Reducing Waste in Manufacturing Industry using Cost Integrated Value Stream Mapping Approach

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Abstract. In recent years, every manufacturing industry has tried to eliminate various wastes in its operations. The effect of wastes will have a direct impact on increasing costs. Therefore, the cost approach is integrated into the value stream mapping to obtain an illustration of the cost losses incurred. This paper describes how to apply integrated value stream mapping with the cost approach. Finally, this approach is considered effective in mapping the amount of cost losses incurred due to the wastes that occur along the value stream.

Keywords: waste, integration, value stream mapping, cost approach

1. Introduction
In the manufacturing industry, a company's productivity can be seen from its ability to carry out the production process effectively and efficiently. Since the mass production system is widely introduced, all manufacturers or manufacturing industries strive to produce products that have a high degree of conformance to standards (high level of homogeneity), so that they are free from zero defect. By being aware of all these things, the company is demanded more so that it can meet customer expectations and can further increase productivity by reducing existing waste.

With a view to avoiding waste and inefficiency so that the cost of production per unit will be low which in turn will make product prices more competitive. From the customer's point of view, waste is any activity that the customer does not want to pay, if they know that it happened. Today in Indonesia many manufacturing industries have applied the concept of lean, which strives continuously to transform all business activities / processes into something that is beneficial to customers [1]. Lean manufacturing is a production practice that considers all the expenditure of available resources to obtain economic value without waste [2]. The lean approach focuses on efficiency without reducing the effectiveness of the process including increasing value-added operations, reducing waste, and meeting customer expectations [3]. The lean production concept introduces a very effective and efficient production system, which uses less resources to produce higher quality at a lower cost as a result [1], [4].

One tool that can be used to describe the entire business process in implementing lean manufacturing is Value Stream Mapping (VSM) [2], [3], [4], [5], [6], [7] To further optimize the retrieval then the VSM can be integrated with cost analysis using the concept of Activity Based Costing (ABC) in the value stream [8], [9]. The basic concept of ABC is that a product will consume activities, activities consume resources, and all of these resources require costs. Therefore, this paper comprehensively discusses the application of VSM integrated with the perspective of ABC concepts.
2. Methods

2.1. Value Stream Mapping Approach
Value Stream Mapping (VSM) is a tool that combines lean manufacturing concepts and techniques to visualize the entire flow of material and information needed when the product runs throughout the manufacturing process [5], [6]. The material flow path of a product is traced back from the final operation and its journey to the raw material storage location. VSM helps detect waste and its source in the manufacturing process. VSM was originally developed in 1995 as a rationale for the collection and use of a set of tools that can help researchers or practitioners identify waste along the value stream and, therefore, need to find the right way to eliminate it. This tool is able to identify activities that are value added and non-value added in the manufacturing industry, making it easier to find the root causes of problems in the process [7]. VSM is also useful so that improvements made can be more focused on the overall waste in the system. VSM makes it easier for company management to make improvements in the manufacturing process.

VSM consists of two types, including; a) Current state map is the configuration of the current production value stream; b) Future state map is a blueprint for lean transformation desired in the future. The steps in making VSM, including [5]; a) First, determine the value stream that needs to be improved; b) Understand how the current process is as a baseline; c) Design a flow that fits the lean principle as a vision for the future; d) Develop a detailed implementation plan so that objectives can be achieved; e) Implementation and check whether the VSM goals are achieved.

2.2. Cost Integrated Value Stream Mapping
The concept of cost integrated value streams is to map and measure the costs contained in value streams, which means that cost integrated value stream mapping is a combination of cost aspects and value stream maps. Costs calculated in the form of value added costs and non value added costs. Value added costs are generated by calculating the direct costs of each process or activity while non value added costs are generated by calculating the holding cost per inventory [8], [9].

According to Garrison et.al. [10], activity based costing is a costing method designed to provide manager with cost information for strategic decisions and other decisions that may affect capacity as well as fixed costs. Basically the ABC principle is that resources are allocated to activities and then activities are allocated to cost objects based on their use. There are several advantages of ABC systems in determining product costs, namely [11]; a) More realistic product costs, especially in the manufacturing industry; b) More and more overhead costs can be traced to the product; c) ABC states that activities cause costs, not products, and products consume activities; d) ABC helps reduce costs (cost reduction), and identifies non-value added activities.

