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Applying value stream mapping tools and kanban system for waste identification and reduction (case study: a basic chemical company)

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Abstract. This paper describes how to apply both of value stream mapping tools and kanban system for identifying and reducing wastes that happened on shop-floor. This research was conducted at a basic chemical company which produces the thinner. This study aims to reduce even to eliminate the types of waste that occur on the production line of jerrycan product type. The plot of VSM is used to picture the entire of value stream. The value stream mapping tools are used to analyze the certain waste after it has been figured out by using waste assessment model. Hence in this study two selected tools were applied and discussed further, i.e. process activity mapping, and supply chain response matrix. The Current-VSM shown that value-added time of 472.33 s compared with total lead time of 132,568.76 s, consequently obtained process cycle efficiency (PCE) approximately 0.36%. Kanban system will be implemented to eliminate waste of unnecessary inventory throughout the value stream. At last, the result of improvements shown that value of PCE probably will increase by 67.25%, non-value activity will reduce 6.74%, as well as order fulfillment time of the whole process will be 13 days with 3.59 days of physical stock.
Keywords: waste, value stream mapping tools, kanban system.

1. Introduction

An old paradigm states that "creating a quality product, expensive." The era of mass customization, all manufacturing industry players strive to produce products that have a high level of conformity to the standards but still able to fulfill the speed of customer demand. If Stalk & Hout's proposition [1] is correct, that time is a powerful source of competitive advantage, then focus for improvement in the process must include time-based method. Lately, many manufacturing industries in Indonesia have tried to apply the lean concept in transforming their business.

The word "lean" was first introduced by Krafcik [2] to explain the Toyota Production System (TPS). Lean is a set of tools or a set of methods or systems to reduce the time between customer orders and delivery of goods by eliminating waste that does not add value. Five lean principles as an implementation framework in an organization, among others; 1) Value: identify the value from customers perspective, 2) Value stream: identify "specific activities required to design, order, and provide a specific product, from concept to launch, order to delivery, and raw materials into the hands of the customer." 3) Flow: "progressive achievement of tasks along the stream so that the product goes from design to launch, order to delivery and raw materials into the hands of the customer with no stoppages, scrap or backflows." 4) Pull: only make what is pulled by the customer signal of need 5) Perfection: by continually removing successive waste from value stream [3].

The lean production concept introduces a highly effective and efficient production system, which uses smaller resources to produce higher quality at lower costs as a result. Lean production is also known as Just-in-Time (JIT) [4]. Management based on lean production principles enables a company to obtain higher levels of efficiency, competitiveness with the lowest costs, high levels of productivity, speed of delivery, minimum inventory levels, and optimal quality [5].

Lean manufacturing means [3]"... a way to do more and more with less and less ...." Based on the TPS, lean manufacturing is a systematic approach to identifying and eliminating waste of non-value added activities, through continuous improvement activities and optimizing value stream [6]. The application of lean manufacturing will create a synchronized production that is pulled according to the "pulse" of customer demand. The lean approach focuses on efficiency without reducing the effectiveness of processes including increasing value-added operations, reducing waste, and meeting customer needs [7]. In manufacturing industry, there are seven types of waste, among others [6,8,9,10]; a) overproduction, b) defects, c) waiting, d) unnecessary inventory, e) inappropriate processing, f) excessive transportation, g) unnecessary motion [3].

This paper discusses an application of value stream mapping tools and kanban system to identify and reduce the wastes. This research was conducted on a basic chemical manufacturing company. First of all, we need to figure out which type of waste is most dominant in influencing the system or the other types of waste. In discussion section, all activities both value adding and non-value adding would be visualized to compare between current state and future state so that improvements could be designed well.

