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Research Article

Lean Analysis Framework for Waste Management: A Case of Indonesian Textile Company

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A B S T R A C T

This study aims to propose a lean analysis framework for waste management and to test it into the field case. The proposed framework was applied in a weaving process of a textile company in Indonesia. The seven classical Lean wastes were identified using value stream mapping (VSM). The result was then analyzed using waste assessment model within which waste relationship matrix (WRM) and waste assessment questionnaire (WAQ) according to the answers of the head of weaving division studied. The major source of wastes was then determined utilizing value stream analysis tool (VALSAT). In order to thoroughly examine the root cause of such dominant wastes and to propose corrective plans to minimize the waste, a fishbone diagram was used. As the main result, this study provides a lean waste analysis framework with examples to orientate managers about wastes. Particularly in our specific case, the results demonstrate that the waiting and defect become the most significant wastes that need to be treated. These findings allow a company to organize its activities and select tools or practices to optimize its efforts to create proper corrective plans in eliminating waste. In our study, the plans include periodic maintenance of weaving machines, clear division of tasks on the distribution of weft yarns, and eliminating unnecessary activities. In addition, it is mandatory to ensure the quality of warp yarns delivered to the weaving process as well as to perform a periodic calibration of equipment on weaving machines. This study advances in the theoretical and practical field by showing a structured way to incorporate lean analysis that can be adopted for any organization.

INTRODUCTION

The rapid change of economic conditions and consumer demands for high-quality products that must reach consumers in a relatively short time has had a major impact on the manufacturing industry. With the intense global competition, companies must be able to improve the level of profit without increasing the selling price of the product. It can be done by minimizing production costs, increasing productivity, and reducing waste during production [1]. To remain competitive and flexible, companies must find problem-solving methods so that they can respond quickly to new demands from consumers. There are several problem-solving methods related to quality improvement in companies, including Total Quality Management (TQM), Six Sigma, Kaizen, Just-in-time manufacturing (JIT), Enterprise Resource Planning (ERP), Business Process Re-engineering (BPR), and Lean manufacturing. During the last decade, there have been many studies conducted using various process improvement methods. Lean manufacturing is considered one of the most widely known approaches to improving organizational performance because the lean manufacturing approach is simple to apply and easy to monitor [2]. Besides, lean manufacturing is also considered a very useful and significant strategy to achieve a competitive advantage in today's global manufacturing environment [1], [3].

Lean manufacturing aims to reduce waste in order to be more responsive to customer demands and to produce quality products in the most efficient manner [4]. A previous study reveals that only 5% of the production time is truly value-added processes, while the remaining 95% represents waste [5]. If neglected, the waste can decrease product quality, swell production costs, and lower consumer satisfaction levels [5]. Through the application of lean manufacturing, the company will get several benefits, such as increasing productivity [1], increasing efficiency [3], increasing market share and improving the flexibility of the company in responding to consumer demand [6], reducing lead time, process time, and work-in-process inventory [7], and ensuring company’s sustainable development [8].

One company that is currently trying to increase its competitive advantage is a textile company producing plain, dobby, pique, twill, and satin fabrics. One of the processes is weaving, which weaves the threads into cloth. Based on preliminary observations on the production floor, there was a waste in this weaving

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process. It was found that there was a large amount of scrap, leftover weft, that can still be used for the production process. Based on that condition, it is important to identify the source of waste found in the weaving process and provide recommendations to minimize the waste. By detecting the major source of waste, it is expected that improvement recommendations are more effective.

Research on the lean manufacturing approach for waste elimination has been carried out by numerous scholars [9]–[18]. These studies show that, when implementing lean manufacturing, researchers employed several different tools: Value Stream Mapping (VSM) [16]; VSM and Value Stream Analysis Tools (VALSAT) [9], [11], [12], [15], [17], [18]; Waste Assessment Model (WAM) [10] which was developed by Rawabdeh [19]; and VSM, VALSAT, and WAM [13]–[15]. Other scholars utilized additional tools such as fishbone diagrams as a technique to identify the root cause of the dominant waste [11], [14], [15]. Thus, they could suggest appropriate recommendations for the company. Prabowo and Suryanto [17] implemented VSM and VALSAT and Life Cycle Analysis (LCA) to assess green manufacturing.

Although the framework and principles for implementing lean manufacturing have been developed, its implementation in the textile industries is still limited [20] – [24]. In fact, the textile industries have unique characteristics, i.e., highly inflexible automatic machinery and high volume/ low variety products. Hence, implementing lean approach in textile industries has been taken up as a challenge [23]. Some researchers used VSM as the primary tool when implementing lean in textile industries. VSM was then combined with other tools according to the research objectives. For example, to eliminate waste in the textile industry in South India, VSM was combined with the 5S method, kanban, kaizen, poka-yoke, and visual control [23]. Another study reported that the combination of VSM and kanban has successfully reduced the production costs of textile companies in Brazil [21]. Further, the integration of VSM and System of System (SoS) offered significant improvements to the performance of the yarn spinning process in the textile industry in Pakistan [20].

According to Hodge et.al [24], lean manufacturing involves various principles and techniques with the same goal, viz eliminating waste and non-value added activities at each stage of the process to provide satisfaction to consumers. The primary tool in lean manufacturing is VSM. However, Carvalho et.al [21] affirmed that when VSM combines with other lean tools, there will be a significant impact on performance. Therefore, this study adopts various lean manufacturing tools, particularly VSM, WAM, VALSAT, and fishbone diagram as executed by [14], [15]. Utama et al. [14] conducted research in a manufacturing industry that produces wind instruments. Meanwhile, Yadrifil et al. [15] carried out a study on the furniture industry producing wooden doors. While the above mentioned studies were carried out in the discrete process-typed industry, this research was carried out in the textile industry, which is a continuous process-typed industry. Although several studies on the application of lean manufacturing in the continuous-process type industry have shown significant improvement results, the implementation of lean manufacturing in the textile industry is very scarce [23]. This study utilized various lean manufacturing tools to comprehensively analyze the waste, started by mapping the existing process through VSM, evaluating waste using WAM, identifying the dominant sources of waste based on VALSAT, and providing improvement recommendations to reduce waste based on the fishbone diagram.

