



AENSI Journals

Journal of Applied Science and Agriculture

ISSN 1816-9112

Journal home page: www.aensiweb.com/JASA



## Implementation of Value Stream Mapping (VSM) in SMEs – Identification of Waste for Continuous Improvement

T.C. Eow, S. Ahmed, M. Dahari

Manufacturing System Integration (MSI), Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.

### ARTICLE INFO

#### Article history:

Received 25 November 2014

Received in revised form

2 December 2014

Accepted 12 December 2014

Available online 27 December 2014

#### Keywords:

Value Stream Mapping (VSM)

SMEs

Lean techniques

Electronic manufacturing firm

### ABSTRACT

SMEs in Malaysia have been trying to adopt lean techniques to remain competitive in global market; however there is only little studies regarding implementation of lean manufacturing especially in the electrical and electronics industry. The aim of this study is to apply Value Stream Mapping (VSM) technique to support and implement lean methods in a small electronic manufacturing organization. Activities such as mapping of current and future state, identifying both the value added and non-value added activities, analysing and visualizing the hidden waste and source of waste will be involved in this case study. Current state map is first being mapped to describe the current situation of the manufacturing firm whereas future state map is used to show the proposed improvement action plans. A six steps modified methodology will be proposed to guide practitioners the correct way to apply lean techniques with the aid of VSM; however this paper does not intend to challenge the notions of VSM methodology long established in literature. The case study shows that there is significant improvement of productivity and lead time by applying VSM.

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**To Cite This Article:** T.C. Eow, S. Ahmed, M. Dahari, Implementation of Value Stream Mapping (VSM) in SMEs – Identification of Waste for Continuous Improvement. *J. Appl. Sci. & Agric.*, 9(21): 18-26, 2014

## INTRODUCTION

Nowadays, increased customer requirements and intensified global competition have forced organizations to transform their current manufacturing management to more efficient strategies so that the overall performance of the organization can be improved (Zhou, 2012). Lean manufacturing has been applied by various leading manufacturing organizations all around the world to respond rapidly to the appertaining changes with the warranty of high quality and low cost. Originating from the Toyota Production System, lean tools and techniques such as Value Stream Mapping (VSM), 5S, Single-Minute Exchange of Dies (SMED), Just-in-Time (JIT), kaizen and One Point Lesson (OPL) have been widely used in various industries (Hines, Holweg, & Rich, 2004; Nordin, Deros, & Wahab, 2010). According to empirical studies which taken wide range of organizations into account, lean manufacturing has successfully generated intangible and tangible advantages such as reduction in lead time, inventories, cost, work-in-process and improvement in productivity, customer satisfaction, quality and delivery time (Abdulmalek & Rajgopal, 2007; Dora, Kumar, Van Goubergen, Molnar, & Gellynck, 2013; Melton, 2005; Pattanaik & Sharma, 2009; Rose, Deros, Rahman, & Nordin, 2011). However, there are many successful implementations reported in large organizations but for small and medium enterprises (SMEs), there is still lack of documented evidence in lean implementation due to their small size, limited managerial capabilities and limited capital investment.

SMEs in Malaysia are facing tremendous pressures as customers are demanding higher quality and lower cost product, more manufacturing flexibility and on time delivery. According to SME Corporation Malaysia (2012), SMEs constitute 97.3% of total business establishments in the country and contribute to Gross Domestic Product (GDP) from 29.4% in year 2005 to 32.7% in year 2012. It demonstrates that the contribution of SMEs to economic growth and development has become more vital. Nordin et al. (2010) stated that automotive industry in Malaysia were classified as in-transition towards lean manufacturing practices based on an exploratory study of lean implementation in Malaysia. Based on previous studies by Nordin et al. (2010) and Wong and Wong (2011), SMEs are less likely to implement lean practices due to impedances and limitations such as lack of professional skills and lack of commitment from both top management and employees. Undeniably, most of the SMEs only focus on production rather than investing capital, time and effort to improve

**Corresponding Author:** T.C. Eow. Manufacturing System Integration (MSI), Department of Mechanical Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia.  
Tel: +60162323194, E-mail: tingchingew@gmail.com

other aspects such as quality and efficiency. Hence, although many SMEs have been trying to adopt lean to remain competitive in this global market, in reality they are not able to transform themselves into a lean-based organization toward creating the world leading organizations (Rahani & al-Ashraf, 2012).