2. Methods

2.1. The value stream mapping tools
Value Stream Mapping (VSM) is used as an underlying rationale by using a set of tools that can help in identifying waste along the value stream. VSM visualizes the process or activity in the form of a flowchart that is useful for mapping activities that provide added value in realizing lean transformation [4,11]. VSM tools is able to identify value added and non-value added activities in the manufacturing industry, making it easier to find the roots of problems in the entire processes. VSM maps not only the flow of material, but also the flow of information that signifies and controls the flow of material. The path of material flow from a product is traced back from the last operation and its journey to the location of raw material storage as a starting point in implementing lean manufacturing. In its development, the typology of seven new tools [12,13,14,15,16] was presented to further analyze the seven types of waste, including: a) process activity mapping (PAM); b) supply chain response matrix (SCRM); c) production variety funnel (PVF); d) quality filter mapping (QFM); e) demand amplification mapping (DAM); f) decision point analysis (DPA); g) physical structure (PS) as shown in Table 1. Further details of the selection process can be found in Hines and Rich [11].

2.2 The seven waste relationships
According to Rawabdeh [17], all types of waste are inter-dependent, and affect other types of waste. The inter-relationships of wastes are very complex because the influence of each type of waste on other types may arise directly or indirectly (O: overproduction, P: processing, I: inventory, T: transportation, D: defects, W: waiting, and M: motion). The relationships between waste consists of; types of waste as O, D and T affect all other wastes, except P; while the type of waste P affects all other waste, except T; and so on until the type of waste W only affects O, I and D. In total there are 31 relationships where type of waste *i* affects type of waste *j* [17].

2.2.1 Waste relationship matrix. A waste relationship matrix (WRM) questionnaire [17] was adopted to measure the inter-relationships of wastes that occurred. The WRM questionnaire consists of 6 questions with rating from 0 to 4, which includes all relationships of wastes . Furthermore, the steps to analyze the survey results of WRM are as follows; 1) add all scores of each waste relationship; 2) convert a total score into a relationship symbol refers to a range of scores of each inter-relationship of waste; 3) then, convert the results into numbers according to the applicable provisions, where the symbols A = 10, E = 8, I = 6, O = 4, U = 2, and X = 0 [17]; 4) last, calculated the total score and percentage of each waste to create a waste matrix value.

Table 1. Selection matrix for the seven value stream mapping tools [11]

Wastes/Structure	Process Activity Mapping	Supply Chain Response Matrix	Production Variety Funnel	Quality Filter Mapping	Demand Amplication Mapping	Decision Point Analysis	Physical Structure (a)Volume (b)Value
Overproduction	L	M		L	M	M	
Waiting	H	H	L		M	M	
Transport	H						L
Inappropriate processing	H		M	L		L	
Unnecessary inventory	M	H	M		H	M	L
Unnecessary motion	H	L					
Defects	L			H			
Overall Structure	L	L	M	L	H	M	H

Notes : H = 9 – High correlation and usefulness
M = 3 – Medium correlation and usefulness
L = 1 – Low correlation and usefulness

2.2.2 Waste assessment questionnaire. WAQ consists of 68 types of questions which are divided into two categories, namely: 1) the "from" category, if the answer is "yes" means that there is a waste, where the answer score for this category is 1 if "yes", 0.5 if "medium", and 0 if "no"; 2) category "to", if the answer is "yes" means there is no waste that occurs, where the answer score for this category is 0 if "yes", 0.5 if "medium" , and 1 if "no". The steps are used in analyzing WAQ [17], among others; 1) group and calculate the number of questionnaire questions both of categories "from" and "to" for each type of waste; 2) weighting for each type of waste from each type of WAQ question based on the weight of WRM; 3) eliminate the effect of variation for each type of question by dividing the weight of each line with the number of questions grouped (Ni) for each question, as formulated by the following equation:

$$S_j = \sum_{k=1}^{K} \frac{W_{j.k}}{N_i} \text{; for each type of waste j} \quad (1)$$

4) sum up the score (Sj) for each column of type of waste; 5) calculate the frequency (Fj) of the appearance of the values in each waste column by ignoring the value of 0 (zero); 6) input the value of WAQ results (1, 0.5, or 0) into each weight of the waste value by using the following mathematical equation:

$$s_j = \sum_{k=1}^{K} X_k \times \frac{W_{j.k}}{N_i} \text{; for each type of waste j} \quad (2)$$