METHOD

The Proposed Data Analysis Framework

In this research, there are four stages to analyze the waste, namely VSM, WAM, VALSAT, and fishbone diagram. The VSM used in this study is the Current State Map as a visualization of material and information flow in the current production process. By mapping the production process through the Current State Map, seven types of waste that occur during the production process can be identified. Next, the relationship of seven types of waste was analyzed using the Waste Relationship Matrix (WRM). Later the Waste Assessment Value (WAV) was calculated using the Waste Assessment Questionnaire (WAQ) instrument. The WAV was then taken as input in VALSAT. Activities having a primary contribution to the non value-added process can be recognized from the biggest score of VALSAT. Non value-added activities are divided into two types, namely Non-Value Added (NVA) and Necessary but Non-Value Added (NNVA). Activities causing dominant waste were then evaluated using fishbone-diagrams, to find the root cause. Based on the fishbone diagram, improvement recommendations is formulated. Figure 1 presents the proposed framework of data analysis. A detailed explanation for each stage of data analysis is described in the following sub-section.

Value Stream Mapping (VSM)

VSM is one of the lean tools adapted from the Toyota Production System (TPS). It is known as material and information flow mapping [4]. VSM describes the process flow by considering

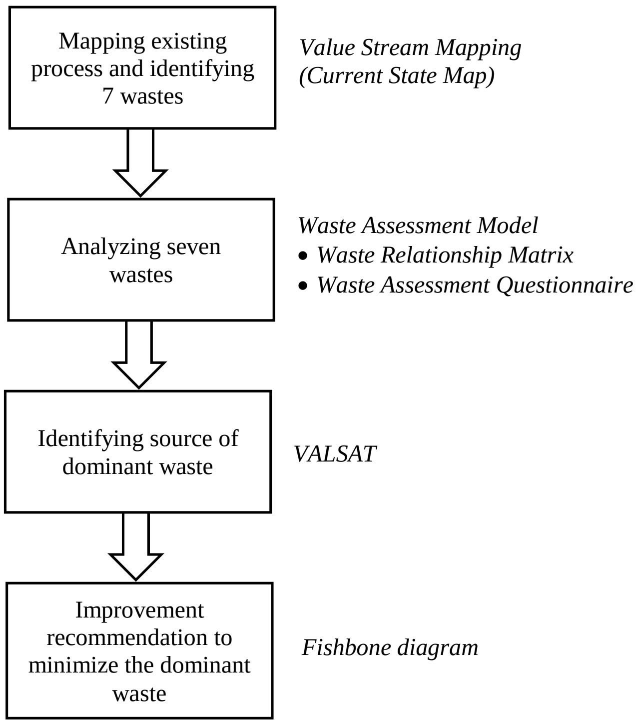

Figure 1. Data Analysis Framework

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value-adding activities (VA) and non value-adding activities (NVA). VSM is a visual method for mapping information that can be used as a starting point to recognize waste and identify its causes. The VSM approach is to initiate problem-solving with the big picture, not just focusing on single processes. VSM also makes improvements as a whole and not only on specific operations. VSM is divided into two categories, namely the current state map and the future state map.

Waste Assessment Model (WAM)

WAM consists of two instruments, i.e., the waste relationship matrix (WRM) and the waste assessment questionnaire (WAQ). WRM describes the strength of the direct relationship between wastes using a scale as depicted in Table 1 [25]. Toyota identified seven types of waste that do not add value to a business processes, i.e., overproduction, inventory, defects, motion, process, transportation, and waiting [4].

The relationships among wastes are complex because the effect of each type of waste on the others can appear directly or indirectly. Each type of waste is symbolized using its initial (O for overproduction, I for inventory, D for defects, M for motion, P for process, T for transportation, W for waiting). Each relationship is assigned with an underscore "_". For example, O_I indicates the direct effect of overproduction on inventory. It means that overproduction requires more raw materials, resulting in the hoarding of both raw materials and work-in-process. This stack takes up space and makes temporary supply that is not needed by the customer or the succeeding process.

WRM represents actual relationships among wastes. Each row indicates the influence of a specific waste on the other six waste types. Similarly, each column shows to what extent a certain kind of waste will be influenced by others [19]. WAQ is used to allocate waste. The integration of WRM and WAQ can help to identify the source of waste. Besides, it is beneficial in differentiating between the waste levels and their effects on the system performance. It thereby enables to rank the significance of the waste types that exist [19]. The WAQ consists of 68 different questions. These questions represent an activity, a condition, or a behavior that may lead to a specific type of waste. Some questions are assigned as “From” type. Other questions are assigned as “To” type. The "From" question represents an existing type of waste that may lead to others while "To" question means any existing type of waste that may have been influenced by other wastes.

Each question has three answers, and each answer was assigned a weight of 1, 0.5, or 0. There are four categories of questions, namely man, machine, material, and method. Each question is related to one of these categories. Upon designing the assessment model questionnaire, it was noted that each question led to a specific type of waste by a certain degree, depending on its answer. The final rank of wastes depends on the combination of answers. This study follows the WAM procedure proposed by [19]. The procedures are as follows:

1. Calculating the final score of existing waste types based on the classification of “From” and “To” questions and original weights obtained from the WRM.
2. Removing the effect of variation of the number of questions for each question type by dividing each weight in the row by the corresponding number of questions (N_i) for each question. Let W be the weight of the relationship and j the type of waste for each question number k, the values in each column under each type of wastes can be summed up to obtain a score based on equation (1). S_j is the score of the waste, and k ranges between 1 and 68.

