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To cite this article: Wilson Kosasih *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **847** 012061

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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.



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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]:

$$\text{Value added activity cost} = m_i + CT_i \left(\frac{M_i + L_i}{3600} \right) \tag{1}$$

$$\text{Non value added activity cost} = h_i \times I_i \tag{2}$$

$$\text{TVAC} = \sum_{i=1}^n m_i + CT_i \left(\frac{M_i + L_i}{3600} \right) \tag{3}$$

$$\text{TVNAC} = \sum_{i=1}^{n+1} h_i \times I_i \tag{4}$$

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
Machining	CNC Lathe	15
	Radial drilling	10
	Welding SMAW	2
Pressure testing	Lapping Polish	5
	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
Machining	Lathe	IDR 24,210.12
	Radial drilling	IDR 3,228.02
	Welding SMAW	IDR 1,320.55
Assembling	Lapping Polish	IDR 16,140.08
	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 = $3,555,834 : (22/8) = \text{IDR. } 20,203.60$. 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:

$$\sum_{i=1}^n 16,000 + 855.28 \left(\frac{42551.12+60610.8}{3600} \right) = \text{IDR. } 40,508.97$$

Example calculation total non value added cost on the process injection wax are as follows:
 $\sum_{i=1}^{n+1} 110 \times 103.16 = \text{IDR. } 11,347.60$

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 is changed to 2 weeks. Delivery of raw materials is intended to prevent excessive 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 5,673.8/pc	IDR 7,178.83/pc
Total value added cost	IDR 438.203,67/pc	IDR 431.024,84/pc	IDR 19,197.27/pc
Uptime	81.50%	81.50%	0 (No different)
Travel distance	260 meters	190 meters	70 meters

