Performance Metric Development to Visualize Setup Losses in Wire Bond Process

Puvanasvaran A. Perumal and Yoong Sai Sieng
Faculty of Manufacturing Engineering
Universiti Teknikal Malaysia Melaka
Durian Tunggal, Melaka, Malaysia
punesh@utem.edu.my, saisiengyoong@gmail.com

Tay Choo Chuan
Faculty of Electrical Engineering
Universiti Teknikal Malaysia Melaka
Durian Tunggal, Melaka, Malaysia
tay@utem.edu.my

Abstract

Performance metric is one of the components of a continuous improvement to achieve and maintain the performance of the machine or process. Setup and changeover losses are one of the losses that increase the lead time and reduce the available time for the operation of machine. Despite of work study that used widely in industry to reduce the losses, there is no effective measurement tool to monitor the setup and changeover losses. Furthermore, excessive working time and idle time are the main focus of the people to improve, but they may miss out the other important element, the frequency of setup process in a period of time. The objective of this study is to visualize the setup losses through performance metric. Therefore, Usability and Human Factor are introduced to measure the frequency of the setup process in a period of time and highlight the excessive working time to be further streamlined. Real data was examined by using the performance metric and it showed that the performance metric able to visualize the setup losses. It is expected to visualize the setup and changeover losses in the industry and assist the user to tackle the issue correctly.

Keywords
Usability, Human factor, Setup losses, Performance metric

1. Introduction

In the manufacturing sector, various types of wastes that available in the production are dragging down the utilization and performance level of the machine or process. As mentioned by Bokrantz et al. (2016), there are eleven major losses that exist in the production. To overcome this issue, manufacturers are trying their best to eliminate wastes through tools and techniques. Although these tools and techniques are effective in elimination of wastes, but it is meaningless if it is not tackled on the correct waste. Therefore, visualization of wastes is important to identify the correct problem and tackle it to achieve better performance of the machine or process. The elimination of the waste is a long journey and it is not going to stop until zero waste is achieved. In this long journey, performance metric is relatively important to allow manufacturers to monitor and measure the current performance level of the machine or process. Furthermore, performance metric also used to gather the information for the production team to identify the area of improvement should be made.

In the perspective of Overall Equipment Effectiveness, setup losses are one of the six big losses that bring impact to the production. It is categorized in the availability factor along with the breakdown losses. As claimed by Mohamed Esa et al. (2015), there are non- value added operations that involved in the setup and changeover process, which classified as waste for the company. The non-value added activities are improper working procedure, work delay, tool searching, unnecessary motion and transportation. In fact, high setup time is one of the setup losses that should be eliminated. Low et al. (2014) claimed that it is necessary to improve the changeover and setup process to make sure the company can respond quickly to the customer demand. The improvement of the changeover and setup process also increases the flexibility of the production and allows companies to make better arrangement.

There are many tools can be used to streamline the setup and changeover such as Single Minute Exchange Die (SMED), time study and predetermined time motion study. The main intention of these tools is to utilize the setup and changeover time to increase the available operating time for the machine. These tools are also used to create proper working procedure and ideal working time for each particular operation. This is useful to utilize resources and reduce manufacturing cost. Pande and Deshpande claimed that they are using predetermined time motion study to utilize manpower by 10% and reduce 25% of excess manpower. However, the high setup time might be caused by another factor, which is the frequency of the setup and changeover time in a given period. Due to the different customer demand, the frequency of the setup might be different and it might mislead the production team, which the excessive setup time is increasing or decreasing. Therefore, it is necessary to find a way to identify the setup losses differently to prevent the resources of the company is wasted when tackle on the incorrect waste.

Usability and human factor are quantifying the setup losses effectively where the frequency of the setup process and excessive setup time are measured separately. This will allow management level or operation team to identify the area of improvement effectively and not misled due to the combination of all setup losses. These performance metrics also able the operation team to monitor the setup losses effectively. Operation team can monitor the setup losses from time to time and maintain the performance of the production.