There is a wide range of lean improvement tools available to organization, which includes TQM, JIT and TPM (Chiarini, 2012; Hines *et al.*, 2004). The selection of suitable techniques and approaches, together with their incorporation and applicability are essential to ensure that organizations can gain maximum benefits from application. Among the lean tools, Value Stream Mapping (VSM) is increasingly recognized by industries from the wealth of assessment tools. Womack and Jones (1996) defined VSM as 'The simple process of directly observing the flows of information and materials as they now occur summarizing them visually and then envisioning a future state with much better performance'. VSM is different from the conventional recording methods, as it captures the information at each individual stations about resources utilization, process cycle time, changeover time, work in process inventory, worker requirement and also the information flow from order to raw material to finished goods (Singh, Garg, & Sharma, 2011). Unlike most of the process mapping techniques which only document the basic product flow, VSM maps simultaneously maps the material flows and information flows that signal and control production (Braglia, Carmignani, & Zammori, 2006). For instance, it records where the raw materials and work in process are stored and triggers the movement of material from one workstations to the next process are key pieces of information.

Toyota production system classified waste into three categories - Muda, Muri and Mura, respectively denoted to non value-added activity, production unevenness and overburden. Taichi Ohno further classified Muda into seven types: transport, inventory, motion, waiting, overproduction, over processing and defects. Most organizations only focus on eliminating Muda because the wastes can be found by using appropriate tools and also by close observations. Not putting any effort in the other two wastes may lead to problems in the organization in the long term run. In fact Mura and Muri are the main causes of Muda in the organization. Undeniably, leaner operations improve production lead time, process reliability and consistency, productivity and cost effectiveness. In turn, it helps to expose further waste and quality problems in the system.

The purpose of this paper is to apply a case-based method to demonstrate that lean techniques can assist organizations in reducing or eliminating waste, improving productivity and quality, reducing lead time and obtaining better financial and operational control. One of the electronic organizations in Malaysia is chosen as case study due to there is limited studies on implementation of lean manufacturing in Malaysia especially in the electrical and electronics industry. The aim is to explore the possibility of integrating of several lean tools to complement VSM particularly at the implementation front. The organization of the paper is first with the methodology, followed by the predicament of current value stream mapping and proposed solutions and methodology.

### *1. Case Study Methodology Applied:*

In this paper, case study research method is applied in one purposively-selected Malaysian SME manufacturing organization. This approach has been adopted by researchers for many years across a variety of field due to its usefulness in examining contemporary real-life situations and provides the basis of the application in the manufacturing industries. VSM was applied as a guideline or method to consider the possibility of integrating different lean tools to improve the current productive system performance.

#### *STEP 1: Identification of problem statement and objectives (Gemba walk):*

At the beginning, problem statement focusing on the issues arise in the organization must be stated clearly. This is important to drive us to the main goal of the research without focusing on the wrong direction. Once problem statement is identified, objectives can then be determined. The objective defined must be able to encounter the stated problem with specific, measurable, attainable, reliable and with a clear time bound. To identify and understand the real situation in the organization, Gemba walk must be conducted with the support of engineers and team of production line so that full understanding on current practice of the organization can be achieved.

#### *STEP 2: Identification of product families:*

With limited resources available and capital investment especially in SMEs, efforts need to be concentrated only on those products that really need to be done. Many criteria have been developed to choose the suitable product family such as highest customer demands, highest percent of sales volume, largest volume, highest mix, most critical one and occupying longest at bottleneck machines (Abdullah, 2003). The selection is based on contextual attributes such as the affordability of resources and the confidence of top management.