7) sum up the score (sj) for each weight value in each waste column; 8) calculate the frequency (fj) for each weight value in each waste column by ignoring the value of 0 (zero); 9) calculate the initial indicator for each waste (Yj) by using the following equation:

$$Yj = \frac{sj}{Sj} \times \frac{fj}{Fj} \text{; for each type of waste j} \quad (3)$$

10) Calculate the final value of each waste ($Yj\ final$), where previously determining the probability factor of the effect of each waste Pj, by using the mathematical equation below:

$$Yj_{final} = Yj\ x\ Pj = \frac{sj}{Sj} x \frac{fj}{Fj} xPj \text{; for each type of waste j} \quad (4)$$

The next step is to determine the rank of each waste by calculating the percentage of a final result. Furthermore the WAQ result is used as a reference in selecting value stream mapping tools (see Table 3, Table 4) that will be used for further analysis.

After the steps mentioned earlier, the whole picture of current process was mapped to calculate the process cycle efficiency (PCE) before improvement. The kanban system is developed and designed so that it will eliminate waste of unnecessary inventory throughout the value stream in a future. Eventually, a comparative analysis is used to explain the results between before and after improvement.

3. Results and discussion

3.1 The selection of value stream mapping tools

Firstly, a survey was conducted by using instruments of waste assessment model. Those questionnares were distributed to respondents who are eligible. Table 2 shows that the "form" value of waste of excessive transportation has the highest percentage approximately 19.08%, which means that if this waste has considerable influence to cause other wastes. The "to" value of waste of unnecessary motion has the highest percentage, ie 19.08%. This indicates that the waste of unnecessary motion is the most widely waste caused by the others. Table 3 shows that the following types of waste which are sorted from three highest occurrences respectively are unnecessary motion, then excessive transportation and unnecessary inventory.

After obtaining the results of WRM and WAQ, next step is a selection of appropriate mapping tools against certain type of waste that occurs in the company refers to the result of weighting of each tool. Table 4 shows that two tools are chosen, i.e. process mapping activity and supply chain response matrix. Therefore both are used to identify the wastes and would be discussed further.

Table 2. The result of waste relationship value

F/T	O	I	D	M	T	P	W	Score	%
O	10	6	4	6	6	0	6	38	14.50
I	4	10	4	8	6	0	0	32	12.21
D	4	2	10	6	6	0	4	32	12.21
M	0	6	6	10	0	10	8	40	15.27
T	4	10	6	10	10	0	10	50	19.08
P	4	6	8	10	0	10	10	48	18.32
W	2	4	6	0	0	0	10	22	8.40
Score	28	44	44	50	28	20	48	262	100
%	10.69	16.79	16.79	19.08	10.69	7.63	18.32	100	

Table 3. The result of waste assessment questionnaire

	O	I	D	M	T	P	W	Total
Score (Y_j)	0.25	0.23	0.23	0.26	0.25	0.27	0.24	1.74
P_j factor	155.00	205.12	205.12	291.36	203.95	139.85	153.84	1354.23
Y_j final	39.33	47.87	47.09	74.31	51.48	38.15	37.42	335.65
Final result (%)	11.72	14.26	14.03	22.14	15.34	11.36	11.15	100.00
Ranking	5	3	4	1	2	6	7	

Table 4. The selected result for mapping tools

Waste	Weight	Mapping tools						
		PAM	SCRM	PVF	QFM	DAM	DPA	PS
Overproduction	11.72	11.72	35.16	0.00	11.72	35.16	35.16	0.00
Unnecessary inventory	14.26	42.79	128.36	42.79	0.00	128.36	42.79	14.26
Defect/reject	14.03	14.03	0.00	0.00	126.26	0.00	0.00	0.00
Unnecessary motion	22.14	199.26	22.14	0.00	0.00	0.00	0.00	0.00
Excessive transportation	15.34	138.03	0.00	0.00	0.00	0.00	0.00	15.34
Innapropriate processing	11.36	102.28	0.00	34.09	11.36	0.00	11.36	0.00
Waiting idle	11.15	100.34	100.34	11.15	0.00	33.45	33.45	0.00
Total		608.45	286.00	88.30	149.34	196.97	122.76	29.60
Ranking		**1**	**2**	6	4	3	5	7