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

3. Removing the effect of the null answer. For each type of waste, which is represented by the waste columns, each cell that was assigned weight was counted, where: F_j is the frequency (number) of cells that were assigned a weight other than 0, for each type of waste (j).
4. Calculating weight values for each type of waste by multiplying rows for each type of waste by the weight of each answer (X_k) obtained from the assessment questionnaire. The values in each column under each type of waste were summed to obtain the new score (s_j), as

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

5. Counting the number of non-zero cells in each column to obtain the frequency (f_j) for each type of waste
6. Calculating the initial indication factor of each type of waste using equation (3). Y_j is the initial indication factor of each type of waste.

$$Y_j = \frac{s_j}{S_j} \times \frac{f_j}{F_j} \text{ for each type of waste } j \quad (3)$$

7. Calculating the final waste factor (YF_j) by multiplying Y_j by P_j as in equation (4). P_j is the probability of “From” and “To” occurrences in the WRM.

$$YF_j = Y_j \times P_j = \frac{s_j}{S_j} \times \frac{f_j}{F_j} \times P_j \text{ for each type of waste } j \quad (4)$$

   Then, YF_j is converted into percentages to obtain the rank of each type of waste.

Table 1. Strength of Direct Relationship of Wastes

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

Value Stream Analysis Tools (VALSAT)

VALSAT is a tool to map in detail the value stream, which is focused on value-adding activities so that it can be used to identify the waste and its causes. VALSAT approach is applied to select effective value stream mapping tools. There are seven types of value stream mapping tools, i.e. process activity mapping, supply chain matrix, production variety funnel, quality filter mapping, demand amplification mapping, decision point analysis, and physical structure. Process activity mapping is used to map every activity stage starting from operations, transportation, inspection, delay, and storage. Each activity is then grouped into existing activity types starting from value-adding activities, necessary but non-value-adding activities, and non-value-adding activities based on seven type mapping tools i.e., Proses Activity Mapping, Supply Chain Response Matrix, Production Variety Tunnel, Quality Filter Mapping, Demand

Amplification Mapping, Decision Point Analysis, and Physical Structure Mapping.

Supply chain response matrix is a diagram that describe the cumulative lead time in the distribution process. Production variety funnel is a visual mapping technique that tries to map the number of product variations at each manufacturing process stage. This tool can identify the point where a generic product is processed into several specific products. It can also be used to pinpoint the bottleneck areas of the process design. The quality filter mapping approach is a new tool designed to identify where quality problems exist in the supply chain. The resulting map itself shows where three different types of quality defect -product defect, service defect, and internal scrap- occur in the supply chain. Demand amplification mapping is a map used to visualize demand changes along the supply chain. The decision point is the point in the supply chain where the actual demand-pull gives way to forecast-driven push. In other words, it is the point at which products stop being made according to actual demand and instead are made against forecasts alone. Decision point analysis shows different production system options, with a trade-off between lead time and inventory levels needed to accommodate during lead time. Physical structure mapping is useful to understand what a particular supply chain looks like at an overview or industry level. This knowledge is helpfull in appreciating what the industry looks like, understanding how it operates, and, in particular, in directing attention to areas that may not be receiving sufficient developmental attention.

VALSAT is presented in a diagrammatic form, as illustrated in Figure 2. Section A contains the description of seven wastes identified in companies. Section B is filled with seven types of mapping tools. Section C is the weight of each waste obtained from WRM. Section D is the multiplication between section C and the correlation value of sections A and B. The correlation value between sections A and B consists of three scales, namely high correlation (H) with a weight of 9, medium correlation (M) which weights 3, and low correlation (L) with a weight of 1. Guidelines for determining the correlation value between each mapping tool and each type of waste refer to [25] as presented in Table 2. The sum of all rows in each column in section D is then displayed in section E so that the ranks of the seven mapping tools are obtained. Further evaluation will be taken to the first rank of the mapping tools.

Waste	**Weight**	**Tool** (B)
(A)	(C)	(D)
	Total Weight	(E)

Figure 2. VALSAT diagram

Fishbone Diagram

In this study, the fishbone diagram was used to identify sources of the most dominant waste. After that, researchers suggested improvement recommendations to the company to reduce waste.

The Case Implementation

This research was conducted at one of Indonesian textile company. One of its processes is weaving which turns threads or yarns into fabrics. There are two main components in a sheet of fabric, warp threads and weft threads. The lengthwise or longitudinal warp yarns are held stationary in tension on a frame or loom. Meanwhile, the transverse weft is drawn through and inserted over and under the warp.

After observing the weaving production floor, especially in the block-U section, it was found that there was a large number of scraps or weft yarns that could still be used for the production process. However, the weaving operator sends the weft back to the thread releaser to remove the spools on the winder stick, then sends them back to the winder machine to be rolled into new weft yarns. After that, the operator sent back the threads to the weaving machines. It causes frequent tardiness of winder stick supply for weaving machines, which will impact both time and financial losses.

Weft yarn reprocessing results in a non value-adding process and causes waste in production time. The existence of unused weft yarn scraps also causes financial losses. Data showed that the weight of weft yarn scraps on the block-U production floor during the morning shift for a 1-month working day is 269.6 kilograms. If converted to Indonesian currency (IDR), the monthly company's loss due to weft yarn scraps is IDR 8,320,988. This company operates 24 hours, meaning there are three shifts every day. If it is assumed that the weight of weft scrap produced on each working shift is the same, then the monthly loss experienced will reach IDR 25 million.

