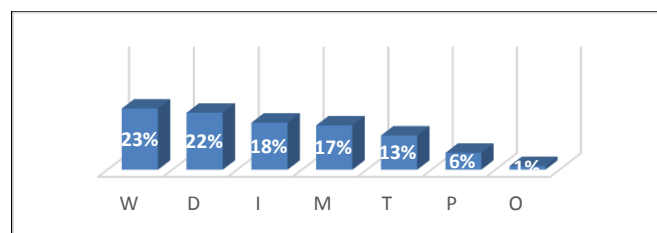
Figure 3. Ranking of Waste Assessment

3.4 Value Stream Mapping Tools

Value stream mapping tools are used to map the origin of waste in the production flow in more detail. The application of this method refers to the approach developed by ref. [25].

Table 4. Value stream mapping tools

| Waste/Structures	Weight	Mapping Tools						
		Process Activity Mapping (PAM)	Supply Chain Response Matrix (SCRM)	Production Variety Funnel (PVF)	Quality Filter Mapping (QFM)	Demand Amplification Mapping (DAM)	Decision Point Analysis (DPA)	Physical Structure (PS)
Overproductions	1.4	1.386	4.159		1.386	4.159	4.159	
Unnecessary Inventory	17.8	53.416	160.247	53.416		160.247	53.416	17.805
Product Defect	21.6	21.559			194.031			
Unnecessary Motion	16.8	150.842	16.760					
Transport	12.9	116.406						12.934
Inappropriate Processing	6.4	57.600		19.200	6.400		6.400	
Time Waiting	23.2	208.398	208.398	23.155		69.466	69.466	
TOTAL		609.607	389.564	95.771	201.817	233.872	133.440	30.739

Based on the ranking in Table 4, it is known that the most related tool processes activity mapping (PAM). Refer to [25], and the tools must be focused on the highest-ranking tools. Therefore, the researchers chose to use the highest tools to make detailed waste mapping; the tool processes activity mapping.

3.5 Process Activity Mapping (PAM)
PAM is used to map the process in more detail by categorizing each process. The purpose of this categorization is to separate and know what processes are included in value-added (VA), non-value added (NNVA), and non-value-added (NVA). The results of the PAM that have been made are then tabulated to facilitate the identification process—Figure 4. shows a tabulation of VA, NVA, and NNVA percentage. Based on Figure 4 it can also be seen the comparison between value added, non value added, and necessary but non value added activities. Value added activities have a percentage of 33%, non value added activities have a percentage of 20%, and necessary but non value added activities are 47%.
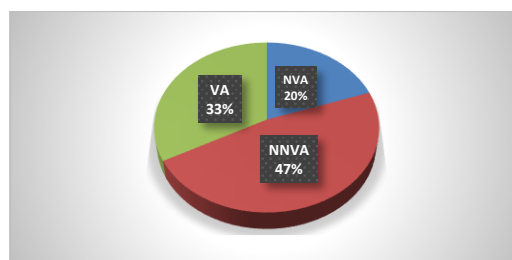
Figure 4. Percentage VA, NVA, dan NNVA