This study was conducted at one of the national manufacturing companies that produce valves. The problem that occurs is the delay in production results and the mismatch of production output results with the specified production targets. The types of products discussed further in this study are gate valve types, because they have the highest number of daily requests. Table 1 shows demand data for several types of products in January 2019. This research was conducted by taking data directly obtained from the results of direct observation and interviews. Data collected in the form of production flow, cycle time, production amount, valve reject, SIPOC and costs incurred based on the ABC concept. The costs collected include; machine usage costs, material usage costs, labor costs, and inventory holding costs. Retrieval of time data using stop-watch with repetition of 30 observations for each process. The cycle time obtained is tested for data adequacy. If the data is sufficient, a data uniformity test can be done by determining the upper control limit (UCL) and the lower control limit (LCL). If the data is in the range of LCL and UCL then data normality tests can be performed.

The next step is to create a current integrated cost stream value map based on the identified value added and non value added costs. The next stage, an analysis is carried out to identify existing waste in the current state map and then make an analysis of improvements based on the causes of waste using the 5W & 1H method. The steps that can be used to implement a cost integrated value stream are
basically the same as creating a value stream mapping in general, but a cost analysis is added by integrating the cost-line into the VSM along with the time-line. To calculate the total value added cost (TVAC) and the total value added non cost (TVNAC), you can use the following formula [8], [9]:

\[
\text{Value added activity cost} = m_i + CT_i \left( \frac{M_i + L_i}{3600} \right)
\]

Non value added activity cost = \( h_i \times I_i \) \( \text{TVAC} = \sum_{i=1}^{n} m_i + CT_i \left( \frac{M_i + L_i}{3600} \right) \)

\( \text{TVNAC} = \sum_{i=1}^{n+1} h_i \times I_i \)

Where; CT = cycle time, M = rate machine per hour; L = rate hourly operator; m = material costs (\( m_i = 0 \), if there is no additional material in the activity); I = inventory (for raw materials, WIP, finished goods); h = holding cost per inventory.

Table 1. Data of demand

| No. | Type of product | Monthly demand for January | Daily demand |
|-----|-----------------|---------------------------|-------------|
| 1   | Gate valve      | 441                       | 20          |
| 2   | Check valve     | 410                       | 19          |
| 3   | Globe valve     | 272                       | 13          |
| 4   | Ball valve      | 441                       | 20          |
| 5   | Butterfly valve | 118                       | 6           |

3. Results and Discussion

The valve manufacturing process from the beginning to the shipment consists of casting, machining, assembling, pressure testing, painting, and finally a final inspection, as shown in Figure 1. The casting process has several sub-processes, including; injection wax, dipping, lost wax, melting, sintering, pouring, and blasting. The machining process consists of several sub-processes such as; turning, drilling, welding and lapping. Then each process is carried out a time study to obtain the standard time and setup time, as shown in Table 2 and Table 3. Table 4, respectively, shows the cost of using the machine per hour for each process or sub-process.

Figure 1. Valve production process

Table 2. Standard time measurement results*

| No. | Process or sub-process | Standard time (seconds) | No. | Process or sub-process | Standard time (seconds) |
|-----|------------------------|-------------------------|-----|------------------------|-------------------------|
| 1   | Injection Wax          | 855.28                  | 9   | Drilling               | 623.48                  |
| 2   | Dipping                | 755.52                  | 10  | Welding                | 686.73                  |
| 3   | Lost wax               | 870.47                  | 11  | Lapping                | 371.98                  |
| 4   | Sintering              | 928.37                  | 12  | Assembling             | 1944.16                 |
| 5   | Melting                | 1854.64                 | 13  | Pressure testing       | 915.36                  |
| 6   | Pouring                | 753.34                  | 14  | Painting               | 1106.75                 |
| 7   | Blasting               | 809.45                  | 15  | Final inspection       | 16.73                   |
| 8   | Turning                | 3147.42                 | 16  | Shipping               | 148.29                  |

