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Implementation of Waste Assessment Model (WAM) and Value Stream Map (VSM) to Reduce Waste in the Deflector Manufacturing Process

Sri Suci Yuniar*, Alfredo Monteiro**

*Faculty of Industrial Technology, National Institute of Technology, Bandung, Indonesia

Email:suciyuniar@itenas.ac.id

** *Faculty of Industrial Technology, National Institute of Technology, Bandung, Indonesia

Email:alfredo.9a.2014@gmail.com

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Abstract:

By minimizing waste during the production process, this research seeks tp improve the performance of the business. PT. SF is a company that manufactures spare parts, one of which is a deflector. The findings of the observations revealed that there was waste that reduced the effectiveness and efficiency of the production process, such as waiting, transportation, and inventory waste. Lean manufacturing implementation is used to reduce waste by utilizing value stream map analysis. The value stream map results revealed that the percentage of value added was 37.92% and the percentage of non-value added was 68.02%. Following that, the waste assessment model is used to identify the most prevalent waste. According to the waste assessment questionnaire results, the three types of waste that occur are waiting, inventory, and transportation. The creation of proposed enhancements such as standard operating procedures, contract agreements, and additional material handling. After making improvements, map activities with the future value stream map and compare the percentages of value added and non-value added to 62.72% and 37.28%, respectively.

Keywords ***—lean manufacturing, waste, value stream map, waste assessment model.***

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I. INTRODUCTION

Waste is defined as any work activity that does not value added during the process of converting inputs into outputs[1].Reducing waste will increase a company's productivity and quality, allowing it to survive in the midst of intense competition in Indonesia's manufacturing industry.PT.SF is a company that manufactures spare parts or parts based on consumer requests. A high level of demand from various consumers motivates businesses to improve the performance of their manufacturing systems.However, during the manufacturing process, there is still waste that has non-value added. Non-value-added activities can be found during the supply of raw materials from suppliers, the flow of materials from the beginning of the manufacturing process to the finished product, the process of repairing defective products, and so on.The Lean manufacturing method is oneo method for reducing waste because it works to increase the time efficiency of the manufacturing process by identifying waste.

Lean manufacturing is used to identify and eliminate waste and non-value adding activities through continuous improvement[2]. The basic concept of lean manufacturing is to eliminate and reduce waste on the production floor. Value Stream Mapping (VSM) is a tool in Lean manufacturing that is commonly used to map the entire flow of both information flow and material flow.VSM is used to map a product's production line, including material and information from each work station[3]. Currently, many studies have been conducted using lean manufacturing and VSM approaches, one of which is Azwir et al (2022) to minimize inefficient processes by implementing lean manufacturing through value stream analysis mapping to identify waste[4]. Based on the findings of the research, the types of waste that affect the level of efficiency are defect type waste and waiting type waste.

In addition to VSM, which is used to identify the type of waste, the Waste Assessment Model (WAM) is a method for locating waste and determining the relationship between the seven wastes[5]. WAM identifies waste and depicts the relationship between waste.Another study was conducted by Henny and Budiman (2018), who measured the level of lean performance in a shoe company using WAM to determine the relationship between the seven wastes and determining the ranking of waste to determine the most important waste to be repaired[6]. Furthermore, Sebayang and Sembiring (2017) use value stream analysis tools to increase efficiency and take a Lean manufacturing approach to reduce waste in the drinking water treatment process[7]. Sigalingging et al. (2014) used WAM and the Taguchi method to implement lean manufacturing at cigarette filter companies. This study determines the best method to solve the problems identified by the WAM calculations[8].

The research to be carried out will be developed from the research that has been done by Henny and Budiman (2018) [6]and adapted to the problems at PT.SF.The application of lean manufacturing will be carried out in this study to identify waste using VSM and WAM, which will then provide suggestions for improvements to minimize waste that occurs.

II. METHODOLOGY

The Value Stream Map (VSM) and the Waste Assessment Model (WAM) will be used in this study to analyze the waste generated during the deflector manufacturing process. The stages of this research begin with the identification of the manufacturing process using the Operation Process Chart (OPC) and VSM. The goal of VSM is to gain an overview of the time and each stage in the process activity so that it is clear which activities have value added and non-value added. VSM is used to determine material flow and manufacturing process information from raw materials to finished goods[9]. VSM can be used as the company's initial process for identifying and determining waste.