2. Literature Review

In this section, the journal papers, articles and any other related information are discussed. The focus of the review of literature is the setup and changeover process. The setup and changeover time and also the factor that influences the setup and changeover also discussed in this section.

2.1 Setup and Changeover Time

Setup and changeover process is one of the important elements in the production because it indicates the stability and the smoothness of the production. It indicates the periods used to prepare for the operation or the periods used to change tools or materials to ensure the production can proceed smoothly. McIntosh et al. (1996) defined changeover process as a complete process of changing between one product to another alternative product to achieve specified production and quality rates. However, Henry (2013) defined changeover time as total time used by machine, device or process to get ready to produce the first unit of good product in normal speed and efficiency from the last unit of the previous good product. It can be said that setup and changeover time is a period of time for the operator to change components and materials from the machine and make sure the machine is operating smoothly. According to Low et al. (2014), setup and changeover process can significantly affect the throughput and availability of the machine. Most of the setup and changeover process are conducted by the manpower, even in the highly automated industry. Therefore, the involvement of the manpower is significantly affected the setup and changeover time.

2.2Factors influencing setup and changeover time

High setup time is one of the losses that lead to high manufacturing costs, long lead time and low productivity. It has been claimed by Kumar and Abuthakeer (2012) that struggling of manufacturers to reduce the setup and changeover time was increasing dramatically due to the wide variety of products they have to manufacture. Therefore, it is always focused by the manufacturers to reduce or eliminate. However, setup and changeover time is needed to ensure the continuity of the production but it can be streamlined. To utilize the setup and changeover time, the factors that influencing the setup and changeover time need to be identified.

According to Mohamed Esa et al. (2015), there are three factors that will lead to the high setup and changeover time. These factors are method, man and machine. Method is the working procedure of the operators to perform setup and changeover process. Standard operating procedure is needed to make sure the operators perform the work in the correct manner and the location of the tools should be convenient for the worker to achieve. The time used by the workers to search tools, move from one place to another place to get tools are non-value added and unnecessarily. These activities are the wastes that needed to be eliminated. Then, man factor is referring to the number of the workers. Lack of the number of workers will contribute to the high setup and changeover due to the increases of the machine idle. Then, the design of the machine also will lead to high setup time because workers need to take a long time to adjust and install components on the machine during setup and changeover process.

In addition, Madhav et al. (2017) showed the seven wastes that available in the excessive setup and changeover time. These wastes are required to eliminate or reduce to optimize the setup and changeover time where the manufacturing time is utilized. These wastes were defined by the Womack and Jones as any human activity that consume resources, but generate zero value (Wong and Wong, 2011). The Table 1 showed the seven wastes that appear in the setup and changeover losses.

Table 1. Seven types of setup wastes (Madhav et al., 2017)

Type of wastes	Description
Overproduction	The production quantity is sooner and faster than the customer demand.
Inventory	Any materials, supplies, parts or tools in excess of the required amount inevitably results in wastes.
Waiting	Idle or downtime due to the unavailable of materials, supplies, parts, information, planning, equipment or manpower.
Motion	Movement of materials, parts, supplies, equipments, tools and people that is unnecessary and no value added.
Transportation	Irrelevant movement of materials, parts or equipment and the unnecessary movement made by people which resulted in time and cost wastage.
Defects/ Rework	Repetition or correction of certain tasks or processes due to incorrect procedures, errors, poor quality or delivery performance.
Inappropriate Processing	Incorrect execution of processes, incorrect utilization of tools due to poor procedures and systems. It can also be the processing involved that beyond the customer’s requirement.

As shown in the Table 1, Madhav and his research team were category setup and changeover wastes into major seven wastes where these wastes are aligned with the seven lean wastes. Overproduction is the wastes when the production of large quantities of product is started sooner and complete faster than the request of the customer. Inventory waste indicates the excessive materials, components or parts which require a space to store. Waiting is the idle time of the machine when the materials, tools or manpower are unavailable. For motion waste, it is presented when the unnecessary movement exists. On the other hand, transportation waste is the movement of the manpower and the irrelevant movement of the materials from one place to another place but no create any value to the production. Defects or rework is the repetitive or the corrective motion of certain tasks or processes caused by the incorrect procedures, errors, poor quality and poor delivery performance. The seventh waste is the inappropriate processing which means the incorrect process execution, inappropriate tooling due to poor procedures and systems. It also exists when the over-processing of the products which beyond the customer’s requirement.