3.6 FMEA Analysis
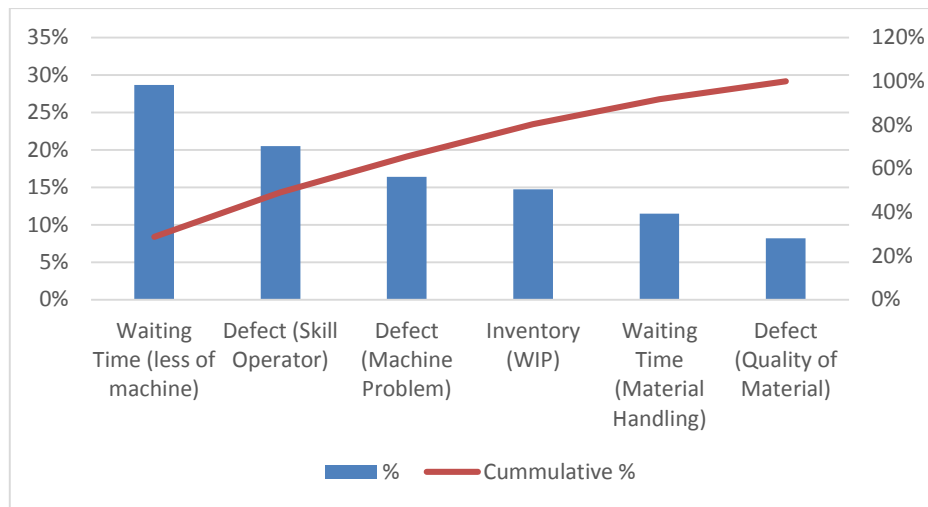
Figure 5. RPN score

Figure 5. shows the Pareto diagram of the failure mode or failure mode of the most critical. The first is waiting time due to lack of machine production, and the second defect is caused by inaccurate machine set-up and lack of skilled employees, third is a defect caused by poor machine maintenance. The fourth is the unnecessary Inventory of WIP during production due to lack of machine production.

3.7 Recommendations for Improvement
Recommendations for improvement are given to the four most significant RPN values resulting from the FMEA analysis. The proposed improvements are as follows:
1. add the machine;
    From the calculation of the RPN in the FMEA Table, it is known that the causes that influence the type of waste waiting time and unnecessary inventory are the same, namely the main cause is due to the lack of machine capacity in the production line. In addition, related to the analysis of takt time which has a cycle time that is greater than takt time, which means the process runs slower than it should. Therefore, additional capacity related to the number of machines needs to be done in order to reduce the existing queuing time and to overcome the amount of cycle time to takt time.
2. providing training or knowledge to workers for uniforming skills and work standards;
3. conducting directions and supervision, and;
4. perform maintenance activities in the form of preventive maintenance to avoid sudden machine trouble so that the time required for production is not long.
    Based on the results of the RPN score, the addition of machines has a dominating score and highest score of 70. As for the other recommendations, it has a low score which can support in overcoming the total waste problem in the company. Therefore, researchers provide recommendations that prioritize adding machines to the production process. In addition to reducing waste, these recommendations can also overcome the company's production targets that were not achieved due to high waiting times. By solving the problem of waiting time as a priority problem, the company's production target can be achieved and can achieve product demand.
    Meanwhile, the other 3 recommendations can be applied by the company to reduce overall waste so that the production process is more effective and efficient.

3.8 Feasibility Analysis
The implementation of the recommendations given is carried out, namely the production process's addition of machines. Then an analysis of the investment feasibility of the machine on the company's

finances. This analysis uses indicators in making alternative decisions to find the best alternative. The indicators used are the net present value, internal rate of return, and profitability index.

Table 5. Profit of add the machine alternative

New Machine Alternatives	1st year	2nd year	3rd year	4th year	5th year
Sales	IDR 16,036,539,626.95	IDR 17,663,221,326.17	IDR 19,463,138,800.42	IDR 21,405,767,073.44	IDR 23,567,831,106.09
Direct Production Costs	IDR 8,136,102,368.16	IDR 9,208,719,450.07	IDR 10,292,449,826.04	IDR 11,354,333,562.67	IDR 12,452,650,706.93
Profit	IDR 7,900,437,258.79	IDR 8,454,501,876.11	IDR 9,170,688,974.38	IDR 10,051,433,510.77	IDR 11,115,180,399.17
Indirect Production Costs	IDR 120,000,000.00	IDR 120,000,000.00	IDR 120,000,000.00	IDR 120,000,000.00	IDR 120,000,000.00
Depreciation	IDR 9,350,000.00	IDR 9,350,000.00	IDR 9,350,000.00	IDR 9,350,000.00	IDR 9,350,000.00
Cash Flow Before Tax	IDR 7,771,087,258.79	IDR 8,325,151,876.11	IDR 9,041,338,974.38	IDR 9,922,083,510.77	IDR 10,985,830,399.17
Tax	IDR 1,942,771,814.70	IDR 2,081,287,969.03	IDR 2,260,334,743.59	IDR 2,480,520,877.69	IDR 2,746,457,599.79
Net Cash Flow	IDR 5,828,315,444.09	IDR 6,243,863,907.08	IDR 6,781,004,230.78	IDR 7,441,562,633.08	IDR 8,239,372,799.37
Profit Margin	36.34%	35.35%	34.84%	34.76%	34.96%
BEP	IDR 8,265,452,368.16	IDR 9,338,069,450.07	IDR 10,421,799,826.04	IDR 11,483,683,562.67	IDR 12,582,000,706.93
BEP UNIT	1,822,189.68	1,871,506.62	1,898,822.25	1,902,085.85	1,894,549.33