*) Each repetition time measurement 30 times per process or sub-process. Then the adjustment factor is considered using the Westinghouse method.
Table 3. Machine setup time

| Process         | Production equipment          | Setup time (minute) |
|-----------------|------------------------------|---------------------|
| Casting         | Auto wax injection           | 10                  |
|                 | electric auto clave          | 5                   |
|                 | Electric Furnace HT          | 15                  |
|                 | Induction Furnace            | 15                  |
|                 | Shot blasting hanger         | 5                   |
|                 | CNC Lathe                    | 15                  |
| Machining       | Radial drilling              | 10                  |
|                 | Welding SMAW                 | 2                   |
|                 | Lapping Polish               | 5                   |
| Pressure testing| Hydrostatic Pressure         | 10                  |
| Painting        | Spray Gun                    | 5                   |

Table 4. Machine usage costs per hour

| Process         | Production equipment          | Total Rate per hour |
|-----------------|------------------------------|---------------------|
| Casting         | Auto wax injection           | IDR 42,551.12       |
|                 | Dipping (Manual with tools)  | IDR 0.00            |
|                 | Electric auto clave          | IDR 12,471.88      |
|                 | Electric Furnace HT          | IDR 264,110.40     |
|                 | Induction Furnace            | IDR 190,746.40     |
|                 | Pouring (Manual with tools)  | IDR 0.00            |
|                 | Shot blasting hanger         | IDR 50,621.16      |
|                 | Lathe                        | IDR 24,210.12      |
|                 | Radial drilling              | IDR 3,228.02       |
| Machining       | Welding SMAW                 | IDR 1,320.55       |
|                 | Lapping Polish               | IDR 16,140.08      |
| Assembling      | Manual                       | IDR 0.00            |
| Pressure Testing| Hydrostatic Pressure         | IDR 44,018.40      |
| Painting        | Spray Gun                    | IDR 322.80         |
| Final Inspection| Manual                       | IDR 0.00            |
| Shipping        | Manual                       | IDR 0.00            |

To count labor hour rate data from the district minimum wage is needed, work hours data, and data on the number of workdays per month. The following is an example calculation labor hour rate; assumption, the district minimum wage = Rp. 3,555,834. ; working days = 22 days; working hours = 8 Jam, then labor hour rate = 3,555,834 : (22/8) = IDR. 20,203.60. Meanwhile, Table 5 shows the amount of material costs required to manufacture valve products.

Table 5. Material costs

| Material        | Unit | Quantity | Price per unit (IDR) | Total Price (IDR) |
|-----------------|------|----------|----------------------|-------------------|
| HS25051000      | kg   | 4        | 4,000                | 16,000            |
| DCMT            | pcs  | 1        | 5,000                | 5,000             |
| RD260           | stem | 1        | 500                  | 500               |
| Paint           | liter| 2        | 1,500                | 3,000             |
| Scrap iron      | kg   | 1        | 4,500                | 4,500             |
| Sandpaper       | sheet| 2        | 1,000                | 2,000             |

Determination of holding costs is based on average inventory and is expressed in rupiah currency. Costs included in holding costs include; warehouse usage / rental fees, maintenance fees, insurance fees, capital fees, obsolescence fees and taxes from inventory. Table 6 shows the holding costs per inventory for WIP that occur in each process or sub-process.
Current vs Future Cost Integrated Value Stream Mapping

Cost value added and non-value added can be calculated using Eq (1) and Eq (2). Example calculation total value added cost to the process injection wax are as follows:

\[ \sum_{i=1}^{n} 16,000 \times \left( \frac{4251.12 + 6061.08}{3600} \right) = IDR. \ 40,508.97 \]

Example calculation total non value added cost on the process injection wax are as follows:

\[ \sum_{i=1}^{n+1} 110 \times 103.16 = IDR. \ 11,347.60 \]

Table 6. Holding cost per inventory

| No. | Inventory                  | Holding Cost | No. | Inventory                  | Holding Cost |
|-----|---------------------------|--------------|-----|---------------------------|--------------|
| 1   | Raw material warehouse    | IDR 103.16   | 9   | WIP turning               | IDR 103.33   |
| 2   | WIP injection wax         | IDR 103.16   | 10  | WIP radial drilling       | IDR 103.33   |
| 3   | WIP dipping               | IDR 103.16   | 11  | WIP welding               | IDR 103.33   |
| 4   | WIP lost wax              | IDR 103.16   | 12  | WIP lapping               | IDR 103.33   |
| 5   | WIP sintering             | IDR 103.16   | 13  | WIP assembling            | IDR 103.37   |
| 6   | WIP melting               | IDR 103.16   | 14  | WIP pressure testing      | IDR 103.37   |
| 7   | WIP pouring               | IDR 103.16   | 15  | WIP painting              | IDR 103.37   |
| 8   | WIP blasting              | IDR 103.16   | 16  | Finished good             | IDR 103.37   |

By calculating using this formula as mentioned earlier, we obtain the total value added cost and the total non value added cost for entire process, can be seen respectively in Table 7 and Table 8.