2.3Frequency of the setup and changeover process

In the manufacturing industry, setup and changeover process is one of the important elements of the production because it is essential for the continuity and smoothness of the machine. According to Karasu et al. (2014), manufacturers want to have a big-batch production with less amount of the changeover process during the production period. When there is involvement of the changeover process, the materials, tools, parts or equipment need to replace with other suitable elements and it involved time and cost. When the frequency of the setup and changeover process is high, it will create financial and inventory problems for the company. Furthermore, it also decreases the elasticity and responsiveness of the production towards the changes of the plan or schedule.

The frequent changeover process is caused by the diversity of the customer requirement where companies have to produce multiple products to fulfil their requirements (Ferradas and Salonitis, 2012). The inclusion of high changeover processes will cause some portion of the production time to be excessive. The management level unable to identify this kind of losses by just looking at the production report. It becomes a crucial issue for the companies to utilize their resources, production and production time. As mentioned by Stefansdottir, Grunow and Akkerman (2017), the efficient use of the resources can only achieved by the correct formulation of the setup and changeover process in the daily production. This issue also rose up by the Agrawal et al. (2012) where the sequence of the setup and changeover process is essential to minimize the total completion time of products. In other word, the proper sequencing of the setup and changeover process will result to a better flexibility production with more production time to allocate.

3. Methodology

In this study, a wire bond machine in a semiconductor company is used as the subject of study. The data collection method can be separated into two categories, which are Automated Data Collection (ADC) and Maynard Operation Sequence Technique (MOST). The ADC is a method to collect data through feedback from the computer. The activities of the machine are recorded 24 hours a day and it has guaranteed the accuracy of the data. On the other hand, MOST is a predetermined time motion study that widely used in the industry to create standard time and standard working procedure for the manpower. MOST will used to create the ideal setup and changeover time for every setup operation. Observation of the working environment and working procedure of the worker is essential to implement the MOST. The detail information regarding the working environment and procedure helps in developing the MOST. Through the real data gathered, two performance metrics are examined and compared to show the visualization of setup losses. The performance metrics are Usability and Human factor. Each of the performance metrics monitor the specific setup losses that influence to the setup and changeover process.

3.1 Maynard Operation Sequence Technique (MOST)

Maynard Operation Sequence Technique (MOST) is a predetermined operation time motion study that widely used in the industry to develop standard procedure and standard time. It is also a useful tool to maximize the human capacity, utilize resources and eliminate non-value added activities. As mentioned by Puvanasvaran (2013), MOST is useful in revealing the value added and non-value added activities in each of the sub-operation. It is also a way of analyzing the operations or sub-operation through several methods, steps and sequences (Tanjong Tuan et al., 2014). In the basic MOST analysis, there are three types of sequence model that used to describe the task or operation done by the operators.

Table 2. Sequence model of Basic MOST (Bondhare, Pawar and Deshpande, 2016)

Activity	Sequence Model	Sub- Activities
General Move	ABG-ABP-A	A = Action distance B = Body motion C = Gain control P = Placement
Controlled Move	ABG-MXI-A	M = Move control X = Process time I = Alignment
Tool Use	ABG-ABP-U-ABP-A	F = Fasten L = Loose C = Cut S = Surface treat M = Measure R = Record T = Think

As shown in the Table 2, each of the activity had its own sequence model and sub-activities. General move indicates the free movement of the object through the air. Control move describes the movement of the object where it is in contact with a surface or attached to another object during the movement. Tool use indicates the use of common hand tools like fastening, loosening, cleaning, gauging and writing. Furthermore, the time measurement unit (TMU) is the time unit that used in MOST analysis. 1 TMU is equal to 0.036 second or 0.0006 minutes or 0.00001 hours.

