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SIMPLIFICATION OF WASTES FOR A WAREHOUSE USING BOOLEAN LOGIC: A CONCEPTUAL PAPER

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Abstract

Warehouse accumulate wastes consisting of inventory, waiting and transportation. However, the existence of warehouse will increase the operation expenditure and can lead to profit losses. Therefore, manufacturers need to identify and minimize wastes to reduce the consumption of resources and keep minimum inventory in the warehouse. Value Stream Mapping (VSM) is an approach to minimize waste. This tool visualizes the information and material flow of manufacturing activities. The development of a model based from VSM determined the current state of wastes in a warehouse. From the information flow, the optimum combination of wastes was determined through Boolean concept. The wastes are simplified and combined by passing through the Boolean operators consist of AND Gate and OR Gate. The outcomes of this paper is to propose a conceptual model of new VSM to identify and minimize wastes in a warehouse. At the same time, to propose a method that can cater for time consumed in every activity which differs from one station to another.

Keywords: Boolean algebra, Lean manufacturing, Value stream mapping, Warehouse, Wastes.

1. Introduction

The main functions of the warehouse is to buffer and store the raw materials [1]. Warehouses act an interchange area for vendors, end users, and production lines [2]. The common activities that exist in the warehouse consist of inventory, waiting and transportation of materials. According to Toyota Production System (TPS), activities such as inventory, waiting, transportation, motion, over-processing, over-production and defect are classified as wastes during the development of TPS [3]. The main contributor for the large part of the total cost of logistic are inventory and warehousing. Wastes contributed up to 95% of all cost in non-lean manufacturing environments [4].

One of the goal in implementing Lean Manufacturing (LM) concept is focused on elimination of wastes. This is an effective way contribute to the high profit of most companies. VSM is applied in the companies to achieve the waste eliminations as an approach to LM. VSM is one an improvement tool in LM to assist in visualizing the whole production process, representing the material and information flow [5]. This tool also reveals the significant waste activities accumulated in the current process that lead to losses. Wastes increase lead time, do not add value to the components and consume extra resources. Apart from that, Lean Enterprise Research Centre concluded that 5% of the total activities in a manufacturing plant consists of Value-Added Activities (VAA), up to 35% described as the Necessary but Non-Value Added Activities (NNVAA) and the last 60% clarified as the Non-Value Added Activities (NVAA). Most manufacturers are aware of the issue and strive to eliminate as much waste as possible [5].

This paper aims to propose a conceptual model of improved VSM to identify and minimize waste in a warehouse. At the same time, to propose a method that can cater for time consumed in every activity [6]. The method will benchmark the most minimum time against with others time that consumed by the different activities. Boolean algebra was applied to determine the optimum combination of wastes that should be retained in the warehouse.

2. Literature Review

The Japanese word for waste known as ‘Muda’, whereas this term is related to each activity that does not add any value to a product [7]. The price of products increase when both time and resources are consumed. The timeline between the costumer’s order and the finished product’s delivery needs to be investigated, and wastes should be minimized to reduce time consumed [4]. The author identified the wastes in the industrial environment which are inventory, transportation, waiting, motion, overprocessing, overproduction, and defects. LM is the elimination of ‘Muda’ contributes for cost reduction, increase flexibility, improve efficiency, and increase the value generation for customers [8].

LM has created a global reputation based on improvement of production, reduction of expenses and increase the value creation of customer by the eliminating the production wastes in several companies [9]. For example, the Lean methods and techniques have changed the automotive industry to a global range of industries by spreading their mission [10]. The effective way to achieve the challenges of sustainable development currently had been proven by lean philosophy [11]. The term ‘Value Stream Mapping’ can be described as the mere process of directly observing the information flows and material flow as summarizing them visually and develop a future state map [12]. This tool has the capability to trace the wastes existing in manufacturing processes [13]. VSM is a well-known technique to optimize the production processes, which is used to visualize the production process and minimize the "seven wastes" [4]. VSM typically consists of two state map which are current and future. The current state map describes the information flow from order to unprocessed parts to completed products and future state map is an output of current state map from elimination of wastes [14].

Meanwhile, the Boolean algebra is an algebra for the manipulation of objects that can take two values, the true represent 1 and false represent 0. Boolean algebra also has operations that can be performed on these objects, or variables and the two common Boolean operators are AND, and OR.