3.2 Waste reduction by using the selected mapping tools

Current-VSM is conducted to understand a big picture that currently occurs on the information flow and physical flow throughout the value stream, as illustrated in Figure 1. CVSM result shows that the production process is still implementing a push system, where there is a relatively high inventory on the production floor. Current state indicates that the process runs inefficiency with PCE approximately 0.36% and the number of manpower is 14 workers.

Process activity mapping describes the proportion between value added activities, non value added activities and necessary but non value added activities in an internal manufacturing context [18]. This mapping tool can also be used to identify the waste that occurs in the value stream and optimize the process to be more effective and efficient by designing it more simply. The result of PAM could be seen in Table 5. Further analysis of 5W-1H (asking: What activity does occur? Why does an activity occur? Who does it? On which machine? Where? When? And How?) is used to identify the root causes of non-value-added activities that are unnecessary, so that it can be eliminated.

The SCRM result illustrates that the average time to fulfill an order is 13 days, where the cumulative inventory is 5.75 days. Cumulative inventory or days of physical stock describes the average time of a material throughout the value stream. Table 6 shows that the longest days of physical stock are in the thinner area. This happens because the average production per day is 18,866.32 liters while the absorption of raw materials on average per day is 67,75 liters, resulting occur in a pile of items that will be processed in the thinner area (noted as "work in process"). Even though the raw material warehouse has the longest lead time which is 5 days since ordering, the physical stock circulation in the raw material is relatively normal as well as finished goods area.

Table 5. The result of process activity mapping

Category	Number of Activities	Time (seconds)	Percentage (%)
Value adding	12	472.23	9.58
Non value adding	1	332.47	6.74
Necessary non-value adding	24	4,125.30	83.68
Total	37	4,930.10	100

Table 6. The detail result of SCRM

Area	Days Physical Stock	Lead Time	Cumulative Inventory (Days Physical Stock)	Cumulative Lead Time
Raw material warehouse	1.13	5	1.13	5
Thinner area	3.59	1	4.73	6
Finished goods area	1.02	1	5.75	7
Total				12.75