Table 7. Value added cost

| No. | Process       | Value Added Cost |
|-----|---------------|------------------|
| 1   | Injection Wax | IDR 40,508.97    |
| 2   | Dipping       | IDR 4,240.06     |
| 3   | Lost Wax      | IDR 12,851.30    |
| 4   | Sintering     | IDR 83,739.28    |
| 5   | Melting       | IDR 123,587.05   |
| 6   | Pouring       | IDR 4,227.83     |
| 7   | Blasting      | IDR 20,468.28    |
| 8   | Turning       | IDR 79,157.52    |
| 9   | Drilling      | IDR 4,058.09     |
| 10  | Welding       | IDR 8,459.92     |
| 11  | Lapping       | IDR 5,755.31     |
| 12  | Assembling    | IDR 21,821.68    |
| 13  | Pressure testing | IDR 22,091.83 | |
| 14  | Painting      | IDR 6,310.44     |
| 15  | Final inspection | IDR 93.89     |
| 16  | Shipping      | IDR 832.22       |

Total IDR 438,203.67

Table 8. Non-value added cost

| No. | Inventory                               | Non Value Added Cost |
|-----|-----------------------------------------|----------------------|
| 1   | Holding Cost Raw Material Warehouse     | IDR 11,347.60       |
| 2   | Holding Cost Inventory WIP Dipping      | IDR 2,884.28        |
| 3   | Holding Cost Inventory WIP Lost Wax     | IDR 1,957.59        |
| 4   | Holding Cost Inventory WIP Blasting     | IDR 2,273.26        |
| 5   | Holding Cost Inventory WIP Drilling     | IDR 1,549.95        |
| 6   | Holding Cost Inventory WIP Pressure Testing | IDR 2,997.73  |
| 7   | Holding Cost Inventory Finished Good    | IDR 1,860.66        |

Total IDR 24,871.07
Plotting the current cost integrated value stream map can be done based on the calculation of the value added cost and non value added cost. As discussed earlier, a cost integrated value stream map is created by adding a cost analysis, which integrates the cost line into the VSM as illustrated in Figure 2. After being analyzed using the 5W & 1H methods, the future cost integrated value stream map is designed (see Figure 3). Some recommended implementation plans include; for example, shipping raw materials that were done once a week changed to 2 weeks. Delivery of raw materials is intended to prevent excess accumulation of inventory of raw material; combining several processes such as combining drilling and welding processes; apply the Kanban system between shipping and final inspection, between painting and pressure testing, and between turning and blasting, as well as between sintering and lost wax. After comparing between current and future, the results of improvement can be seen in Table 9.

**Table 9.** Comparison results between current state and future state

| Metric                      | Baseline before | Baseline after | Reduce                  |
|-----------------------------|-----------------|----------------|-------------------------|
| Total value stream inventory| 241 pcs/day     | 55 pcs/day     | 186 pcs/day             |
| Total processing lead time  | 12.05 days      | 2.75 days      | 9.3 days                |
| Total processing time       | 15814.62 seconds/pc | 15634.62 seconds/pc | 180 seconds   |
| Total non value added cost  | IDR 24,871.07/pc | IDR 7,178.83/pc | IDR 19,179.27/pc       |
| Uptime                      | 81.50%          | 81.50%         | 0% (No different)       |
| Travel distance             | 260 meters      | 190 meters     | 70 meters               |

![Figure 2. Current cost integrated value stream map](image-url)
4. Conclusion

The cost approach integrated into the value stream map can help identify costs and activities that can be minimized or eliminated. This approach is considered more effective in helping management understand the activities or processes that trigger costs, as well as focus on continuous improvement. Further research is suggested to consider more accurate overhead costs.

5. References

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