#### *STEP 3: Development of current state map:*

Current state map is mapped out by using paper and pencil as it is important for us to have an overall picture of the current manufacturing practices. Once again Gemba walk is an essential approach for data

collection. It is preferable that walk begins at the end of the process, working way upstream to the start of process, to obtain a customer-supplier perspective at each of the process. The flow of material is drawn from left to right on the bottom half of the paper. The information flow is drawn from right to left in the top half of the mapping paper by using a narrow line (Keyte & Locher, 2004). The standard icons are used to represent the information such as the number of operators. Apart from the standard symbols, other symbols are permitted however the consistency must be maintained throughout the mapping and people in the organization are acknowledged about the symbols. Besides, data collection such as cycle time, waste time, transportation time, machine time and changeover time will be tabulated.

*STEP 4: Identification of waste and key problems:*

Basically, the vital goal of VSM is to identify, demonstrate and eliminate waste in the manufacturing system of an organization. Waste that is occurring and whether it is unnecessary or acceptable can be identified. Once the wastes and the key problems have been discovered, it is important to evaluate if such problems are related to inefficiency spread among the entire critical stream or if they are focused in certain areas (Braglia *et al.*, 2006).

*STEP 5: Development of future state map:*

While developing the current state map, the process of defining and identifying the future state map begins, where target areas for improvement begin (Abdulmalek & Rajgopal, 2007). The future state map is a chart that proposes how to generate a lean flow. It uses lean manufacturing tools and techniques to reduce or eliminate wastes and hence minimize all the non value-added tasks. The future state map facilitates visualization of the expected production state after implementation of suggested improvements has been done. The provision of two specific plant layouts based on current state and future state is suggested to help the organization to visualize the proposed improvements.

*STEP 6: Development of implementation plan:*

All the improvements will be divided into smaller project with manageable size and as independent as possible. Short-term targets should be identified as improvements have to be done progressively with realistic short-term targets accomplished by stages. These targets should be linked to critical performances measured in the organizations associated to the Kaizen bursts in the current state map. On this, consultations as well as later cooperative agreement should be sought with affected departments.

## 2. VSM Case Study:

### *Company Manufacturing Profile:*

Company X runs a manufacturing plant which has been established in year 1994 in Malaysia. It produces a wide range of Flex Printed Circuits (FPCs), included single-sided, double-sided, multi-layer, rigid flex, thin-core PCB and assembly (FPCA). Overall there are approximately 50 full-time employees in the manufacturing plant. Operations are run in two staggered shifts, five working days a week.

*STEP 1: Identification of problem statement and objectives (Gemba walk):*

A kaizen team helmed by the production manager was deployed in this stage. Gemba walk was conducted and joined by all the team members so that a full understanding on the operations and manufacturing processes can be obtained. The kaizen team had identified few problem statements after the Gemba walk. Manufacturing plant encountered the problem of inadequate data capturing and analysis system to support the productivity monitoring and improvement efforts. Besides, lean wastes were not identified and managed using lean methodology, hence inventory control, product quality were relatively hard to be maintained and improved. Hence, the main objective of project is to establish a strong foundation for continuous improvement in manufacturing plant by reducing the long lead time while improving the productivity. Sub-objective is to identify both the value added and non-value added activities, analyse and visualize the hidden waste and source of waste with the aid of VSM.

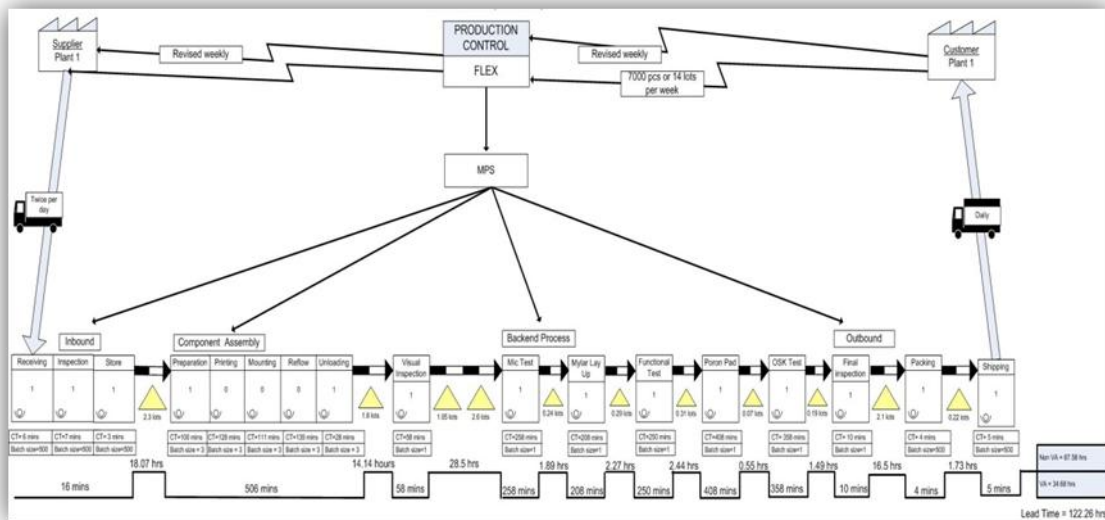
*STEP 2: Identification of product families:*