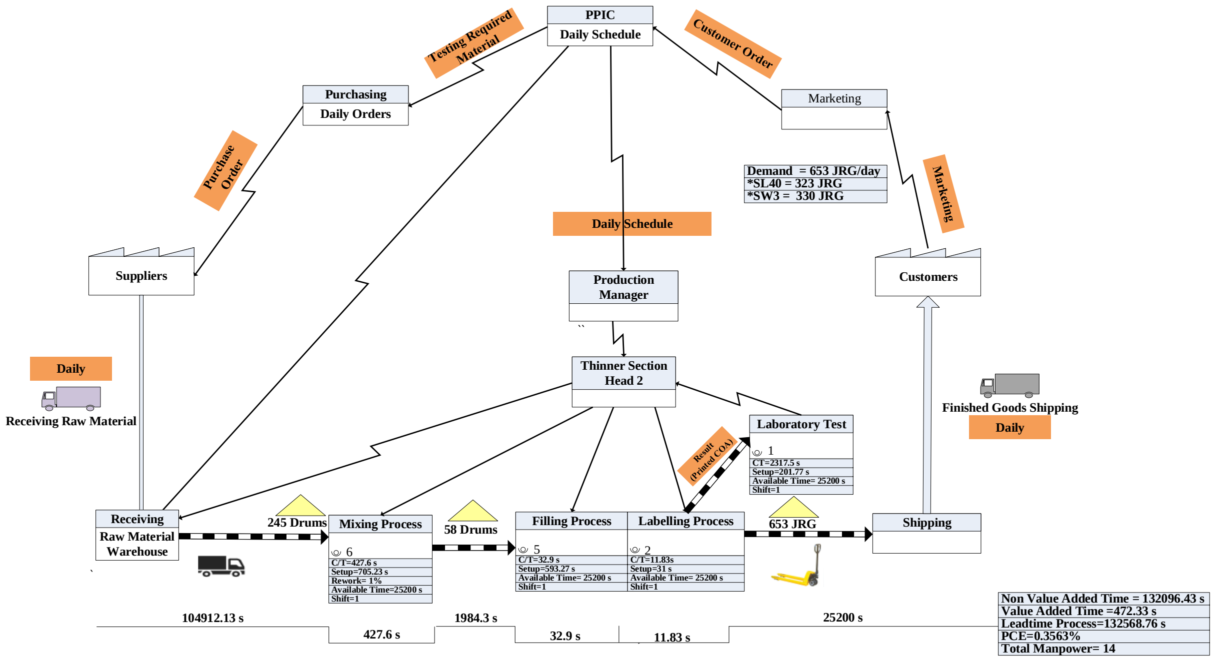

Figure 1. Current value stream mapping

3.3 Waste of inventory removal by using kanban system

Future-VSM as illustrated in Figure 2, shows that the kanban system is developed and implemented to eliminate waste of inventory that accumulates throughout the value stream. In shipping, it is known that numbers of daily demand are 653 jerry cans, the takt time can be calculated as follows:

$$Takt\ time = \frac{\text{available working time}}{\text{daily customer demand}} \tag{5}$$

$$Takt\ time = \frac{25200}{653} = 38.59 \text{ seconds}$$

Therefore, number of transport kanban is needed to move goods from labelling process to shipping which can be calculated as follows:

$$\text{Number of kanban} = \frac{\text{Daily demand} \times (1 + \%\ \text{Safety Stock})}{\text{Container Capacity}} \tag{6}$$

$$Number\ of\ kanban = \frac{653 + (653 \times 0.1)}{50} = 14.40 \approx 15 \text{ Kanban}$$

and, pack-out quantity and pitch can be formulated and calculated as follows:

$$Packout\ quantity = \frac{daily\ customer\ demand}{amount\ of\ kanban} \tag{7}$$

$$Packout\ quantity = \frac{653}{15} = 44 \text{ jerry cans/kanban}$$

$$Pitch = takt\ time \times packout\ quantity \tag{8}$$

$$Pitch = 38.59 \times 44 = 1{,}697.96\ seconds$$

Meanwhile, required the number of production kanban in filling process as well as the number of transport kanban to move goods from mixing process to filling process as follows:

$$Number\ of\ kanban = \frac{65.3+(65.3\times0.1)}{5} = 14.37 \approx 15 \text{ kanban}$$

Where assume that one drum could produce ten jerry cans and takt time is 32.9 s hence pack-out quantity and pitch are respectively 5 drums/kanban and 1,645 s. Similarly, needed one production kanban in mixing process, as well as one transport kanban to move goods from receiving to this process. Consequently, here has pack-out quantity and pitch are respectively 66 drums/kanban and 28,221.6 s.

Table 7 describes the results of a comparison between CVSM and FVSM, where non-value added time and total lead time decreased which impact to the increase of PCE by 67.25% with total workers unchanged. After eliminating a non-value added activity which is identified by using PAM, it will decrease setup time of filling process to be 260.8 s. Hence the lead time of filling process decreased by 332.47 s, could be seen in Figure 2.