RESULT AND DISCUSSION

The current state map was designed using the data of material and information flow at the weving process. Due to limited access, this study did not use the future state map. The data was obtained by direct observation or field survey to the production floor. The

Table 2. Seven Stream Mapping Tools

Waste	**Proses Activity Mapping**	**Supply Chain Response Matrix**	**Production Variety Tunnel**	**Quality Filter Mapping**	**Demand Amplification Mapping**	**Decision Point Analysis**	**Physical Structure Mapping**
Over Production	L	M	0	L	M	M	0
Inventory	M	H	M	0	0	M	L
Defect	L	0	0	H	0	0	0
Unnecesary Motion	H	L	0	0	0	0	0
Transportation	H	0	0	0	0	0	L
Inappropiate process	H	0	M	L	0	L	0
Waiting	H	H	L	0	M	M	0

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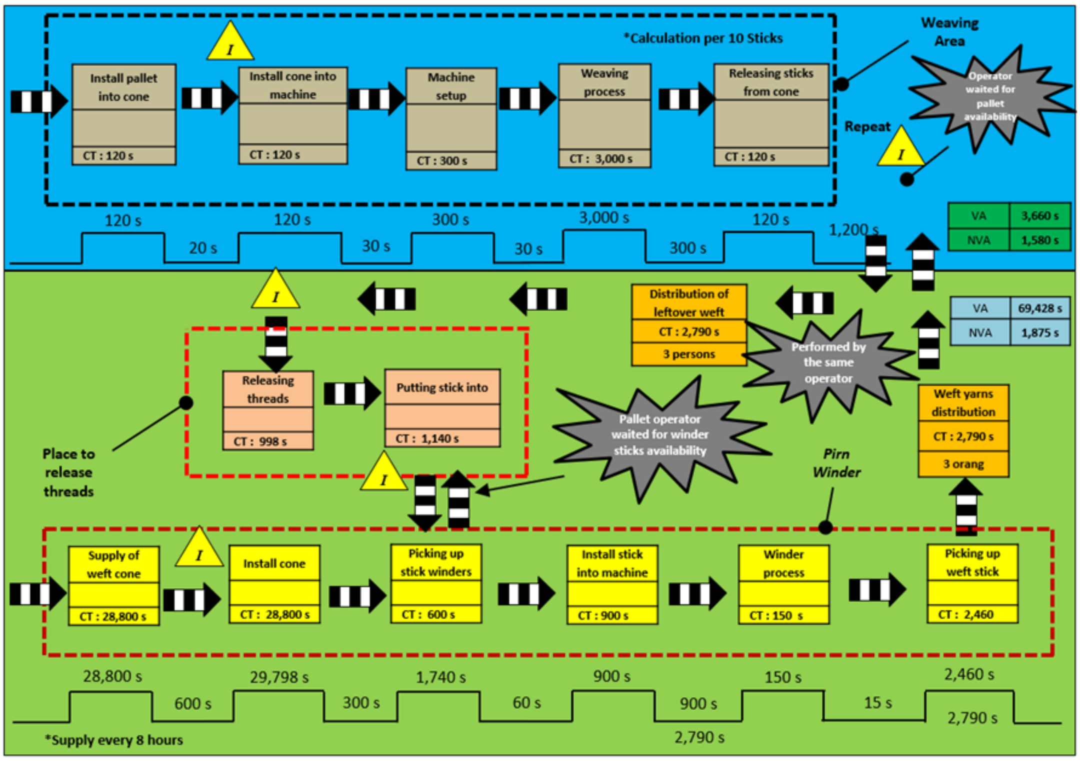

Figure 3. Current State Map of the Weaving Production

survey aimed to understand the production process flow from receiving raw materials to shipping. Furthermore, several important things found in each process were noted to identify critical things arising in each process. Cycle time data recording for each operation was carried out using a stopwatch. The raw data obtained was then confirmed to the field supervisor. The material flow and cycle time in each process for the weaving area are displayed in Figure 3. It shows the existence of several problems related to waste on the production floor in the form of non-value-adding activities, which resulted in the piling up of weft scrap. The non-value-adding activities referred to the weaving operators who sent back the weft to the thread releasers to remove the spools on the winder stick, then sent them back to the winder machine to be rolled into new weft yarns. After that, the weft yarns were sent back to the weaving machine, which resulted in a delay in the supply of winder sticks for weaving machines, so that pallet operators often waited for the sticks to arrive. Table 3 shows each type of waste found on the weaving production floor.

WRM was obtained through three stages: distributing questionnaires, weighing the questionnaire results (tabulation), and arranging WRM. The WRM final result is the waste matrix value. The questions in the questionnaire were related to the relationship between wastes. The respondents were the Division Head of Warehouse, the Division Head of Quality Control, and the Division Head of Production. The Warehouse division filled out a questionnaire with the following types of questions: O_I, O_D, O_M, O_T, O_W, I_O, I_D, and I_M. The Quality Control division answered a questionnaire related to D_O, D_I, D_M, D_T, and D_W. And the Production division filled in the question items related to M_I, M_D, M_W, M_P, T_O, T_I, T_D, T_M, T_W, P_O, P_I, P_D, P_M, P_W, W_O, W_I, and W_D.

The weight of waste relationships and the WRM recapitulation are presented in Table 4 and Table 5. The letter codes in the WRM were then converted to scores with a conversion reference of A = 10; E = 8; I = 6; O = 4; U = 0 so that the waste matrix value was obtained, as shown in Table 6. From Table 6, it can be seen that the score from over-production and the score from the process have the highest value, indicating that the two wastes significantly affect other types of waste.

