Value Stream Mapping to Improve Workplace to support Lean Environment

Ahmad Nur Aizat *Ahmad*.^{1,*}, Te Chuan *Lee*.¹ Rohaizan *Ramlan*.¹, Md. Fauzi *Ahmad*.¹,
Norafifah *Husin*.² and Mustaqqim *Abdul Rahim*.³

¹Department of Production and Operation Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia (UTHM), Malaysia

²Department of Industrial Engineering, Faculty of Mechanical Engineering, Universiti Teknologi Malaysia (UTM), Malaysia

³Department of Civil Engineering, School of Environmental Engineering, Universiti Malaysia Perlis (UniMAP), Malaysia

Abstract. In recent years, lean manufacturing is being followed by various sectors in order to keep their competitiveness in the global markets. Lean manufacturing plays a vital role in improving the efficiency of operation by eliminating or reducing wastes. Nonetheless, most of small and medium enterprises (SMEs) lack sufficient knowledge or information on the benefits of implementing lean manufacturing. The main objective of this study is to apply value stream mapping, one of lean manufacturing tools, for improving the productivity in a SME by eliminating non-value added activities. In this study, lean manufacturing was adopted at a SME, particularly a food industry. Value stream mapping was served as main tool to identify the wastes and improvement opportunities in production line. Subsequently, different lean manufacturing tools such as Kaizen Burst, one piece flow, and 5S were applied to eliminate or reduce identified wastes. Based on the future state value stream mapping, final results showed that the total operation time and non-added value activities time were successfully decreased from 1993 seconds to 1719 seconds, and 234 seconds to 104 seconds, respectively. The findings of this study indicate that value stream mapping is an effective approach to eliminate the wastes and improve the productivity.

1.0 Introduction

Despite an abundance of obstacles, the biggest challenge faced by manufacturer is how to deliver their products or services quickly at low cost but high quality. A number of approaches have been undertaken using computer simulation, statistical analysis, and lean manufacturing for improving the productivity and efficiency of production line [1]. Among these, lean manufacturing is one of most popular approaches and has been widely implemented in many manufacturing industries around the world.

* Corresponding author: aizat@uthm.edu.my

Lean manufacturing is currently becoming more popular in manufacturing industries. It can be seen that lean manufacturing has been developed, growth up, and adopted progressively in many major manufacturing industries in order to remain their competitive in an increasingly global market [2]. The main focus of this approach is on cost reduction by eliminating waste or non-value added activities. In other words, the perfect strive of the manufacturing system can be achieved through successful implementation of lean elements [3].

Lean manufacturing has been proven its capability in improving workplace effectiveness, most notably in waste reduction. In general, workplace is defined as physical structure and location where work is undertaken and organized. It is necessary to ensure the processes in the workplace are run smoothly and absence of non-value added activities such as waiting time, overproduction, and unnecessary movement. Nowadays, almost all the manufacturing industries trying to improve the productivity performance by minimizing the production lead time and waste. However, most of SMEs facing obstacle such as production waste management. This is attributed to the fact that SMEs lack sufficient knowledge or information on the benefits of implementing lean manufacturing [4,5].

In order to address these issues, a case study was conducted in a domestic SME, particularly food industry, to reduce the total production lead time through elimination of non-value added activities. Value stream mapping (VSM), one of lean manufacturing tools, was applied to eliminate non-added value activities in production line. There are three objectives for this study: (1) To apply VSM for identifying non-value added activities and highlighting the improved area, (2) To analyse the current state of VSM to improve process flow of the operation, and (3) To propose future state of VSM for the company.

2.0 Literature Review

2.1 Lean Manufacturing

Lean manufacturing concept was originated from Japan after the World War II owing to the vast shortage of materials, financial, and human resource. Lean manufacturing or known as Toyota Production System (TPS) is a production strategy that aims to eliminate waste and deliver increased value to the product and customer. Generally, lean manufacturing focuses on pinpointing the major source of wastes and eliminate the wastes using lean manufacturing tools [6–10]. There are several lean manufacturing tools have been extensively used to identify and eliminate wastes, for example, include but not limited to Kanban, 5S, Kaizen, Value Stream Mapping, Total Productive Maintenance, and Poka-Yoke [11]. Apparently, lean manufacturing attract a great of attention in manufacturing industries owing to its exclusive advantages, i.e. reduce lead time, reduce inventory, require less space, less process waste, increase process understanding, and financial saving [10].