The Waste Assessment Model (WAM) is used in this research to provide output in the form of the root of the waste problem that occurs based on the Seven Waste Relationship, which is used to identify the type of waste during the production process. WAM consists of two steps: first, create a matrix to measure the strength of the relationship between seven different types of waste, from weakest to strongest. Then, combine the Waste Relationship Matrix (WRM) results with the questionnaire results obtained using the Waste Assessment Questionnaire (WAQ).WAQ is addressed to two company experts, namely divisional managers. The questionnaire [5]were based on several changes approved by the company. The weighted result of the Seven Waste Relationship is the Waste Assessment Matrix.

After obtaining the WRM value, the questionnaire data must be processed in WAQ. The final waste ranking is influenced by the combination of answers obtained. The final rank of waste that affects the company's production process is the output of WAQ. Table 1 shows the different types of waste and Fig 1 depicts the seven waste relationship.

Table 1. Seven Waste[5]

Waste	Abbreviation
Overproduction	O
Inventory	P
Defect	C
Motion	G
Process	P
Transportation	T
Waiting	M

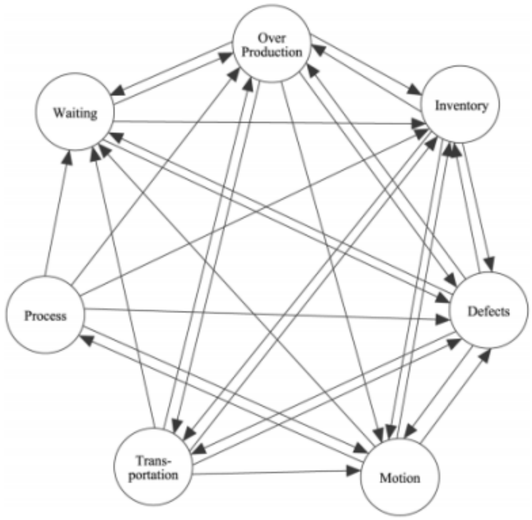

Fig 1. Seven Waste Relationship[5]

Waste that has the potential to affect other waste is denoted by a "_" sign between the initials of the waste, such as "O_P," which denotes the impact of overproduction on inventory.

III. RESULTS AND DISCUSSION

1. Waste Identification

The identification of waste in this study begins with a description of the flow of information and material flow in the production process of PT.SF using a value stream map (VSM). The flow of company information starting from incoming requests to product delivery to consumers is as follows.

1) The Marketing Division receives and explains to the customer the payment terms for ordering goods, one of which is the deflector.
2) To discuss product specifications, the Marketing Division will collaborate with the Engineering Division.
3) After conducting research and observations for the products to be manufactured, the Engineering division will coordinate with the Production division.
4) The Production Division will schedule production to meet the customer's desired target.
5) The Production Division will inspect the raw materials in the warehouse; if there are insufficient raw materials, the purchasing department will order the necessary raw materials.
6) The Production Division executes the production process in accordance with the request.
7) After finishing in production, deflectors are brought to the finished product warehouse to be re-checked by the QC section.
8) Deflectors that have passed the QC section's test will be delivered to customers at the time agreed upon with the Marketing division. There are two methods of delivery. If the quantity of goods is large, they will hire a vendor or a third party. However, if the quantity of goods is not too large, it will be sent using a PT. SF inventory car.

The following is an explanation of the material flow of the deflector production process at PT.SF:

1) Suppliers send raw materials to the production division. The QC section then inspects the raw materials for quality.
2) Using a gantry crane and a handlift truck, the inspected raw materials are then transferred to the raw material warehouse.
3) In addition, the raw materials required will be delivered to the production floor on a predetermined schedule.
4) Before the finishing process, the material in the form of SS 304 plate will go through a cutting process using a grinding machine, welding, drilling, and inspection.
5) A bending process is carried out outside of the PT. SF production floor; this process is carried out at an outside vendor and is completed in two to three days.
6) Completed and passed inspection deflectors will be transferred to the finished product warehouse to await delivery to the consumer in accordance with the predetermined location.

The following stage is an overall description of VSM. Fig 2 depicts the current VSM image.