Table 3. The Observed Wastes

Waste	Observation Results
Overproduction	Excessive stocks of fabric from the weaving process, which is still waiting for the quality control and finishing process
Inventory	The piles of winder stick
Defect	Stack of weft scrap that cannot be used for the subsequent production process
Motion	The mixing of several types of winder sticks so the operator must find the one that suits their needs
	Thread releasers had to remove the spools of thread that are on the winder sticks
Process	Yarns stuck in the winder
	Reprocessing of weft yarns
Transportation	The weaving operator sent the weft back to the thread releaser and then sent it back to the weaving machine
Waiting	Operators waited for pallet availability
	Operators waited for winder sticks availability to be processed in the weaving machine

Table 4. Waste Relationship

Division	No	Question Type	Score	Relationship
Warehouse	1	O_I	12	I
	2	O_D	10	I
	3	O_M	13	E
	4	O_T	8	O
	5	O_W	18	A
	6	I_O	11	I
	7	I_D	18	A
	8	I_M	4	U
	9	I_T	12	I
Quality Control	10	D_O	13	E
	11	D_I	8	O
	12	D_M	10	I
	13	D_T	14	E
	14	D_W	10	I
Production	15	M_I	4	U
	16	M_D	6	O
	17	M_W	18	A
	18	M_P	11	I
	19	T_O	3	U
	20	T_I	7	O
	21	T_D	6	O
	22	T_M	18	A
	23	T_W	18	A
	24	P_O	6	O
	25	P_I	11	I
	26	P_D	15	E
	27	P_M	10	I
	28	P_W	19	A
	29	W_O	18	A
	30	W_I	19	A
	31	W_D	17	A

The waste value obtained from WRM was then used for initial input in WAQ based on the question type. Respondents who filled out the questionnaire were companies with positions fitted

Table 5. Waste Relationship Matrix

From/To	O	I	D	M	T	P	W
O	A	I	I	E	O	X	A
I	I	A	A	U	I	X	X
D	E	O	A	I	E	X	I
M	X	U	O	A	X	I	A
T	U	O	O	A	A	X	A
P	O	I	E	I	X	A	A
W	A	A	A	X	X	X	A

to the question types on the questionnaire. Furthermore, the WAQ steps follow the procedure proposed by [19] using equations (1) to equation (4). The final result of the waste assessment calculation is shown in Table 7. It can be seen that the first rank is waiting at 20.42%, and the second rank is defect at 20.17%.

The WAQ final results in Table 7 were inputted to the VALSAT. The concept of VALSAT is to select the appropriate mapping tools to handle the wastes. The VALSAT score is achieved by multiplying the weighting of each waste by the correlations between the waste and the mapping tool. The final results of VALSAT are displayed in Table 8. It can be inferred that Process Activity Mapping has the highest score.

The VALSAT scores show that the Activity Mapping Process has the highest score, so it was selected to be used as an analysis tool for the causes of waste. Process Activity Mapping is a tool to describe the process flow from beginning to end in a work activity that is used as the object of study. This map depiction aims to determine the percentage of value-added activities (VA = value-added) and non-value-added activities (NVA = non-value-added and NNVA = necessary but non-value-added) in the weaving process. This delineation is used to help identify waste in the value stream and identify whether the process can be designed more efficiently. Process Activity Mapping can also be used to identify parts of the process that can be improved by eliminating unnecessary things in the process so that a process becomes simpler and runs effectively and efficiently. The

Table 6. Waste Matrix Value

From/To	O	I	D	M	T	P	W	Score	%
O	10	6	6	8	4	0	10	44	15.94
I	6	10	10	2	6	0	0	34	12.32
D	8	4	10	6	8	0	6	42	15.22
M	0	2	4	10	0	6	10	32	11.59
T	2	4	4	10	10	0	10	40	14.49
P	4	6	8	6	0	10	10	44	15.94
W	10	10	10	0	0	0	10	40	14.49
Score	40	42	52	42	28	16	56	276	100%
%	14.49	15.22	18.84	15.22	10.14	5.80	20.29	100%	

Table 7. Waste Assessment Value

Description	O	I	D	M	T	P	W
$\mathbf{Y_j}$	1.50	1.46	1.50	1.59	1.54	1.53	1.48
$\mathbf{P_j}$ **Factor**	231.04	187.46	286.70	176.43	147.03	92.42	294.06
$\mathbf{YF_j}$	345.97	273.86	430.52	281.10	225.84	141.15	435.80
Final Result (%)	16.21	12.83	20.17	13.17	10.58	6.61	20.42
Rank	3	5	2	4	6	7	1

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Table 8. Result of VALSAT

Waste	Weight	Mapping Tool						
		Proses Activity Mapping	Supply Chain Response Matrix	Production Variety Tunnel	Quality Filter Mapping	Demand Amplification Mapping	Decision Point Analysis	Physical Structure Mapping
Overproduction	16.21	16.21	48.63	0	16.21	48.63	48.63	0
Inventory	12.83	38.49	115.47	38.49	0	0	38.49	12.83
Defect	20.17	20.17	0	0	181.53	0	0	0
Motion	13.17	118.53	13.17	0	0	0	0	0
Transportation	10.58	95.22	0	0	0	0	0	10.58
Process	6.61	59.49	0	19.83	6.61	0	6.61	0
Waiting	20.42	183.78	183.78	20.42	0	61.26	61.26	0
Sum		531.89	361.05	78.74	204.35	109.89	154.99	23.41

Table 9. Summary of Process Activity Mapping

Activities	Total	VA	NVA	NNVA	Time (Mins)	%
Operation	36	6	0	30	619	65.9
Transportation	8	1	0	7	84	8.9
Inspection	2	0	1	1	7	0.8
Delay	9	0	9	0	221	23.5
Storage	5	0	0	5	8	0.9

Table 10. Percentage of VA, NVA, and NNVA

Activity Category	Total	Time (Minutes)	%
VA	7	513.5	54.7
NVA	10	193.0	20.5
NNVA	43	232.5	24.8

summary of the Process Activity Mapping is portrayed in Table 9 and Table 10.