Table 3. MOST result in wedge tool changeover process

Sub-operation	Sequence model	TMU(×10)
Walk three steps, move cursor	$A_6B_0G_4$-$M_4X_0I_0$-A_0	140
Get cartridge put on the table	$A_3B_0G_1$-$A_0B_0P_1$-A_0	50
Sit down and drag the microscope to the left	$A_1B_{10}G_3$-$M_3X_0I_0$-A_0	170
Use mouse and click 7 times	$A_3B_0G_7$-$M_7X_{16}I_0$-A_0	330

Push microscope to the right	$A_1B_0G_1$-$M_6X_0I_1$-A_0	90
Open the cover of the machine	$A_1B_{10}G_3$-$M_3X_0I_0$-A_0	170
Open the cover of the bond head	$A_1B_0G_1$-$M_1X_0I_0$-A_0	30
Get one tweezer and screwdriver from tool bag	$A_1B_0G_2$-$M_6X_0I_0$-A_0	90
Position tweezer and hold on wedge	$A_1B_0G_1$-$M_1X_0I_1$-A_0	40
Unscrew wedge from bond head and put aside	$A_1B_0G_1$-$A_1B_0P_1$-T_6-$A_1B_0P_1$-A_0	120
Get wedge container and remove the cover	$A_1B_0G_1$-$M_3X_0I_0$-A_0	50
Insert old wedge into the container	$A_1B_0G_1$-$M_1X_0I_1$-A_0	40
Close wedge container cover	$A_1B_0G_1$-$M_3X_0I_1$-A_0	60
Put wedge container aside	$A_0B_0G_0$-$A_1B_0P_1$-A_0	20
Obtain old wedge bottle and insert into the other side of cartridge	$A_2B_0G_2$-$A_1B_0P_1$-A_0	60
Get the new wedge tool from the other side of cartridge and put aside the cartridge	$A_1B_0G_1$-$A_1B_0P_1$-A_0	40
Open the cover of the wedge tool container	$A_1B_0G_1$-$M_3X_0I_1$-A_0	60
Get one tweezer and hold on wedge	$A_1B_0G_1$-$M_1X_0I_1$-A_0	40
Screw wedge at bond head and put tweezer into tool bag	$A_1B_0G_1$-$A_1B_0P_1$-T_6-$A_1B_0P_1$-A_0	120
Clip wire using tweezer	$A_0B_0G_0$-$A_1B_0P_3$-C_3-$A_0B_0P_0$-A_0	70
Insert wire into the hole of wedge tool	$A_0B_0G_0$-$A_1B_0P_6$-C_6-$A_0B_0P_0$-A_0	130
Close cover of the machine	$A_1B_{10}G_3$-$M_3X_0I_0$-A_0	170
Click Next button	$A_1B_0G_1$-$M_1X_{32}I_0$-A_0	350
Total TMU		2440
Total time in second (s)		87.84

Table 3 showed the MOST analysis for the wedge tool changeover process. Direct observation is essential to understand the flow of the operation. The operations and sub-operations of the operator are considered as the combination of the simple motion. The steps are presented in the form of the sequence model and value is given based on the MOST Datacard. The value of each sub-activity are summed up and multiplied by 10 to get the TMU for each step. Then, the total number of TMU is transformed in seconds. This MOST result is used as the ideal changeover time for the wedge tool changeover process that is available during the production.

3.2 Usability

Usability is a new performance metric developed to quantify the frequency of the setup and changeover time. The frequency of the setup and changeover time is the total number of the setup and changeover process in a given period without the inclusion of excessive setup and changeover time. Each of the setup and changeover process are in the ideal form which is the result of the MOST analysis.

$$\text{Usability} = \frac{\text{Theoretical running time}}{\text{Actual operating time}}$$

The equation above is the formula of the usability and it is the ratio of the theoretical running time to the actual operating time. The actual operating time is the period where the machine is available to operate with no unplanned downtime such as breakdown. Theoretical running time is the running time that the machine had if all the setup and changeover process is performed ideally by the manpower with no excessive working time. The ideal setup procedure and ideal setup time are developed through the implementation of the Maynard Operation Sequence Technique (MOST). MOST is one of the predetermined time motion study which is widely used in the industry to create standard working time.