According to Fig 2, the cycle time is 225.8 minutes and the lead time is 595.6 minutes. The percentage of operating time is 37.92%, with the remaining 62.08% being an activity that non-value added to the product and others. As a result, there is waste in the manufacturing process, resulting in high non-value added activities.

According to the findings, the wastes discovered include waiting, transportation, and inventory types. Waiting is a form of waste that is frequently encountered during the observation process. As a result, this demonstrates that there are processes that can still be improved and developed in order to reduce waste.

Furthermore, waste with the method of interviews and discussions with company-related parties. The following are the findings from waste interviews conducted on the company's production floor.

1) Waiting
PT. SF does not process raw material supply further in anticipation of receiving orders from customers in both large and small quantities. This has an impact when the order is frequently PT. SF has to wait a few days for raw materials, so there is a waiting process to carry out the production process from the day there is an order, causing the production process to be delayed.

2) Inventory
PT. SF uses a zero inventory system and a make-to-order production system, so raw materials are never kept in stock because raw materials are only purchased if a customer requests them. There is no storage warehouse at PT.SF, only a temporary storage area for raw materials and finished products. PT.SF does not produce semi-finished goods because it typically directs the manufacturing process until the product is completed. Due to changing consumer demands in both design and raw materials, PT. SF implements zero inventory in inventorymanagement.

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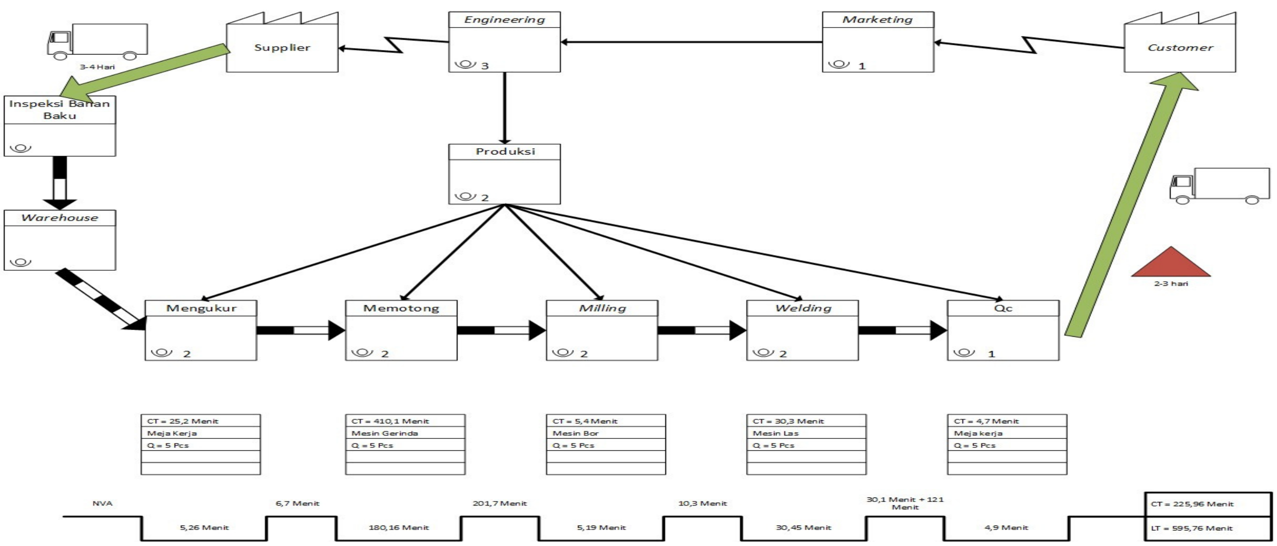

Fig 2. Value Stream Mapping (Current)

The following step is to determine the relationship between the seven wastes that can occur using the seven waste relationship. The waste relatedness calculation is carried out by consulting with several departments within the company, including the production manager, marketing manager, and engineering manager.

Table 2 shows the conversion value of the seven waste relationship, and Table 3 shows the results of the Seven Waste Relationship questionnaire.