3. Methods

This study consists of five phases that has been shown in Fig. A-1 (*Appendix A*). Phase 1 starts with observation and data collection that will leads to the further research. Phase 2, the data gathered from the Phase 1 are used to draw the Current State Map of activities. Phase 3, wastes from the warehouse can be distinguished by utilizing the Current State Map and can be eliminated with the Boolean logic concept. The Logic OR and Logic AND gates can be used to eliminate the unnecessary activities and to retain the necessary for both activities required by the warehouse. The truth table was constructed based on the Logic gates. The truth table indicated the optimum combination that can be accomplished by choosing the minimum activities. Phase 4, Future State Map is developed based on optimum combination that had obtained from the previous phase.

New Approach to Improve the Future State Map (Phase 5)

In this phase, the time of the activities need to be normalized to obtain the most minimum time, whereas this value is the smallest value among of the times consumed by the different activities in the current state map. The most minimum time is needed for the benchmark against with others time that consumed by the different activities in the current state map. This can be used to indicate the gap between the times of the activities that exist in the current state map and the shortest time among of those activities. In Eq. (1), the time normalized Z_{Un}, can be derived by dividing the time of each activity with the minimum time among activities.

$$Z_{Un} = X_{Un} / X_{U\min} \tag{1}$$

The normalized time Z_{Un}, can be existed by the different values in the truth table. Hence, the different values of Z_{Un} need to be reduced to achieve the most minimum requirement of the activities in the warehouse. Fig. A-2 (*Appendix A*) shows a flow chart shown how the time reduction can be conducted. The time reduction consists of 4 steps as the guidelines to obtain the most minimum value of Z_{Un}. 1) Draw the Boolean logic diagram of Z_{Un}. 2) Construct the truth table of Z_{Un}. 3) Determine the minimum combination of Z_{Un}. 4) Reduce the value of Z_{Un}.

4. Results and Discussion

The proposed method had been illustrated in this section.

Assume that, I_1, I_2, and I_3 represent the time for each inventory activities, while W_1 and W_2 represent the time for each waiting activity, and finally, T_1, T_2, T_3 and

T_4 represent the time for each transportation activity as shown in Fig. 1. T_1 represents receiving raw material from the receiving bay, and T_4 represents the transportation of the finished good into the outgoing area. T_1 and T_4 can be considered as the minimum requirement for the transportation in the warehouse because the transportations from receiving bay and to the outgoing are cannot be avoided. Therefore, the transportation activities consist of T_1 and T_4 need to be retained in the warehouse. The time consumed for each activity shown in Table 1.

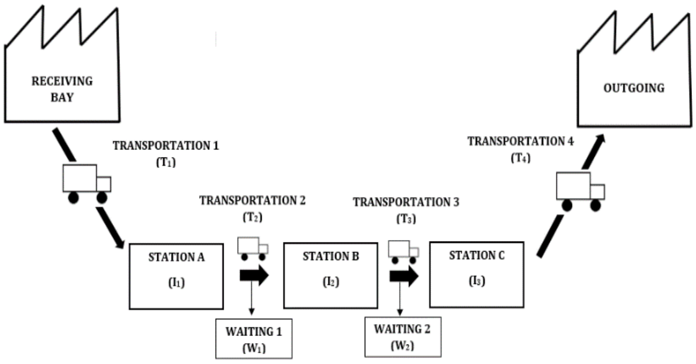

Fig. 1. Current State Map.

Table 1. Current time consumed.

Activities	Time, h
I_1	X_1=13
I_2	X_2 =3
I_3	X_3 =12
W_1	X_4 =2
W_2	X_5 =30
T_1	X_6 =9
T_2	X_7 =20
T_3	X_8 =3
T_4	X_9 =12

4.1. Time normalization

The time normalized for each activity is obtained from substitution of time of each activity into the Eq. (1) has been shown in Table 2.

Table 2. The time normalized.

Activities	Time Normalized, h
I_1	Z_{I1} =5
I_2	Z_{I2} =1
I_3	Z_{I3} =4
W_1	Z_{W4} = 1
W_2	Z_{W5} =5
T_2	Z_{T6} =7
T_3	Z_{T7} =1

4.2. Step 1

The Boolean diagram can be illustrated based on the value of Z_{Un} as shown in the Fig. 2. The Boolean diagram shows that P represent the output of all the process in the production line to deliver the part required by the outgoing bay. *I*, *W* and *T* are the activities involved to create the output *P*.

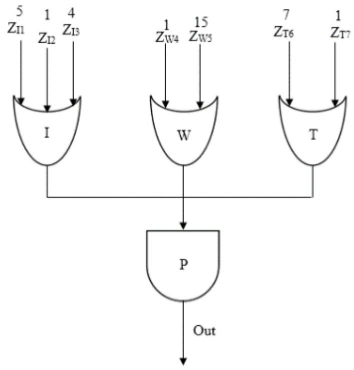

Fig. 2. Boolean diagram of Z_{Un}.