3.3 Human Factor

Human factor is a performance metric used to quantify the excessive working time performed by the manpower during setup and changeover process. The excessive working time might due to poor working procedure, unnecessary motion or transportation, work delay, idle, lack of material or manpower and search for the tool. The time needed to perform an ideal setup or changeover process is not included in this performance metric because it was quantified by the Usability.

$$\text{Human factor} = \frac{\text{Actual running time}}{\text{Theoretical running time}}$$

The human factor is the ratio of the actual running time to the theoretical running time. The theoretical running time is the time where all the setup and changeover process is performed ideally. However, it is not applicable in the real production because there might have any delay or excessive working behaviour that creates non-value added activities.

Table 4. Data collected during production

Planned production time	86400
Breakdown	190
Total setup and changeover time	10345
Ideal wedge tool changing time	87.84
Frequency of wedge tool change	8
Ideal wire pool changing time	215.64
Frequency of wire pool change	2
Ideal lot changing time	120.6
Frequency of lot change	4

Table 4 showed the data collected during the production. Planned production time is not including the planned downtime likes planned maintenance, public holiday and others. The usability and human factor can be calculated through this information. The calculation is shown in the below.

Actual operating time = Planned production time – breakdown
= 86400 – 190
= 86210
Theoretical running time = Actual operating time – (frequency of setup process × ideal setup time)
= 86210 – [(8×87.84)+(2×215.64)+(4×120.6)]
= 86210 – 1616.40
= 84593.60
Usability = theoretical running time/ actual operating time
= 84593.60/ 86210
= 98.13%
Actual running time = actual operating time – excessive setup and changeover time
= 86210 – 10345
= 75865
Human Factor = Actual running time / theoretical running time
= 75864 / 84593.60
= 89.68%

4. Result and Discussion

Setup losses are one of the main losses that manufacturers want to eliminate to achieve better elasticity and ability to respond quickly to the changes of the customer demand. In this study, the wire bond process is chosen as the study subject and it is found that three types of setup and changeover process available. The processes are wedge changing, wire changing and lot changing. During the five quarter monitoring period, the total number of each setup and changeover processes are presented in the Figure 1.

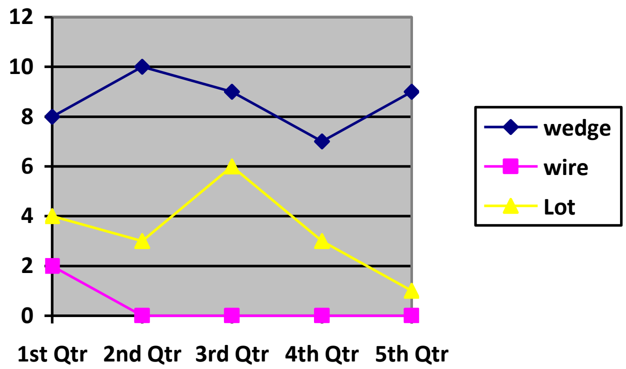

Figure 1. Type of Setup and Changeover process in the production

Figure 1 showed the three types of the setup and changeover process available in five days. As shown in the Figure 1, the number of each process is changing from day to day. It is due to the different customer demand and requirement to be achieved. The wire used for the machine is unchanged after the first day. It means the type and diameter of the wire is still the same for the products from second day to fifth day. For the lot changing, it is due to the lot size. Lot size is combination of a certain number of similar products to avoid large number of setups (Schmidt, Munzberg and Nyhuis, 2015). The wedge is changing due to the tool wear rate. It is supported by the Zhang et al. (2014), the buildup is occurring when the tool is being used for a period and it will affect the quality of wire bond. The wedge has to change to ensure the quality of the product. Then, the frequency of the setup and changeover might be affected by the skill of the operator which caused a higher number of setup process is needed. A low skilled and not experience operator might set up the tools or materials improperly and have to change again to ensure the quality of the products produced. All these losses should be visualized to make sure the losses can be identified and develop plan to improve it.