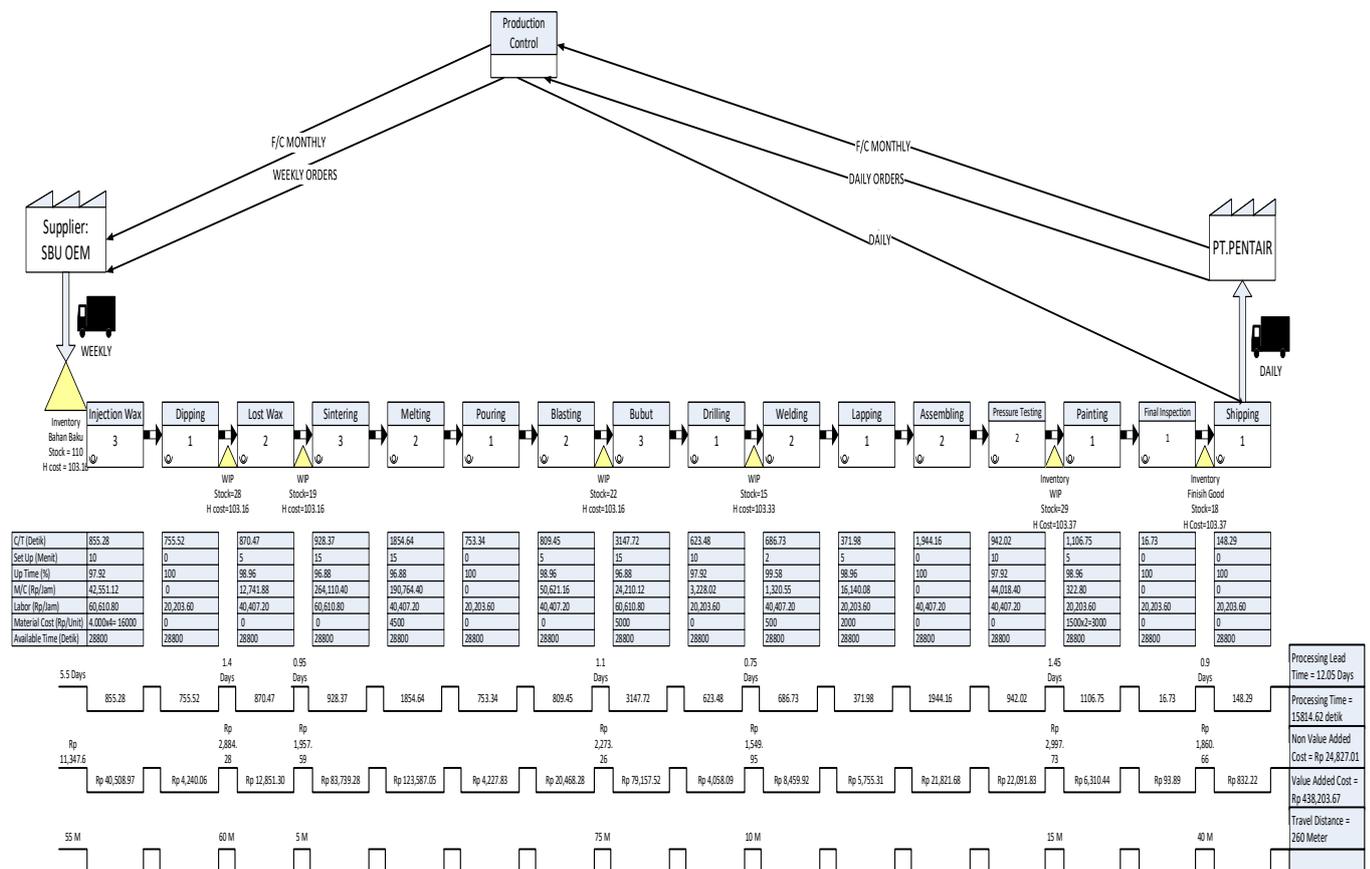


Figure 2. Current cost integrated value stream map

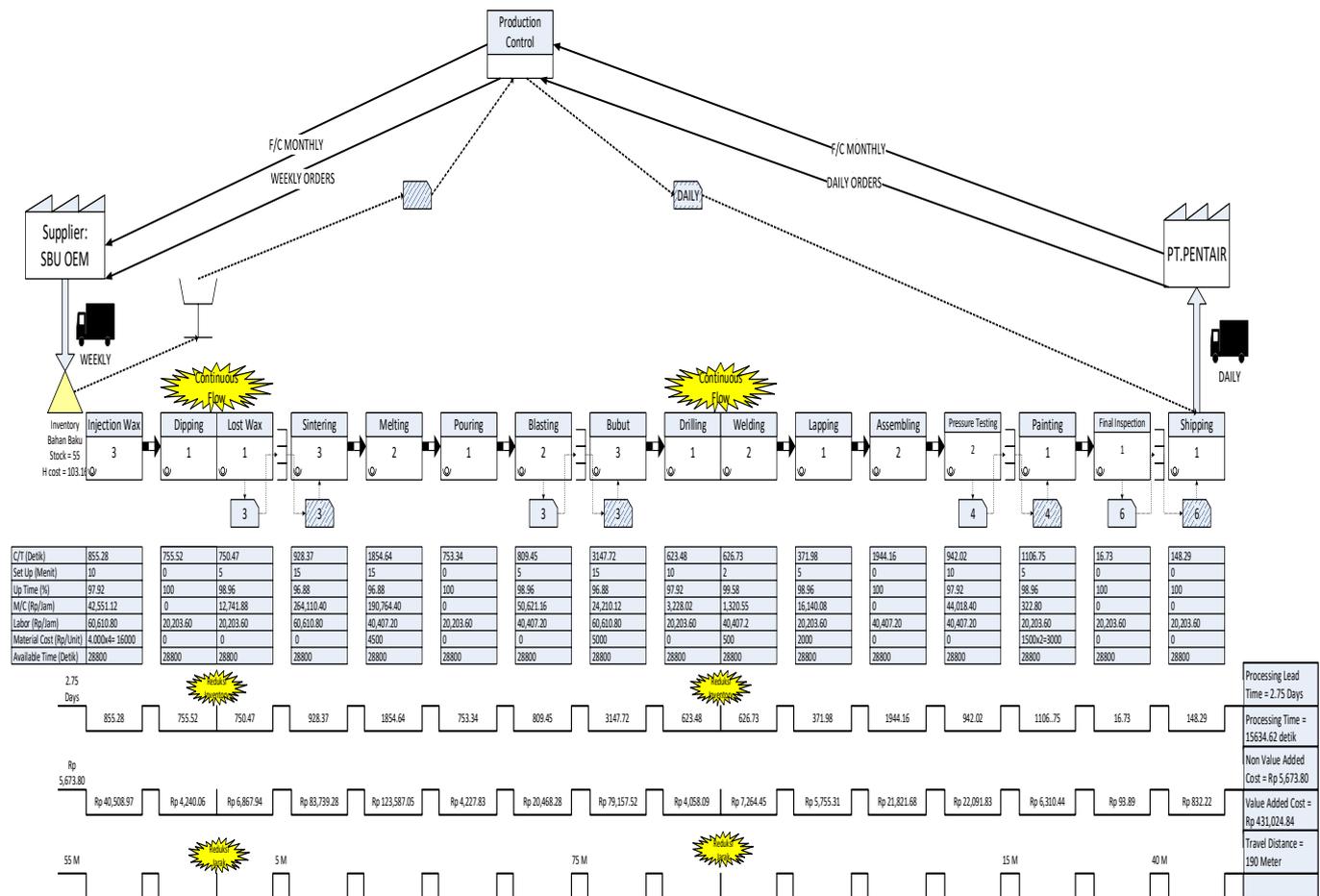


Figure 3. Future cost integrated value stream map

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

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