Table 2. Conversion Value Of The Seven Waste Relationship[5]

Range	Relationship	Symbol
1-4	Unimportant	U
5-8	Ordinary Closeness	O
9-12	Important	I
13-16	Especially Important	E
17-20	Absolutely Important	A

Table 3. The Results Of The Seven Waste Relationship Questionnaire

Relationship	Question						Score Total	Symbol
	1	2	3	4	5	6		
O_I	2	0	0	0	1	0	3	U
O_T	0	0	0	0	1	2	3	U
O_M	0	0	2	2	1	2	7	O
I_O	2	0	0	0	1	2	5	O
I_C	0	0	2	0	1	0	3	U
I_T	2	2	2	0	1	0	7	O
C_O	2	0	2	0	1	2	7	O
C_T	0	0	2	0	1	0	3	U
C_M	2	0	0	0	1	0	3	U
G_I	0	0	0	0	2	0	2	U
G_M	2	0	4	0	1	0	7	O
T_O	0	1	0	0	1	0	2	U
T_I	2	0	2	0	1	0	5	O
T_M	4	2	4	1	1	2	14	E
P_O	2	0	0	0	1	0	3	U
P_I	0	0	0	0	2	0	2	U
P_M	2	0	2	0	1	2	7	O
M_O	0	1	0	1	1	0	3	U
M_I	2	0	0	1	1	2	6	O

According to the results of the seven waste relationship questionnaire in Table 3, the relationship between the largest waste is the relationship between transportation waste and the relationship between waiting waste, which is especially important. Create a waste relation matrix based on the results of the waste relationship. The waste relationship matrix in the deflector manufacturing process is as follows:

Table 4. Waste Relationship Matrix Results

F/T	O	I	C	G	T	P	M
O	A	U	X	X	U	X	O
I	O	A	U	X	O	X	X
C	O	X	A	X	U	X	U
G	X	U	X	A	X	X	O
T	U	O	X	X	A	X	E
P	U	U	X	X	X	A	O
M	U	O	X	X	X	X	A

The Waste Relationship Matrix (WRM) results are then simplified by converting them into percentage units. Table 4 is converted with the following values: A=10, E=8, I=6, O=4, U=2, X=0 [5]. The following is the result of converting the waste relationship matrix value from Table 5.

Table 5: Waste Matrix Value

F/T	O	I	C	G	T	P	M	Score	%
O	10	2	0	0	2	0	4	18	14.06
I	4	10	2	0	4	0	0	20	15.63
C	4	0	10	0	2	0	2	18	14.06
G	0	2	0	10	0	0	2	14	10.94
T	2	2	0	0	10	0	8	22	17.19
P	2	4	0	0	0	10	4	20	15.63
M	2	4	0	0	0	0	10	16	12.5
Score	24	24	12	10	18	10	30	128	100
%	18.75	18.75	9.38	7.81	14.06	7.81	23.44	100	

The "from" and "to" values of each type of waste can be seen in Table 5. The value of "largest from" is in "from transportation," which means that the majority of waste on the PT. SF production floor is caused by transportation activities. Meanwhile, the value of "to the greatest extent" is "waste waiting," indicating that the greatest extent has an impact on the type of waste "waiting".

The initial WAQ is then evaluated based on the type of questionnaire questions derived from the waste value in WRM. The questionnaire consists of 68 questions that have been adjusted to the company's terms and agreements, after which the waste rating is calculated. The following are the steps for calculating the waste rating.

1) Based on the WRM, enter the weight of each questionnaire question.
2) Determine the total frequency of each type of waste (N_j) and assign a score (C_j).
3) Determine the initial indicator (I_o) and final value of each waste ($I_{o\ Final}$)
4) To determine the rank of each waste, enter the probability of influence between wastes (P_j).

Table 6. Waste Rating Calculation

	O	P	C	G	T	P	M
I_o	0,10	0,12	0,18	0,30	0,13	0,05	0,20
P_j	263,67	292,97	131,84	85,45	241,70	122,07	292,97
$I_{o\ Final}$	27,43	35,97	24,11	26,02	32,09	6,23	57,38
%	13,11	17,19	11,52	12,44	15,34	2,98	27,43
Rank	4	2	6	5	3	7	1

An example of how to calculate the inventory waste score (I_o):

$$I_o\text{Inventory (P)} = \frac{cj}{Cj} x \frac{nj}{Nj} \quad (1)$$

$$= \frac{6.78975}{36.5} x \frac{33}{50}$$

$$= 0.12277$$

Calculating the Inventory $P_j$factor:

InventoryP_j*factor*= Inventory score "from" x Inventory score "to" (2)

= 15,63 x 18,75= 292,97

a calculation of the final result ($I_{o\ Final}$) type of inventory waste:

$$\text{Inventory } I_{o\text{Final}} = I_o \text{ x} P_j \quad (3)$$

$$= 0,13 \text{ x } 292,97$$

$$= 35,97$$

Example of calculating the percentage of wasted inventory :

$$\text{Inventory waste (\%)} = \frac{Io\ Final}{Io\ Final\ Total} \text{x100} \quad (4)$$

$$= \frac{35,97}{209,23} x\ 100 = 17,19\ \%$$

According to Table 6, the three types of critical waste in the company are "waiting," with a percentage of 27.42%, "inventory," with a percentage of 17.19%, and "transportation," with a percentage of 15.33%. This type of "waiting" waste occurs as a result of the time it takes to transition from one process to the next. Furthermore, the QC division was understaffed, with only one employee, so other divisions had to wait for the QC division's work to be completed.This type of "inventory" waste occurs when items accumulate when the production process begins; this is caused by raw materials that are not directly processed due to the limited number of employees in the production department, resulting in some materials piling up and waiting to be worked on. This type of "transport" waste occurs as a result of insufficient material handling and issues with the layout of the production floor.

2. Improvement Strategy

Based on the results of the calculation of the depiction of the production flow using the value stream map and a waste assessment model, the company's proposed improvements are as follows.

1) Make a contract with the delivery vendor.

According to the current Value stream mapping, when an order is received, the company must wait 3-4 days for the raw materials to arrive and begin the production process. Because PT. SF manufactures to order, it does not keep raw materials on hand. This is done in order for the company to reduce inventory costs and defects that occur when goods are stored. Furthermore, the company lacks a raw material warehouse, preventing it from stockpiling raw materials.

The following aspect that can be improved is delivery after the product has been completed. According to the current Value stream mapping, the waiting time for the product to be sent is 1-2 days. This can be reduced by agreeing with the delivery vendor to pick up goods to be sent when the product is finished in production. As a result, it can reduce the processing time waiting for delivery to 0-1 days and lower the percentage of non-value added.

2) Implementation of 5S in PT.SF

The lack of 5S implementation at the company impedes the operator's work and reduces the company's production efficiency. The 5S method is explained further below.

- Seiri/Sort
- Identify and delete the desired object in the workspace.
- Seiton/ Set In Order
  Arranging goods in specific locations to facilitate storage and retrieval.
- Shine/ Seiso
  Employees work together to keep the workplace clean, such as by sharing the employee's picket schedule in the workplace.
- Seiketsu/ Standardize
  Correctly implement 5S and practice skills in creating and maintaining visual controls.
- Shitsuke/Sustain
  Ensuring that all 5S standards, such as conducting company audits by managers or designing performance measurement formulas, are carried out properly and correctly.

3) Adding Material Handling Facilities to the Production Floor

One of the issues that arises in the production process at PT.SF is the type of waste known as "waiting." This is because the company's material handling capabilities are limited. PT. SF has two types of material handling equipment: a handlift truck and a gantry crane. Both material handling systems are only used for transferring raw materials to the production floor. When the production process reaches the finished product, it is manually moved to the warehouse.As a result, it has an effect on the length of the transfer process, particularly between the cutting and milling processes, with a transfer time of 180.16 minutes. After consulting with the engineering manager, the company determined that it requires 1-2 pieces of material handling equipment to aid in the process of moving from one work station to another. Implementing material handling in the cutting process into the milling process can reduce non-value added time from 180.16 minutes to 87.2 minutes.

4) Management and Production System Improvement

This enhancement aims to reduce "waiting" waste when the product is subjected to a final inspection before being shipped to the consumer/customer. It is proposed in this improvement to create SOP: Procedure for Inspection of Production Results. Fig 4 depicts the standard operating procedure for inspecting production results.