Product M, a type of double-sided flex was chosen because it has the highest customer demands. The customer demand was stable with annual and bimonthly revised forecast provided by the customer. The process path was short and not significantly improved previously. Besides, the inventory level of this product was the highest among all of the product families. Assembly of flex imposed strict standard on the process procedures. The common sequential process route started from inbound, component assembly, backend process and outbound before sending to the customers. The processes started with inbound where flex was received and visual inspected by quality control personnel. Component assembly performed Surface Mount Technology (SMT) processes including preparation, printing, mounting and reflow. Backend process was a manual

operation where operators were needed to insert manually the components and test the functionality of electronic components of the flex. Outbound prepared products for delivery and also acted as final storage.

**STEP 3: Development of current state map:**

The constructed current state map was shown in Figure 1. Data was collected during the Gemba walk to obtain reliable data. Basically, there are four main processes, which consist of inbound, component assembly, backend process and outbound. The small boxes in the map indicate the process and the number inside the box is the number of manpower involved in that process. Process cycle time was recorded inside small data box under each process. The cycle times for component assembly line and backend process are all taken during the direct observation besides referring to the data provided by engineers. The total lead time is about 122.26 hours which is around 5 days, however only 28.37% of the lead time is value added time whereas 71.63% of the lead time is non value added time.



**Fig. 1:** Current state map

**STEP 4: Identification of waste and key problems:**

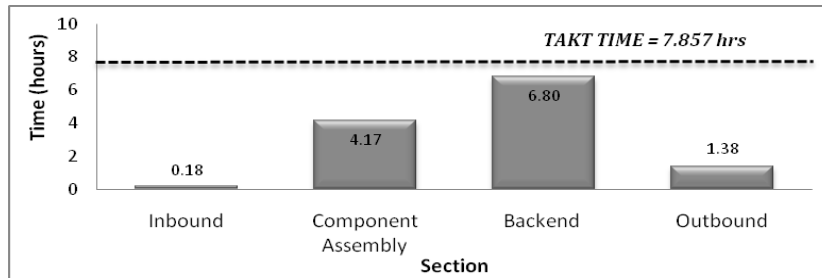
Muda, Mura (unevenness) and Muri (overburden) along the station were identified during the Gemba walk and direct observation. Component assembly and backend process will be focused as the inventories level in these two sections were the highest. Although packing in the outbound station has high inventories, it will not be considered because data was taken at the end of each shift, which was 7am daily, therefore inventory level was the highest at that time.

**Table 1:** Lean waste identification.

Section	Muda	Mura and Muri
Component assembly	<p><b>Waiting</b></p> <ul style="list-style-type: none"> <li>❖ Long changeover time and the changeover time varied each time.</li> <li>❖ Machine waiting time as sometimes flex has not been delivered from supplier.</li> </ul> <p><b>Inventory</b></p> <p>High inventory at visual inspection due to pace of unloading and visual inspection is different.</p>	<p><b>Mura</b></p> <ul style="list-style-type: none"> <li>❖ There is no standard procedure about changeover.</li> <li>❖ The operator in visual inspection station is overburden.</li> </ul>
Backend process	<p><b>Waiting</b></p> <p>Operators waiting for flex from previous station as there are lack of operator to do the manual job.</p> <p><b>Inventory</b></p> <ul style="list-style-type: none"> <li>❖ High inventory at front backend as operators cannot cope with the demand.</li> <li>❖ High inventory between stations as cycle time for each station is different.</li> </ul> <p><b>Motion</b></p> <p>There are inconsistent work methods (no standardization) of operators especially for new and unskilled operator.</p> <p><b>Overproduction</b></p> <p>There is excess inventory at the front backend process.</p>	<p><b>Muri</b></p> <p>There is no special allocation or arrangement of operators if some operator was absent.</p> <p><b>Mura</b></p> <ul style="list-style-type: none"> <li>❖ Operators do not follow the standard procedures to perform task but based on their own way although there are work instruction on the workstation.</li> <li>❖ There are always inconsistent inventories between workstation in the backend process.</li> </ul>