It is often suggested that lean should be understood on two levels: (1) the strategic level of how to understand value, and (2) the operational level (tools) of how to eliminate waste [12]. It is noteworthy to mention that lean manufacturing strives for perfection through continuous improvement to eliminate waste by identifying value added activities (VA) and non-value added activities (NVA).

Lean means manufacturing without waste. Waste, or known as “Muda” in Japanese term, is defined as any activity in a process which does not add value to the customer. However, sometime the waste cannot be eliminated as it is a necessary part of the process and adds value to the company, for instance, financial control [10]. There are seven sources of the NVA wastes commonly found in manufacturing industries, which are, overproduction, waiting, transportation, unnecessary motion, unnecessary inventory, defects, and inappropriate processing. Elimination of these wastes is achieved through the successful implementation of lean elements. Continuous improvement is the core of lean thinking, therefore, all the processes will continually improve to reduce the waste and ultimately achieve a waste-free process [6–8,20].

2.2 Value Stream Mapping

Value stream mapping (VSM) is one of the lean manufacturing tools to identify wastage of resource and eliminate or reduce them for improving productivity [14]. Nowadays, VSM has been widely used in many sector such as healthcare industry, manufacturing industry, finance firm, office environment, etc [15]. It has been recognized that VSM is a powerful lean tool to improve the productivity of manufacturing industries.

Generally, VSM is a collection of all actions such as value added and non-value added activity that are required to bring a product through the main flows, starting with raw material and ending with customer [16]. According to Rother & Shook [16], VSM is a drawing map using a predetermined set of standardized icons to virtualize a product's production path from start to end. There are two different in the method of VSM, which are future state of VSM and current state of VSM.

- *Current state map*: A current state map (CSM) is a snapshot of how a process is currently done. It is also known as current state process flowchart, or a current state value stream map, but the principle is the same. The CSM shows the current methodology of how the products being produced or service being performed to customer. The CSM enables process flow to be identified, analysis data, as well as identity and prioritise areas for improvement [7,9].

- *Future state map*: Future state map (FSM) illustrates how things should be done based on takt time requirements [17]. FSM presents the flow of product after eliminating all inefficiency activities. There are three phases for mapping the future state which have to be performed together, namely (1) Customer demand phase: Understanding the customer needs for service, quality, and lead time, (2) Continuous flow phase: Implementation of continuous flow by make sure customer receive the right item, in the right quality, and at the right time, and (3) Levelling phase: Distribute the works evenly to reduce queue times [18].

Basically, there are 4 steps to improve efficiency of manufacturing industries using VSM, which are: (1) choose a particular product or product family as the target for improvement, (2) illustrate a current state map after walking and observing along the actual process, (3) analyse the current system and identify the weakness and waste, (4) create the future state map to virtualize a picture of how the production line should look after eliminating wastes [9].

In the practical situation, Ventakaraman et al. [19] applied the VSM for reduction of cycle time in a machining process in order to increase the export sales. The results showed that the manufacturing time successfully reduced by 40 %, defects were reduced, higher process capability and quick response to the customer demand in small lots were achieved.

Meanwhile, Rohani and Zahraee [1] conducted a case study to improve the production line using VSM. A leading manufacturer of industrial building paint was selected as a case study for their research. The FSM showed that production lead time decreased from 8.5 days to 6 days, and the value added time decreased from 68 minutes to 37 minutes after implementing some lean manufacturing tools such as 5S, Kanban method, and Kaizen.

Similarly, Ahmad, A.N.A [20] applied VSM in a manufacturing firm producing aircraft parts. He mentioned that application of VSM uncovered number of problems and bottlenecks in company production process. Surprisingly, huge improvements had been made after applying VSM. Total lead time successfully reduced by 24.8%. On the other hand, the VA index increased around 32%.

Recently, Stadnicka and Ratnayake [21] demonstrated the use of VSM in aircraft maintenance processes for minimizing the lead-time of maintenance services and subsequently minimizing the costs of maintenance services. As expected, production lead-time decreased by 63% after eliminating NVA. Additionally, they also revealed that the process cycle efficiency has increased about four times.

3.0 Research Methodology

A SME company in Batu Pahat, Johor was selected as a case study for this paper. This company is a popular manufacturer of various fried chips. The total number of operators is 19. All the operators in the production line were involved in this study. The average daily demand of customer is approximately to 462 kg. Meanwhile, the working time is 8 hours per day including 1 hour break.