It can be concluded from Table 9 that operating time is mostly used in Operation activities (619 minutes) and Delay (221 minutes). Of the 36 Operation activities, 30 are NNVA. And of the 9 Delay activities, all of them fall into the NVA category. These results support the results of data processing from the WAM questionnaire using WRM and WAQ. The finding is, waiting which is correlated with delay activity becomes the most dominant waste. The second rank of waste is defects which are closely related to operational activities. From Table 10, it is known that NVA and NNVA are still relatively large that is 20.60% and 24.80%, respectively. This condition results in inefficient production time.

Based on the waste assessment results, it was found that waiting and defect were the two dominant wastes that resulted in wastes on the weaving production floor. Fishbone diagrams were then developed to reduce the two dominant wastes. The fishbone diagrams function as a foundation for providing improvement recommendations to the company. The fishbone diagrams are presented in Figure 4 and Figure 5. The cause-effect analysis in the fishbone diagram was grouped into four factors, humans, machines, materials, and work methods.

The production process at the company contains several stages, preparation, weaving, quality control, and finishing. The preparation stage aims to prepare the warp yarn. It starts from the spinning process of warp yarn using the spinning machine. This process is called warping. Afterward, the sizing process aims to coat the starch on the warp threads. After that, proceed to the reaching-in and tying-in to arrange the desired thread pattern. There is a difference between the reaching-in and tying processes during the weaving process of the thread. Reaching-in is an operation to set the yarns for a different pattern. Tying-in is the process of tying the ends of a new warp beam to the corresponding ends of the old warp beam after the depletion of a warp beam on the weaving machine if there is no change in design. During the tying-in process, the weaving machine needs to be stopped which discontinues the weaving process. The following operation is weaving the yarns into fabrics. In the weaving process, additional threads are required, namely weft threads, to make a fabric. In weaving, the warp thread and weft yarn are crossed over one another in a set method, in order to weave the required type of fabric. Then proceed with the process of quality control on a roll of fabric. The last operation is the finishing process to remove starch on the fabric so that the fabric is not stiff. When the production process took place, there were several problems occur.

The first problem was found on the weaving production floor, especially in the block-U. The main problem is the scrap accumulation of weft yarn that cannot be used in the weaving process. This problem was caused by several factors: the winding engine, winder operator, the winder stick, the condition of the weaving cones, and the suttle setting on the weaving machine. The first problem was related to the pirn winder engine and winder operator. The spinning on the winder stick did not work as expected. Yarn at initial spinning process got stuck or passed the joining process on the winder machine. This problem affects the weaving process, namely breaking up in the middle of the operation. Secondly, the problem is about the winder stick, using different types of winder sticks in the winding process. This difference happened due to the mixing of several different types of winder sticks so that the detection of the suttle on the weaving machine becomes problematic and affected the automatic replacement of the winder stick. The third problem was the condition of the cones and the settings on the suttle. The effect on this condition was common because the use of a plugin for a certain period will affect the clamping of the winder stick, so there was trouble in the accuracy of the suttle in detecting how much thread to use.

The various conditions lead to weft threads should still reusable but not utilized because the weaving operator sent them back to the thread releaser to release the spools on the winder sticks. Then they will be sent back to the winder machine to be rolled back