**STEP 5: Development of future state map:**

Takt time was the rate at which an organization must produce a product to satisfy the customer demand. It was calculated by dividing available working time per shift (in hours) to customer demand per shift (in pieces). After excluded the lunch and tea breaks for the shift, for a target production of 1400 pieces or 2.8 lots per day, the takt time was computed as 7.857 hours. This takt time means that the organization needs to produce one lot of flex every 7.857 hours from its production line. As mentioned earlier, time and motion study was done to establish individual workstation cycle times. A graphical comparison of workstation cycle times against the takt time was shown in Figure 2. All the cycle times from individual workstation did not exceed the takt time. This means that the production was able to produce the product to fulfill customer demand.

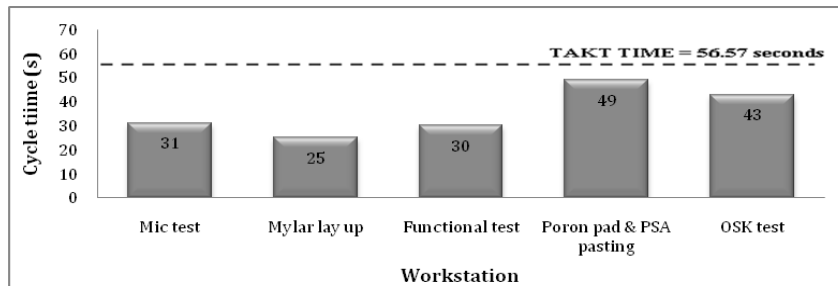


**Fig. 2:** Comparison of workstation cycle times and takt time

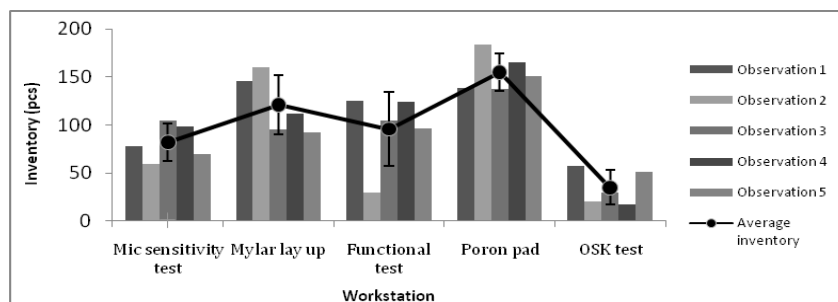
**Improvement Strategies:**

**Stage 1: Line balancing:**

Due to the unbalanced line in backend process, line balancing was introduced to reduce the variation among workstation and avoid excessive workload in some workstation. Line balancing was a technique in which each task assigning to the workstation has approximately same amount of work. Firstly, for current situation, there are 5 operators in the manual backend process. The cycle time of each workstation versus takt time was shown in Figure 3. For this section, takt time is 56.57 seconds per piece for the ease of calculation and analysis. Poron pad and PSA pasting process (49 seconds) has the highest cycle time compared to cycle time of other workstations. The inventory level variation in backend process was shown in Figure 4. The inventory level is varied and fluctuating as cycle time for each operation was unbalanced, therefore some workstation has higher inventory level.