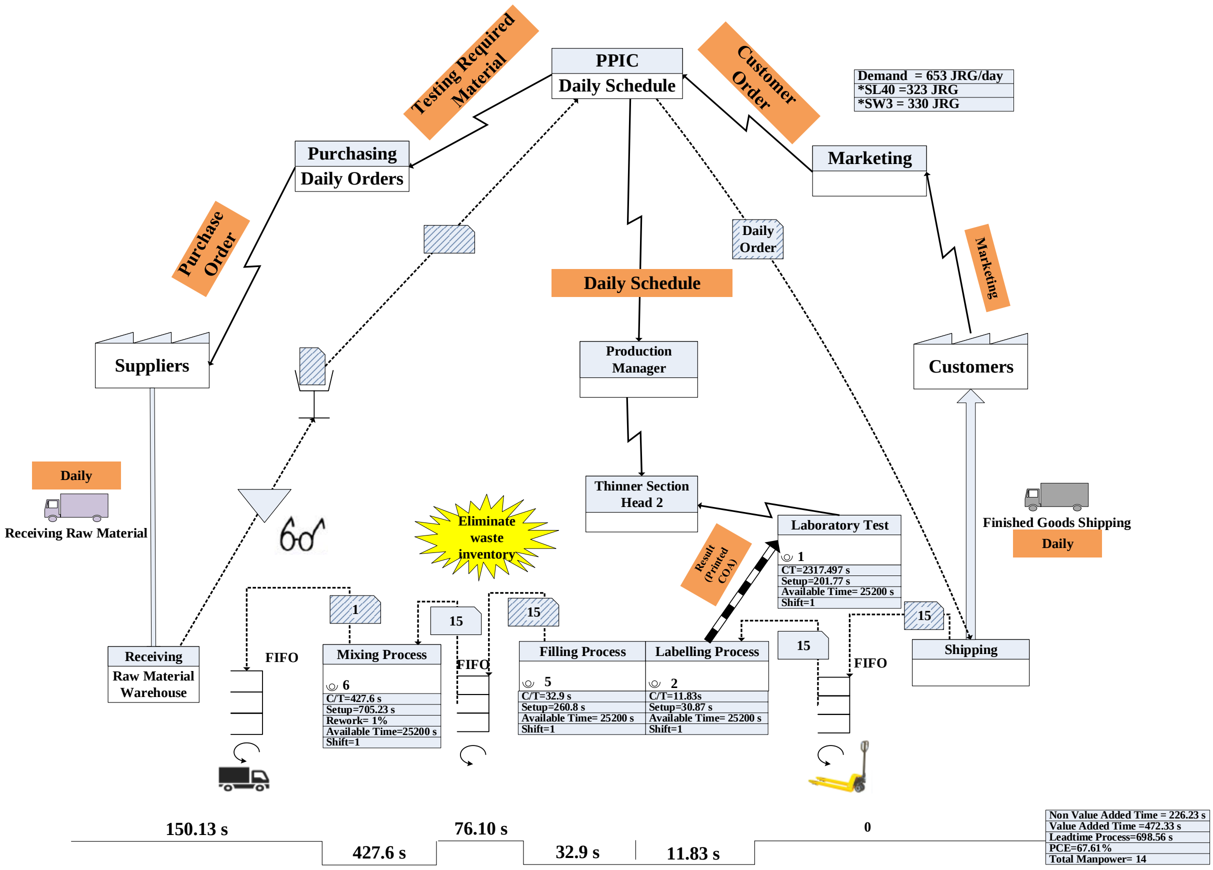

Figure 2. Future value stream mapping

Table 7. A comparison result between CVSM and FVSM

Indicator(s)	CVSM	FVSM	Result
Non value added time	132,096.43 s	226.23 s	Decrease 99.83%
Value added time	47.33 s	472.33 s	
Total Lead time	132,568.76 s	698.56 s	Decrease 99.47%
Process cycle efficiency	0.36 %	67.61 %	Increase 67.25 %
Total workers	14	14	

4. Conclusion

In this study, the wastes could be identified and further analyzed using value stream mapping tools where previously conducted a survey using a waste assessment model. In order to obtain the detailed description of each process at current state, a big picture of value stream was mapped. Kanban system is also applied on this improvement. Finally, some type of identified wastes can be reduced or even eliminated. Thus, process cycle efficiency will increase significantly by 67.25%. However, various studies still need to be developed and elaborated to transform this organization into a fully lean enterprise**.**

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