Qualitative approach was used in this study for collecting data. Observation and time study were carried out for obtaining accurate data. The cycle time of each process was recorded using a stopwatch. As mentioned previously in literature review, there are seven types of wastes in production line. However, underutilizing talent was added in this study as the eighth waste because this factor is directly affected the production system and create unwanted waste, as discussed by other author [22].

Initially, the observation was made for collecting data such as layout and facilities of company, number of operators, number of processes and cycle time for each process. Next, the current state map of the company is prepared in order to identify the potential wastes and improvement opportunities in the production line. Subsequently, several lean manufacturing tools such as Kaizen Burst, one piece flow, and 5s were implemented for enhancing the efficiency of production line. Takt time also was calculated to set the pace of production process. In the end of the study, a future state map was illustrated to examine the effectiveness of proposed improvements by comparing the total operation time between the current state and future state map.

4.0 Results and Discussion

4.1 Current State Value Stream Mapping (CSVSM)

The ultimate goal of CSVSM is to illustrate how a product flow through the value stream, starting from raw materials to finished product. In this study, 9 processes were identified as follows:

- Process 1: Materials preparation
- Process 2: Peeling process
- Process 3: Cutting process
- Process 4: Wash and transfer into basket
- Process 5: Frying process and put on the tray
- Process 6: Packaging for 5 kg
- Process 7: Arrange on the rack
- Process 8: Packaging for 500 g
- Process 9: Warehouse

4.1.1 Takt Time

Takt time is defined as the time needed to produce a product to meet customers’ demand. Basically, if the demand increases, the Takt time decrease, and vice versa. On the other hand, if bottleneck cycle time less than Takt time, then customers’ demand met, and vice versa [7]. Hence, Take time is served as a management tool to determine whether the production line is ahead or behind the production schedule. Additionally, it also plays a vital role as an alignment tool to calculate the real-time production needs. In this case, Takt time was calculated as below:

Customer demand per day : 462 kg
Working time : 8 hours (one shift per day)
Break time : 1 hour
Available time : 7 hours per day

$$\begin{aligned} \text{Takt time} &= \text{Net Operating Time} / \text{Customer Demand} \\ &= (8 \text{ hours} - 1 \text{ hours}) \times 60 \text{ min} / 462 \text{ kg} \\ &= 0.9 \text{ min per kg} \\ &= 54 \text{ sec} \end{aligned}$$

Fig. 1 demonstrates the CSVSM. Meanwhile, a summary of NA and NVA data is tabulated in Table 1. Based on Fig. 1 and Table 1, it can be clearly seen that the total lead time for manufacturing process is 2227 seconds (approximately to 37.12 minutes). Specifically, the time of VA and NVA are 1993 seconds (approximately to 33.22 minutes), and 234 seconds (approximately to 3.9 minutes), respectively, Hence, it can be inferred that the time of NA is higher than NVA, and the flow of process is stable. However, there’s still have room for improvement.

Fig. 1: The current state value stream mapping.

Table 1: Summary of VA and NVA

Operation Number	Processes	Total Operation Time (sec)			% NVA (to be eliminated)
		VA	NVA	Lead Time	
1	Materials preparation	1280	15	1295	1.17
2	Peeling process	109	0	109	0
3	Cutting process	8	55	63	87.3
4	Wash and transfer into basket	55	55	110	50.00
5	Frying process and put on the tray	462	44	506	8.7
6	Packaging for 5 kg	25	3	28	10.71
7	Arrange on the rack	4	4	8	50
8	Packaging for 500 g	41	31	72	43.06
9	Warehouse	9	27	36	75
	Totals	1993	234	2227	

4.2 Problem Identification and Improvement Proposal

To improve the process flow of the production, identifying the waste in the process is the first step to be carried out. The problems can be solved when the wastes are identified as well as where the problems are coming from. Based on observations and CSVSM, a summary of improvement proposal is presented in Table 2.