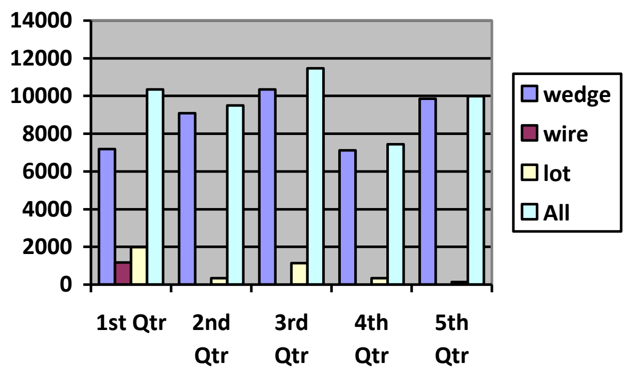

Figure 2. Time taken by each of the setup and changeover process

As shown in the Figure 2, the number of the wedge changing had brought great impact to the total setup and changeover time of the particular period. The highest setup and changeover time is on the third day, while the lowest setup and changeover time is on the fourth day. The number of the wedge changing process is recorded as nine and seven for the third day and fourth day. It can be said the increases of the number of the setup and changeover process has led to increases of the setup and changeover time. If the ideal setup and changeover time is not excluded from the total setup and changeover time, the excessive setup and changeover time is remains unknown. This is because the excessive setup and time and ideal setup time are mixed up. Thus, the production team cannot identify the causes of the long setup and changeover time effectively.

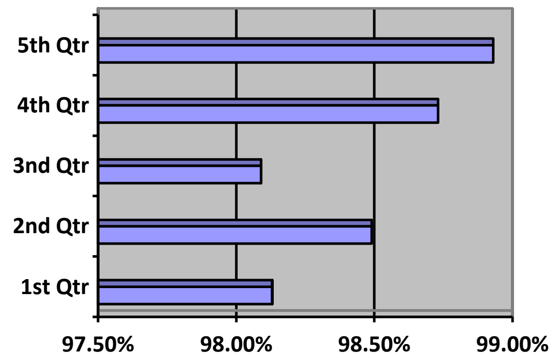

Figure 3. Percentage of Usability

In Figure 3, the percentage value of the usability for 5 quarters is presented. The usability percentage for each quarter is more than 98 percent. Fifth quarter recorded with the highest percentage, 98.93 percent. On the other hand, first quarter resulted with the lowest percentage, 98.13 percent. Although the percentage difference in between the highest and lowest percentage is only 0.80 percent, but it showed that the frequency of the setup and changeover process has difference due to other factors. During the whole production time, the setup and changeover time is only a small portion, but it will affect the quality and quantity of the products produced by the machine. The unnecessary setup and changeover process that can be streamlined is actually reducing the human capacity, reducing the utilization of resources and reducing the flexibility of the production time.

The usability percentage is mainly affected by the frequency of the setup and changeover process. The higher the frequency of the setup and changeover process, the usability percentage will be higher. If there is no excessive setup time caused by work delay, transportation, searching tool or unnecessary working procedure, the influence of the setup and changeover process is resulted as the usability percentage. Then, usability percentage is different for different process and industry due to the number of batches, variety of products, customer demand and tool wear rate. In other word, the number of the setup and changeover process is different for different types of process and industry.

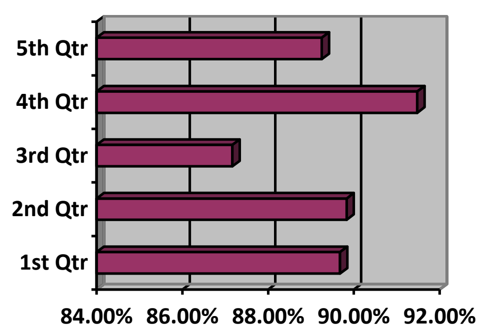

Figure 4. Percentage of Human factor

Figure 4 showed the human factor percentage for five quarters. All the human factor percentage are not lower than 86 percent. Along all the five quarters, the fourth quarter has the highest human factor percentage, 91.48 percent. This means the fourth quarter has least excessive setup time compared to other quarters. The lowest human factor percentage belongs to third quarter with 87.17 percent. It means that third quarter has highest excessive setup time among the other quarters. The range of the human factor percentage is 4.31 percent. Anyway, the human factor should achieve 100 percent, which mean no excessive setup time during the setup and changeover process. The excessive setup time reduces the utilization of the resources and increases the difficulty for the company to absorb the changes of the customer demand.