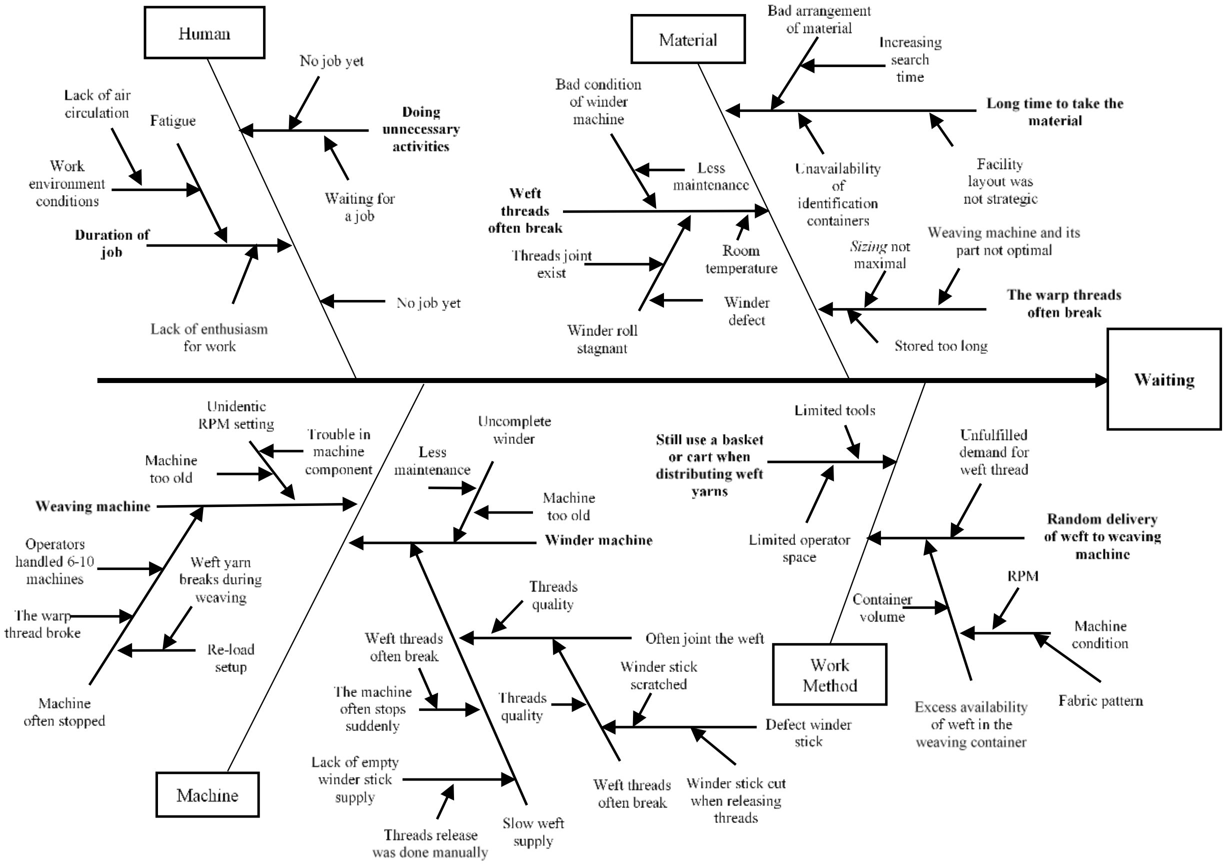

Figure 4. Fishbone Diagram for Waiting

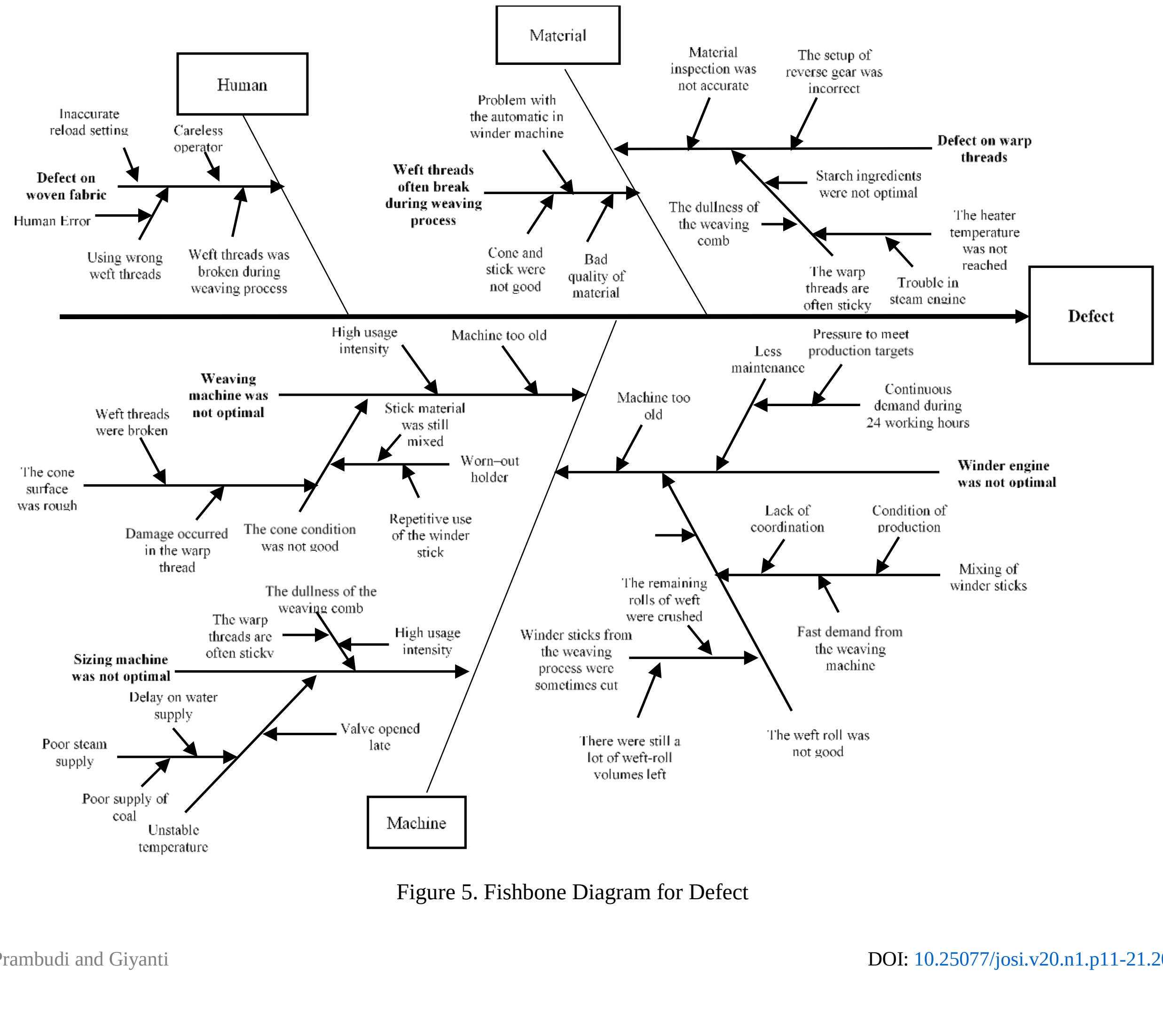

Figure 5. Fishbone Diagram for Defect

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into new weft threads and finally sent them back to the weaving machine. As a result, there were often delays in the supply of winder sticks to the weaving machines.

Based on Figure 4, it can be concluded that the first cause of waste of waiting-time related to the machine was the poor condition of the winder machine, which was characterized by the re-spinning process. This condition made the demand for additional weft yarns from weaving took a long time. The second cause of wasted waiting time related to the method was the weft distribution procedure. Regarding the waste of waiting time, it is recommended that an explicit system of area division should be used during the weft yarns distribution. The existing production process showed that weft demand for the western area on block U and block X, which is still in the same room, was not achieved. Then the weaving activity process stopped, resulting in loss of efficiency and cost losses that had to be borne by PT SLP. The third cause of the waste of waiting time concerning humans is the number of unnecessary activities. Basically, doing activities that do not add value to work is usual for all workers. However, if activities that do not provide added value are not reduced, it will lead to another type of waste in work. Things that do not need to be done at work include frequent conversations with fellow workers, which can cause delays in the process.