Table 2: The improvement proposal

No.	Waste	Observations	Proposed Improvement
1	<i>Unnecessary motion</i>	Operators needed to walk further to get the materials	<ul style="list-style-type: none">• New floor layout for the production area• Apply one-piece flow in the production line
2	<i>Space</i>	Moving space of forklift was limited owing to a portion of finished product and raw materials inventory were placed outside of the warehouse	<ul style="list-style-type: none">• Make the packaging room become the storage room• Apply the 5S concept in the production area
3	<i>Underutilizing talent</i>	Creative and talented operators were instructed to do only one task	<ul style="list-style-type: none">• Give the operators an opportunity to express their opinions for improving the current production line flow
4	<i>Defects</i>	The materials is overcooked or undercooked	<ul style="list-style-type: none">• Set the timer to avoid overcooked or undercooked
5	<i>Excess Processing</i>	Packaging for 5 kg and 500 g products were done in different workstations.	<ul style="list-style-type: none">• Combine the packaging process for 5 kg and 500 g
6	<i>Waiting</i>	Operators cannot proceed their task if the previous processes were delayed	<ul style="list-style-type: none">• Reallocate the number of operator at each workstation
7	<i>Transportation</i>	Lack of wheelbarrow and trolley cart and consequently affect the daily output	<ul style="list-style-type: none">• Rearrange the tool cart's schedule to maximize its usage

4.2.1 Kaizen Burst

Kaizen Burst is a lean manufacturing tool to generate the improvement ideas during pahse of developing current and future state of VSM. In this study, there are 6 Kaizen Burst had been applied to reduce the NVA and lead time. As shown in Fig. 1, the 6 Kaizen Burst applied in this study are as follows:

- 1st : Reallocated the operators
- 2nd : Reduced the operators in the workstation
- 3rd & 5th : Transferred the operator to other workstation
- 4th : Place the basket in the basin during washing process
- 6th : Combine the process 6 and 8

4.2.3 One-piece Flow Concept in the Production Line

Continuous flow, or sometimes to be called as single piece flow or one-piece flow, refer to the concept of the movement of work in progress (WIP) /work piece at 1 time between production process in a work cells. It keeps WIP at the lowest possible inits and encourage balance in work as well as improve the quality of work. [23]. As mentioned previously, unnecessary movement of operators resulted increasing of lead time. Therefore, one piece flow process was suggested in this case to avoid spending time on walking from one station to another.

4.2.4 Application of the 5S in the Production Area

5S is a method on how to organize workplace in the proper and tidy environment. This method is applied at a production area either others areas which to entrust the areas are in proper arrangement f material and in proper flow of the material movement. In this case, the floor in production area was dirty, dusty, and slippery. This occurred mainly due to the fallen soil from the raw materials, spillage of water during the washing process, and spillage of cooking oil during the frying process. Therefore, 5S was implemented to eliminate wastes that resulted from a poorly organized production area and avoid the unwanted accident. Few improvements were made in this case, for example, the floor of production line were swapped and mopped frequently, the rack was arranged properly to maximize the usage of the space for other purposes, and tools were cleaned and placed properly after being used.

4.2.2 New Floor Layout

The biggest waste occurred in the production line was unnecessary movement, especially operators from the cutting and frying station. Operators of both stations needed to walk further to get the materials and return with heavy loads. Consequently, the cycle time was increased. Fig. 2 and 3 illustrates the movement of operators in the production area before and after implementing proposed improvement, respectively.

Fig. 2: Floor layout before implementing proposed improvement.

Fig. 3: Floor layout after implementing proposed improvement.

4.3 Future State of Value Stream Mapping (FSVSM)

FSVSM is a tool to illustrate the improvement plan after implementing lean manufacturing tools. In this case, the existing processes had been combined and reduced to 8 processes, as follows:

- Process 1: Materials Preparation
- Process 2: Peeling process
- Process 3: Cutting process
- Process 4: Wash and transfer into basket
- Process 5: Fryng process and put on the tray
- Process 6: Packaging for 5kg and 500g
- Process 7: Arrange on the rack
- Process 8: Warehouse

The FSVSM of this study is shown in Fig. 4. Meanwhile, comparison of cycle time between current state and future state is presented in Table 3. It is noteworthy to mention that the quality of finished product remain unchanged even though the 2 packaging processes were combined. As shown in Table 2, it can be inferred that the total operation time reduced from 1993 seconds to 1719 seconds, or 13.75 % reduction. On top of that, the NVA was successfully decreased from 234 seconds to 104 seconds. Additionally, negative values of total reduced can be noticed from Table 2. This occurred mainly due to the increasing number of operators at that particular process. However, it resulted in a reduction of waiting time, bottleneck at workstation, and production flow became smoother. It is critical to note that increasing of cycle time in this study does not lead to increasing of waste, and conversely increased the value added time to the products.

Fig. 4: Future state value stream mapping.