4.3. Step 2

The truth table can be constructed based on the values of Z_{Un} as shown in Table A-1 (*Appendix A*).

4.4. Step 3

Based on the Table A-1 (*Appendix A*), the minimum combination of the Z_{Un} can be obtained when Z_{I2}=1, Z_{W4}=1, and Z_{T7}=1 that can produce *P*=3.

4.5. Step 4

The values of Z_{Un} can be reduced with step-by-step reduction is shown in Fig. 3. From Table A-1 (*Appendix A*), $Z_{I1}+Z_{I2}+Z_{I3}+Z_{W4}+Z_{W5}+Z_{T6}+Z_{T7}=34$ is the maximum combination of Z_{Un} and $Z_{I2}+Z_{W4}+Z_{T7}=3$ is the minimum combination of Z_{Un}. The minimum combination of Z_{Un} leads to 91% of waste elimination whereas this combination consists of the minimum activity for the warehouse.

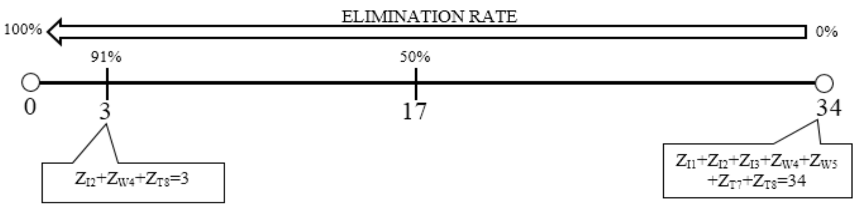

Fig. 3. The reduction of Z_{Un}.

Table 3 shows the 6 combinations of Z_{Un} had obtained from the elimination of 50% of wastes. Among these 6 combinations, 1 combination can be used to construct the future state map as shown in Fig. 4. Future state map that has been obtained from the proposed method can be used by the manufacturer as a target to reduce wastes that are accumulated in a warehouse. This target is used by manufacturer to determine the minimum time of activities that can be retained in a warehouse. This target is needed to assist manufacturer during the implementation of the improvement activities on current state map. This combination can be determined based on 2 requirements. First, the combination should contain the highest Z_{Un} because the large amount of wastes need to be reduced in the next reduction to achieve the most minimum combination of Z_{Un}. At the same time, the combination should consist of at least 1 inventory, 1 waiting and 1 transportation as shown in Fig. 5. Thus, the 2nd can be considered as the combination that have both requirements compared to other combinations.

Table 3. The combinations of Z_{Un} produce 50% reduction.

No.	Z_{I1}	Z_{I2}	Z_{I3}	Z_{W4}	Z_{W5}	Z_{T6}	Z_{T7}	P_{Out}
1st	0	0	0	1	15	0	1	17
2nd	0	1	0	0	15	0	1	17
3rd	0	1	0	1	15	0	0	17
4th	5	0	4	0	0	7	1	17
5th	5	0	4	1	0	7	0	17
6th	5	1	4	0	0	7	0	17

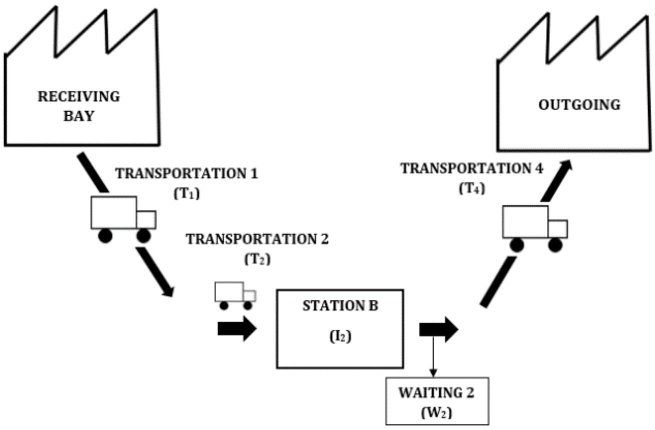

Fig. 4. Future state map.

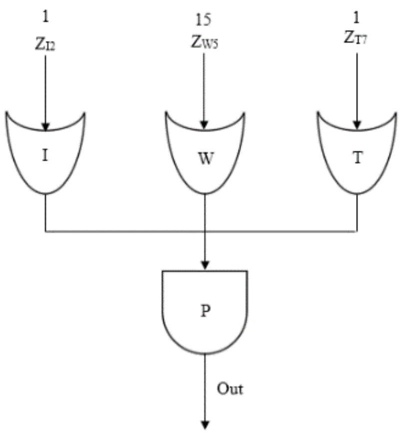

Fig. 5. Boolean diagram of the reduced Z_{Un}.