Figure 5 shows that the first cause of the defect is from the material side, particularly the non-optimal supply of material, where the warp yarn material from the sizing process was sometimes not good. It was indicated by the frequent joints of the warp threads that broke during the weaving process. The second cause of waste defects is related to machines, the obsolete equipment on the weaving machine. As the existing equipment is used on a weaving machine continuously, it causes a decrease in work efficiency on the weaving machine. This condition, if left unchecked, will make the weft yarn often not constant during the weaving operation so that it can affect the read size of the suttle on the weaving machine.

Regarding waste of waiting time, to minimize unnecessary waiting times, the company needs to design periodic machine maintenance and an explicit division of tasks to fulfill the required supply of weft threads to the weaving section. The clear division of jobs is also requisite for the activities of taking a new winder and taking the remaining winder. Workers discipline should also be improved by initiating more productive activity during the waiting time. The wastes was also in the form of transportation activities. Therefore, it is essential to review the existing material handling because the material handling tools were still limited, and the transportation distance between work stations was relatively far. Related to defects, it suggested that PT SLP carry out some actions, such as quality assurance of the weft threads distributed to the weaving process, replacement of cone holders, and maintenance or recalibration of weaving machines to reduce the amount of scrap or remaining weft. The weft yarn scrap, if omitted continuously, will cause losses for the company. To minimize excess losses due to weft yarn scrap, the company can utilize the weft yarn scrap for resale. However, it is necessary to examine in detail the re-use of weft threads to meet the weaving demand in the weaving area.

Referring to WAM, the results showed that the most dominant source of waste was waiting and defects. Waiting time indicates idle machines or workers because of running out of material, delays in material delivery, or bottlenecks due to imbalance in production speed. The waiting time, as depicted in the current state map, was a condition where the operator often waited for the supply of winder sticks for the weaving machines. On the other hand, defects happened if there were repairs or reprocessing required for defective components. Repair or rework, scrap, manufacture of substitutes, and inspections mean additional wasted handling, time, and effort. It was found that the spinning process of the thread on the winder stick was not as expected. The yarn in the initial spinning process got stuck or passed the splicing process on the winder machine. This condition affects the weaving process broken up in the middle of the operation. Defects were also found in the presence of weft yarn scrap that had to be rolled back into new weft threads and then sent them back to the weaving machine.

This study shows that applying various lean tools is capable to systematically analyze the causes of the dominant waste and provide the appropriate tools to find the root cause of the waste. These results are in line with previous studies conducted by [9]–[16]. Thus, this study strengthens the effectiveness of lean manufacturing tools as an effort to reduce waste.

Therefore, the company can adopt lean manufacturing as part of the daily production process so that the company can improve its performance sustainably. The implementation of lean manufacturing provides several benefits. However, the company must understand the system comprehensively to get the maximum advantages from lean manufacturing [7]. This statement indicates that the application of lean manufacturing must involve various parties related to the production process, which are the objects of lean analysis. The involvement of various parties allows the company to understand the big pictures of the current flow of material and information to further analyze and improve the system according to lean principles. Besides, the success of implementing lean manufacturing depends on the nature of the organization and the flexibility of company members to change [26]. Basically, lean manufacturing is continuous improvements or mini improvements on an ongoing basis. For this reason, to apply lean principles, the company must continue to strive to build a culture of continuous improvement starting from the top management level down to the labor level. To support the growth of a continuous improvement culture, the top management can develop rewards for all company members who can contribute the slightest improvement to growing the company performance. The awards are not only in the form of financial but also non-financial rewards, such as compliments, felicitations, or employee of the month programs, and the like that can motivate all company members to make innovation in their work.

CONCLUSION

Lean approach and practices have been gaining much attention in many organizations. Eventhough waste elimination is of major focus of this approach, it is also essential to know the major source of wastes as well as its root cause in order to create a proper improvement plan. We propose a lean analysis framework for waste management by incorporating various lean tool i.e., VSM, WAM, VALSAT and fishbone diagram to solve a waste management problem in one of Indonesian textile industry. During implementation, the waste assessment model results in the largest source of waste among the seven types of waste is waiting time and defects. Referring to VALSAT weighting calculations, waiting time and defects have a percentage of 20.42% and 20.17%, respectively. The results are in harmony with the Activity Mapping Process whereby the constraints on production processes in the weaving area were delays, consisting of 9 activities that took 221 minutes or 23.5% of the total time of 939 minutes. Of the time of 939 minutes, it is known that the activities that truly add value (VA) were 54.7% (513.5 minutes). The rest were activities that did not add value, which was divided into NVA of 20.6% (193 minutes) and NNVA of 24.8% (232.5 minutes).

Corrective action related to machine aspects is to carry out periodic maintenance and recalibration of all equipment on weaving machines. For the material, the company needs to guarantee the quality of the weft and warp yarns used in the production process to reduce the occurrence of breaks in the middle of the process, which then necessitates reprocessing. Further, a clear division of tasks should be initiated to ensure the fulfillment of the requisite supply of weft in the weaving section. As for the human aspect, discipline is needed for workers to reduce non-productive activities. Workers tend to do non-productive activities on the sidelines of waiting time or delay. Therefore, reducing waste related to waiting time or delay is the key to minimize waste in the weaving process.

Since we apply VSM only for describing the current state map due to the limited access during research, further study can be carried out using various experimental design methods to provide a picture of the future state map once improvement has been implemented. Providing the future state map can produce more sophiticated and convincing result, that will motivate the company to conduct improvement action plans to minimize waste.

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NOMENCLATURE

Seven types of waste:

O	: Notation for Overproduction
I	: Notation for Inventory
D	: Notation for Defect
M	: Notation for Motion
P	: Notation for Process
T	: Notation for Transportation
W	: Notation for Waiting

Waste relationship:

A	: Notation for Absolutely necessary
E	: Notation for Especially important
I	: Notation for Important
O	: Notation for Ordinary closeness
U	: Notation for Unimportant

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