**Fig. 3:** Cycle time of workstation in backend process.



**Fig. 4:** Inventory level variation in backend process

Classification of value added and non value added activities before and after improvement was shown in Figure 5 and Figure 6. By applying line balancing technique, tasks of workstation 4 which was Poron pad and PSA pasting was divided to other workstations. There were total 4 workstations for the proposed solution, which were microphone sensitivity test, Mylar layup test, functional test and open, short keypad test. Details of backend process before and after improvement were shown in Table 2. Manpower was reduced to 4 and this definitely saved the labour cost. Besides, stacked time reduced from 178 seconds to 149 seconds, which was 16.3% reduction. This was due to the elimination of non value added time in Poron and PSA pasting workstation. Open, short, keypad (OSK) test has the highest cycle time, which was 43 seconds compared to cycle time of Poron pad and PSA pasting, which was 49 seconds. Therefore, it increased the productivity and reduced the lead time of flex in the organization. Line balance ratio increased from 72.7% to 86.6%, which mean that the manual assembly line was more balanced with the proposed solution. There will be no waiting from previous workstation as the cycle time from one workstation to next workstation was increasing. This can eliminate the idling time of operators and reduce the inventory between workstations.

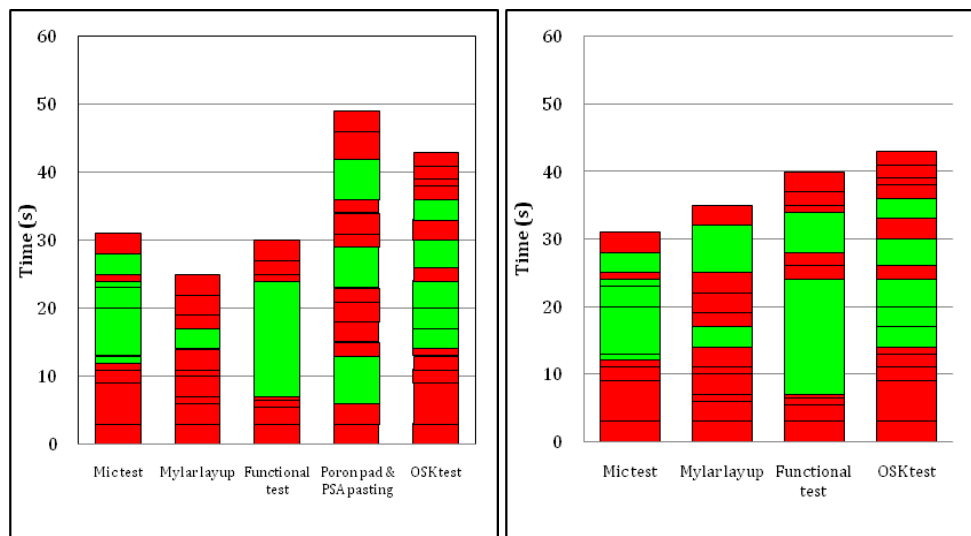


Fig. 5.1: Classification of value added and non value added activities before and after improvement

Table 2: Details of backend process before and after improvement.

	Before	After
Number of manpower	5	4
Stacked time (s)	178	149
Line balance ratio (%)	72.7	86.6
Line balance efficiency (%)	62.9	65.8

Stage 2: One point lesson:

One of the main problems in backend process was operators did not follow the standard operating procedures although the work instruction was being placed at each workstation; hence there was high cycle time variability. Cycle time variation in backend process was shown in Figure 7. It shown that the standard deviation was high and based on the five direct observations, cycle time was varied and fluctuating and hence constant output cannot be obtained with the variation in cycle time of operators.