5. Conclusions

The method that had been proposed in this research can be used as one of the methods for the manufacturer to identify and minimize wastes in a warehouse. A method that can be used to cater the different amount of time consumed in each station had been developed in this research. This method can be used as a method to benchmark the minimum time against time that is consumed by different activities. This method indicates the gap that can exist between times of activities with the shortest time among those activities. The optimum combination of the wastes can be obtained from the truth table of the Boolean algebra. The future state map can be constructed based on the combination whereas the combination was chosen based on two requirements.

- The combination should contain the highest time of activity
- The combination should consist of at least 1 inventory, 1 waiting and 1 transportation.

This method produces the combinations for the wastes which are exist in the production line based on Boolean algebra from Value Stream Mapping. However, this method will have the tendency to make the mistakes or errors during the creation of the combinations among wastes. Therefore, the improvement should be made on this method in determining the amount of wastes in the production line without making mistakes or errors.

Acknowledgement

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Nomenclatures

I	Inventory
n	n-th of the activities
P	Output
T	Transportation
U	The type of activities
W	Waiting
X_{Umin}	The most minimum time among of the activities, h
X_{Un}	The time of the activities, h
Z_{Un}	The normalized time, h

Abbreviations

LM	Lean Manufacturing
NNVAA	Necessary but Non-Value Added Activities
NVAA	Non-Value Added Activities
TPS	Toyota Production System
VAA	Value-Added Activities
TPS	Toyota Production System
VSM	Value Stream Mapping

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Appendix A

Table A-1. The truth table of Z_{Un}.

Z_{I1}=5	Z_{I2}=1	Z_{I3}=4	Z_{W4}=1	Z_{W5}=15	Z_{T7}=7	Z_{T8}=1	P_{OUT}	Total
0	0	0	0	0	0	0	0	0
0	0	1	0	1	0	1	1	20
0	0	1	0	1	1	0	1	26
0	0	1	0	1	1	1	1	27
0	0	1	1	0	0	1	1	6
0	0	1	1	0	1	0	1	12
0	0	1	1	0	1	1	1	13
0	0	1	1	1	0	1	1	21
0	0	1	1	1	1	0	1	27
0	0	1	1	1	1	1	1	28
0	1	0	0	0	1	1	1	9
0	1	0	0	1	0	1	1	17
0	1	0	0	1	1	0	1	23
0	1	0	0	1	1	1	1	24
0	1	0	1	0	0	1	1	3
0	1	0	1	0	1	0	1	9
0	1	0	1	0	1	1	1	10
0	1	0	1	1	0	1	1	18
0	1	0	1	1	1	0	1	24
0	1	0	1	1	1	1	1	25
0	1	1	0	1	0	1	1	21
0	1	1	0	1	1	0	1	27
0	1	1	0	1	1	1	1	28
0	1	1	1	0	0	1	1	7
0	1	1	1	0	1	0	1	13
0	1	1	1	0	1	1	1	14
0	1	1	1	1	0	1	1	22
0	1	1	1	1	1	0	1	28
0	1	1	1	1	1	1	1	29
1	0	0	0	1	0	1	1	21
1	0	0	0	1	1	0	1	27
1	0	0	0	1	1	1	1	28
1	0	0	1	0	0	1	1	7
1	0	0	1	0	1	0	1	13
1	0	0	1	0	1	1	1	14
1	0	0	1	1	0	1	1	22
1	0	0	1	1	1	0	1	28
1	0	0	1	1	1	1	1	29
1	0	1	0	0	1	1	1	17
1	0	1	0	1	0	1	1	25
1	0	1	0	1	1	0	1	31
1	0	1	0	1	1	1	1	32
1	0	1	1	0	0	0	1	10
1	0	1	1	0	0	1	1	11
1	0	1	1	0	1	0	1	17
1	0	1	1	0	1	1	1	18
1	0	1	1	1	0	1	1	26
1	0	1	1	1	1	0	1	32
1	0	1	1	1	1	1	1	33
1	1	0	0	1	0	1	1	22
1	1	0	0	1	1	0	1	28