Table 3: Comparison between current and future value stream mapping

Processes	Total Operation Time (sec)			% reduced or increased
	Current State	Future State	Total reduced	
Operation Number	9 processes	8 processes	1	12.5
Peeling process	109	0	109	0
Process 1	1280	920	360	39.13
Process 2	109	101	8	7.92
Process 3	8	11	-3	-27.27
Process 4	55	10	45	450
Process 5	462	616	-154	-25
Process 6	25	50	16	32
Process 8	41			
Process 7	4	2	2	100
Process 9	9	9	0	0
Total	1993	1719	274	13.75

5.0 Conclusions

In summary, this study has shown that VSM is an effective tool to eliminate waste in production operation of industry. The application of VSM associated with different lean manufacturing tools had successfully enhance the efficiency of production line. Moreover, the new floor layout and combination of two packaging processes were effectively reduced the unnecessary movement and NVA. The total operation time and NVA time were successfully reduced from 1993 seconds to 1719 seconds, and 234 seconds to 104 seconds, respectively. Consequently, it can reduce the company’s operation cost, enhance the operating performance of production line, and lastly meet the customers’ demand.

6.0 Acknowledgment

Appreciation to UTHM and ORICC, Universiti Tun Hussein Onn for supporting this research. Appreciation also to Manufacturing Technology Management (MTM) focus group, Faculty of Technology Management, UTHM.

References

1. J.M. Rohani, S.M. Zahraee, *Procedia Manuf.* **2**, 6–10 (2015)
2. A. Azizi, T. T. Manoharan, *Procedia Manuf.* **2**, 153–158 (2015)
3. A. Agarwal, A. Kumar, A.K. Madan, *Int. J. Ind. Eng. Technol.* **7**, 31–38 (2015)
4. A. Raghunath, R.V. Jayathirtha, *J. Adv. in Res. & Technol* **2**, 1–7 (2013)
5. O. Bakås, T. Givaert, H. Van Landeghem, *Challenges and success factors for implementation of lean manufacturing in European SMES* (Tapir Academic Press, Norway, 2011)
6. E.W. Dickson, S. Singh, D.S. Cheung, C.C. Wyatt, A.S. Nugent, *J. Emerg. Med.* **37**, 177–182 (2009)
7. R. Sundar, A.N. Balaji, R.M. Satheesh Kumar, *Procedia Eng.* **97**, 1875–1885 (2014)
8. M.G. Yang, P. Hong, S.B. Modi, *Int. J. Prod. Econ.* **129**, 251–261 (2011)
9. F.A. Abdulmalek, J. Rajgopal, *Int. J. Prod. Econ.* **107**, 223–236 (2007)
10. T. Melton, *Chem. Eng. Res. Des.* **83**, 662–673 (2005)
11. A. R.R. Rahani, M. Al-Ashraf, *Procedia Eng.* **41**, 1727–1734 (2012)
12. P. Hines, N.L. Rich, *Int. J. Oper. & Production Manag.* **17**, 46–64 (1997)
13. R. Shah, P.T. Ward, *J. Oper. Manag.* **25**, 785–805 (2007)
14. S.K.P.N. Silva, *Int. J. Lean Think.* **3**, 36–56 (2012)
15. P. Senna, A. Gomes, A. Monteiro, D. Pinha, *Brazilian J. Oper. Prod. Manag.* **13**, 406–420 (2016)
16. J. Rother, M. & Shook, *Learning to see: value stream mapping to create value and eliminate muda* (The Lean Enterprise Institute, Massachusetts, 1999)
17. D. Seth., V. Gupta, *Prod. Plan. Control.* **16**, 44–59 (2005)
18. T. Tapping, D. Shuker, *Value stream management for the lean office* (Productivity Press, New York, 2003)
19. K. Venkataraman, B.V. Ramnath, V.M. Kumar, C. Elanchezhian, *Procedia Mater. Sci.* **6**, 1187–1196 (2014)
20. A.N.A. Ahmad, H. Sulaiman, *Int. J. Mech. Eng. And Adv. Mat.* **1**, 13-18 (2015)
21. D. Stadnicka, R.M.C. Ratnayake, *Procedia Eng.* **182**, 665–672 (2017)
22. A. Muse Ouma, D.A. W. Njeru, J. Dennis, *Int. J. Acad. Res. Bus. Soc. Sci.* **4**, 361–368 (2014)
23. A. C. Yamagar; P. M. Ramanan, *Proc. 2nd Int. Conf. Manuf. Eng. Qual. Prod. Syst.* 104–112 (2010)