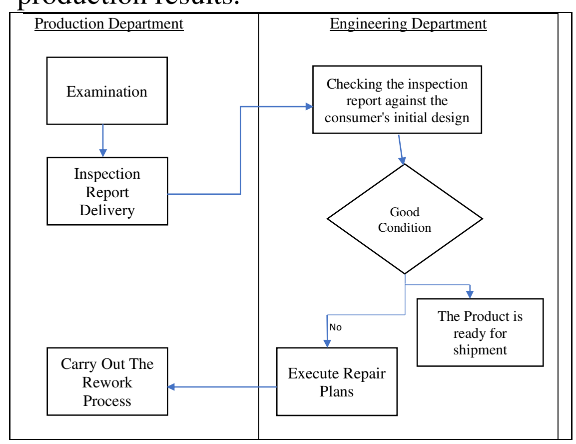

Fig 4. SOP for Production Results Inspection

3. Value Stream Mapping (Future)

The previously described proposed improvements are implemented over the course of approximately one month. The implementation yielded a value stream mapping (future). Fig 5 reflects the enhancements made by depicting it using future value stream mapping.

Based on the results of implementing the proposed improvements, the calculation of value added and non-value added activities is summarized below.

Table 7. Summarized of Value Added and Non Value Added Percentage

VA (Minute)	%	NVA (Minute)	%
225,96	62,72%	134,3	37,28%

The time difference between value added, lead time, and non-value added on current and future dates is shown in Table 8 below.

Table 8. Current and Future time comparison

	Current	*Future*
Lead time(Menit)	595,76	360,26
Value Added Activity (Menit)	225,96	225,96
Non ValueAdded Activity (menit)	396,8	134,3

According to Table 8, the company can reduce non-value added activities by 66.15% by making suggestions for improvements. The proposed

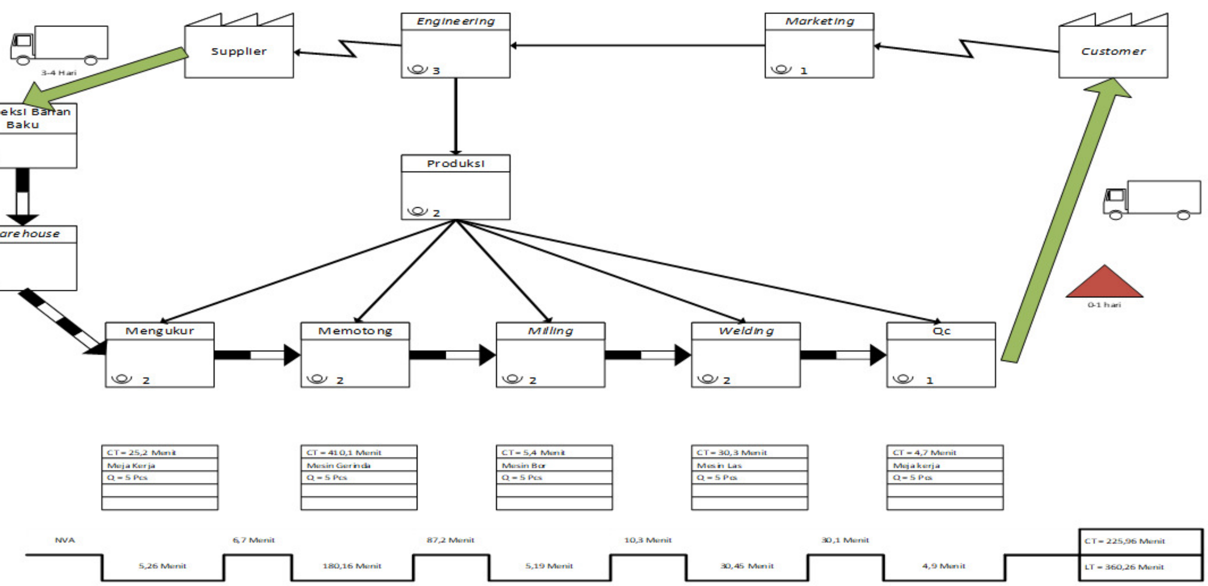

Fig 5. Value Stream Mapping (Future)

improvements can be implemented continuously, and the remaining non-value added activities can be re-analyzed in the hope of reducing non-value added activities and thus improving the company's performance.

IV. CONCLUSION

The study's conclusion is that PT should implement the proposal designed to reduce waste in the manufacturing process. SF can reduce non-value added activities from 62.08% to 37.28%. The proposed improvement plan is to create a standard operating procedure for product inspection and to include material handling.

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