1	1	0	0	1	1	1	1	29
1	1	0	1	0	0	1	1	8
1	1	0	1	0	1	0	1	14
1	1	0	1	0	1	1	1	15
1	1	0	1	1	0	1	1	23
1	1	0	1	1	1	0	1	29
1	1	0	1	1	1	1	1	30
1	1	1	0	1	0	1	1	26
1	1	1	0	1	1	0	1	32
1	1	1	0	1	1	1	1	33
1	1	1	1	0	0	1	1	12
1	1	1	1	0	1	0	1	18
1	1	1	1	0	1	1	1	19
1	1	1	1	1	0	1	1	27
1	1	1	1	1	1	0	1	33
1	1	1	1	1	1	1	1	34

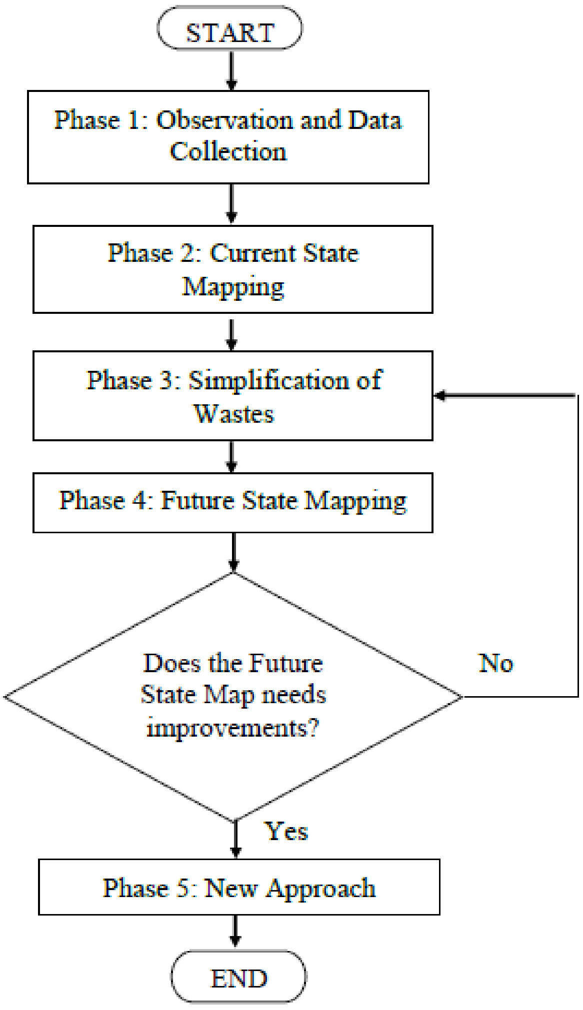

Fig. A-1. Flowchart for the methodology employed [6].

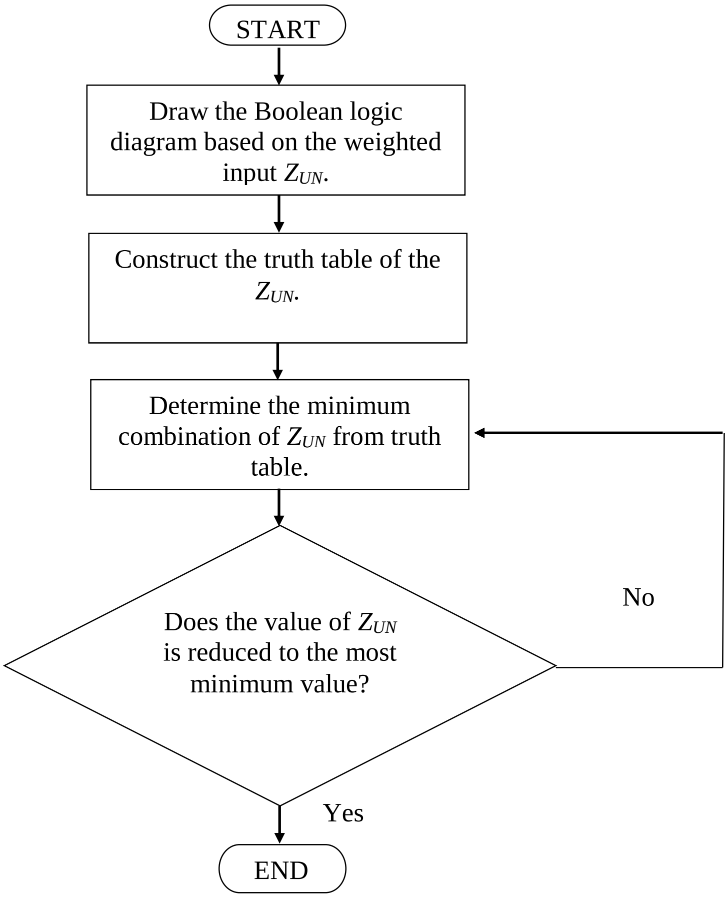

Fig. A-2. Flowchart for time reduction.