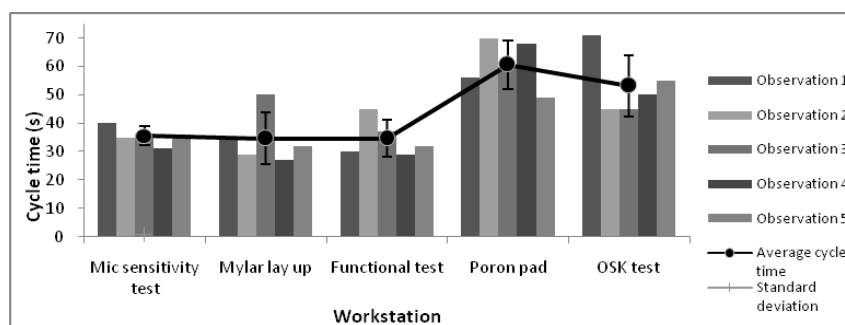
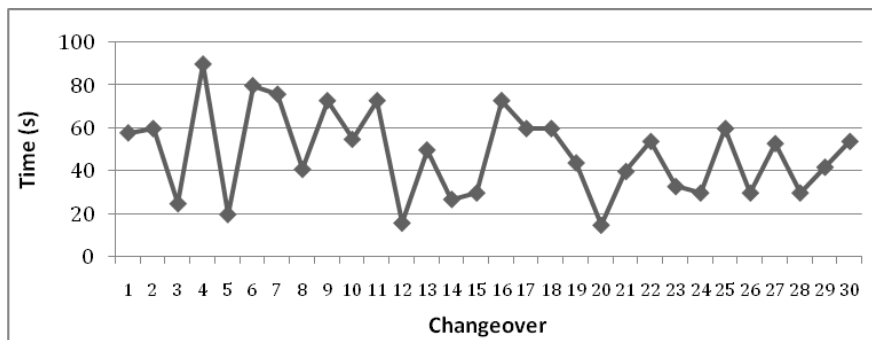


Fig. 7: Cycle time variation in backend process.

One point lesson was introduced to enable operators and production team to share the key learning and builds on a common understanding of the standard procedures and standards that apply to the flex. When properly managed, this technique supports greater transparency of knowledge and helps to rapidly bring new operators in the workstation to speed and perform tasks based on standard procedures. It was a lesson on standard procedures for each workstation, on one sheet of paper. Simple languages and short sentences are written and plenty of pictures are shown on the paper. This is to make sure operators can understand easily and clearly about the procedures by looking at the step-by-step shown diagrams. Besides, training was given to operators from time to time to make sure operators understand completely the basic knowledge and procedures of the work. They need to honour and sign once they gone through the training. One point lessons can also be used as a tool to review and standardize knowledge. When operators and technicians sign the training record at the bottom they are agreeing to follow the message on the paper sheet. If they disagree with the information stated, they can raise it at that time as a group review and knowledge on the paper sheet can be modified based on agreement.

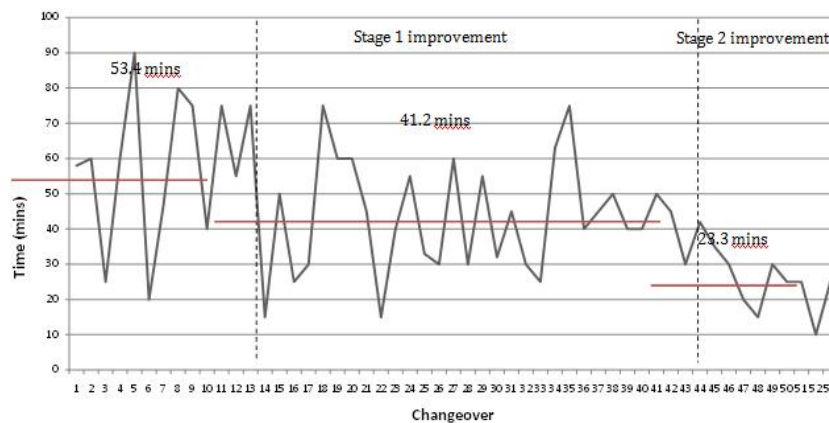
*Stage 3: Single Minute Exchange of Die (SMED):*

Lengthy changeover time was the main problem in the component assembly process. Normally, it took around 50 minutes to change from previous model to the next model and there will be at least 2 times of changeover in one shift, therefore machine was idling during the changeover. Changeover time for model M was shown in Figure 8. As can be observed, the changeover time was fluctuating and varied each time.



**Fig. 8:** Cycle time variation in backend process

SMED was introduced to reduce the high idling time of machine and shorten the changeover time. First of all, changeover team was set up and all the related operators were being trained to understand and learn the basic knowledge of SMED. All the activities during changeover were break down into detailed procedures so that it was separated into internal and external activities. All the external activities which mean can be done while machine was still in the operation were converted and carry out before the changeover starts. Duration of changeover before and after improvement was shown in Figure 9. There were two stages of improvement, where stage 1 improvement included labelling of pallet rack, stencil, alignment jig and stencil rack and rearranging stencil; stage 2 improvement included introducing pallet carrier and repositioning double-sided tape on pallet. Hence, changeover time was reduced from 53.4 minutes to 41.2 minutes in stage 1, again reduced to 23.3 minutes in stage 2. There is total reduction of 56.3% in changeover time.