It was based on the calculation of net cash flow using a minimum attracted rate of return (MARR) is 10% resulting in an NPV of IDR 34.8 Billion. It shows that the calculation result is positive, which shows that the investment in adding new machines to the production process is feasible. The feasibility of adding fixed machine investment according to the profitability index (PI) method to calculate the ratio between the value of future net cash flows with the present investment value. Based on the PI calculation above, it is 5.90 showing that the investment in adding a new machine is feasible. We also get a 24.21% internal rate of return (IRR). Based on an analysis of existing financial projections, it can be found that the investment plan for adding new machines is feasible. Based on Net Present Value (NPV), the addition of machines IDR 34.8 billion. The Profitability Index of adding a new machine is only 5.90. The internal recovery interest rate is 24.21%. Within five years, the company's alternative to adding new machines to reduce waste in the production process is feasible.

3.9 The Comparison before and after implementation
Table 5 shows the result of the comparison between the implementation before and after improvement. After making improvements, it is proven that the company's profit has increased by 58.29% from the previous.

Tabel 6. Comparison of before and after implementation

Aspect	Before	After
Unit/day	6125	10796
Sales for five years	IDR62,003,471,202.57	IDR98,136,497,933.08
Direct Production Cost for five years	IDR32,507,127,500.90	IDR51,444,255,913.87
Profit per 5 years	IDR29,496,343,701.67	IDR46,692,242,019.21

There are seven types of waste identified: waste product defects, waiting time, unnecessary inventory, unnecessary motion, overproduction, transportation, and inappropriate processing. Based on the value stream mapping and waste assessment model, the highest-ranking of waste is waiting time with a percentage of 23%, defect with a 22% discount, and inventory with a rate of 18%. The types of waste identified, as for the most influential factors in causing waste to occur for waiting time. The waste waiting time here is the lack of machines on the production line, resulting in a difference in processing time, which causes the waiting time of the material to enter the next process. Besides, waste waiting time is also due to the material handling transportation time between work stations.

The cause of product defects in the actuator is the presence of excessive pressure on the material, impulses, and the presence of material that falls during the production process due to the lack of ergonomics of production facilities and equipment used. Defects also occur caused by the operators are less thorough, less focused, and less skilled in doing the product production process. Based on the material, the problem is caused by inappropriate material. Unnecessary Inventory (WIP) The cause of unnecessary waste inventory (WIP) is the lack of machines and operators, thus causing WIP. Machines that have different cycle times between stations cause waiting time in the next process. Based on FMEA analysis, the improvement that has the highest rating is to increase the number of machines. Companies can reduce production time, so that company productivity increases and will get more benefit. The company can consider alternatives to adding new machines by proposing an appropriate financing scheme. After adding the machines, the company can improve the operating system by referring to the new machines purchased.

4. Conclusion

This paper presents a case study for implementing a lean manufacturing process in the electronic components company as a case study. This article proposed a data analysis framework using VSM, WRM, WAQ, VALSAT, and FMEA tools. The proposed guidance seems to help the company reduce the seven waste and increase unit production. The investment was analyzed using NPV, IRR, and profitability index. An investment feasibility analysis is carried out, which can be used to prove the feasibility of the proposed addition of new production machines. It is expected that the production process will be more effective and efficient. Therefore, future research is needed to analyze the seven existing wastes, increase company productivity, and improve company performance.

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