**Fig. 9:** Duration of changeover before and after improvement.

#### Stage 4: Kaizen and lean thinking into culture:

The *kaizen* strategy aimed to involve workers from multiple functions and levels in the organization in working together to address a problem or improve a process. Rapid continuous improvement processes typically require an organization to foster a culture where everyone in the organization include operators were empowered to identify and solve problems. Excellent managing system and excellent management in the organization were required to alter the culture of people about lean thinking and *kaizen*. Management need to be in Gemba more often to know the actual situation of the production line to sustain continuous improvement.

#### STEP 6: Development of implementation plan:

After the improvements being suggested and implemented, the lead time was reduced from 122.26 hours to 83.99 hours, which was 68.7% of reduction. This definitely reduced the production cost and boost productivity of the product. The short-term targets were supposed to be achievable in a short period, and these targets enhanced the success rate of the project to achieve the long term targets. Hence, the short-term targets were the implementation of the solutions in Figure 10, which were the *kaizen* bursts stated in future state VSM with *kaizen* bursts. When the production line was stable and smooth after improvements, ideal state VSM was possible to be carried out throughout the line.

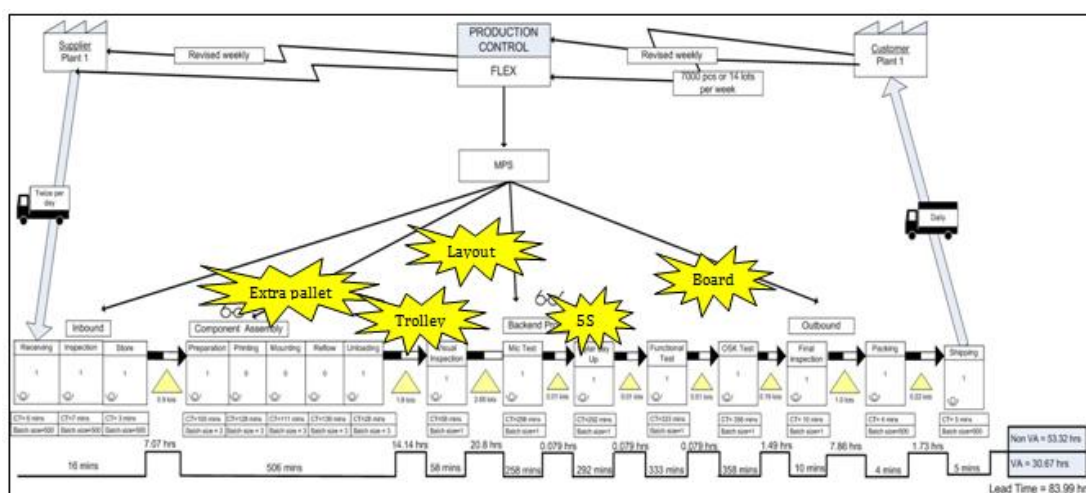


Fig. 10: Future state map with Kaizen bursts.

#### Conclusion:

The case study presented in this paper, has demonstrates that wastes such as inventory, waiting, motion and defects can be reduced which in turn improves the productivity and reduces the manufacturing cost of the organization. VSM helps to visualize and identify the waste in the organization and the future possibilities of reducing or eliminating them. Different lean tools such as one point lesson, SMED and line balancing are integrating into VSM to help reduce or eliminate waste effectively. However, it is impossible to apply continuous flow in the organization although continuous flow is the ideal lean state of a process. This is due to the environment of organization where job functions change frequently and operators are swapped from task to task. VSM can be done in the same way for practically any organization and expanded upstream or downstream. The concept can be replicated for other manufacturing industries to capture various scenarios and discover wastes in their organization.

#### ACKNOWLEDGEMENT

The authors thankfully acknowledge the financial support from the University of Malaya Research Grant UMRG Project RG139/12AET for this research.

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