The human factor is mainly affected by the human behavior and also the location of the tools and materials. As mentioned by the Puvanasvaran et al. (2016), for the semi-automated or manually industries, the impact of the performance of the manpower is crucial. The lack of monitoring might cause the workers perform their work inefficiently. Furthermore, the lack of standard operating procedure and improper orientation of the tools also increase the unnecessary setup operations and time.

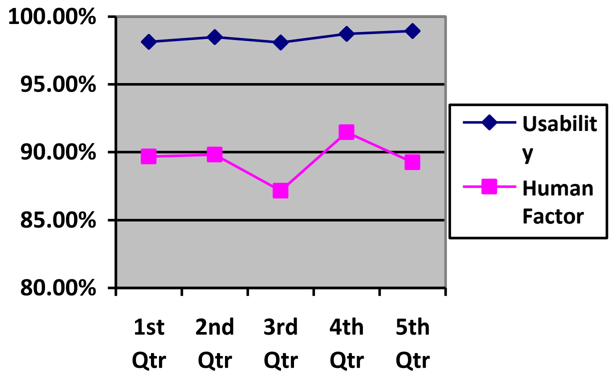

Figure 5. Comparison between Usability and Human Factor

As shown in the Figure 5, the usability is compared with the human factor. The usability percentage over the five quarters shown stable and the range is just 0.80 percent. However, the human factor percentage is up and down over the five quarters. This showed that the increases of the frequency of the setup and changeover process are not the main factor to the human factor. For the fifth quarter, the usability percentage is 98.93 percent, which is the highest among the other quarters. However, the human factor percentage is only 89.25 percent, which is the second lowest among the other quarters. This showed the relationship between usability and human factor is not strong and the problems that lead to low human factor rate is not affecting the usability rate.

Based on the percentage of the usability and human factor, operation team able to identify and monitor the setup losses that available in the production line. They may develop plans to improve the setup and changeover process to increase the flexibility and respond quickly to the changes to the customer demand. The performance level of the setup and changeover process is visualized by the two metrics. If the usability percentage is lower than usual, it means the problem might be the orientation of the setup and changeover process. It may be the repeat or corrective changeover process due to the improper set up that cause machine to produce low quality products. In addition, if the human factor percentage has not achieved 100 percent, it means that excessive working time exists during the production. The operators have performed their task with a longer time than the ideal setup time. It is necessary for the operation team to monitor the performance of the manpower and also the frequency of the setup and changeover process to prevent the waste of the manufacturing cost, manufacturing time and resources. This is supported by the Puvanasvaran et al. (2016a) with the statement, the guidance is useful to control or monitor the operational time of operators. This could reduce the problem in scheduling, utilization of manpower and also the coordination between men and machines.

5. Conclusion

Setup loss is one of the factors that reduce the flexibility of the production time. High setup losses in the production might lengthen the time for the industry to respond to the changes of the customer demand. The usability and human factor can be the performance metric used to quantify the setup losses and allow the production team to identify the area of improvement effectively. Furthermore, these two performance metrics allow users to monitor and measure the setup and changeover process regarding the process scheduling and performance of the manpower. As shown in the result, the high setup time might not only caused by the excessive setup time, but also the frequency of the setup and changeover process. This is necessary for the production team to identify to tackle on the correct waste in an efficient way. These performance metrics are expected to give a better picture to the companies in quantifying the setup losses and assist companies in identification of area of improvement. In future, it can be implemented with other tools and techniques to improve the performance of the manpower.

Acknowledgements
The acknowledgement is expressed by the author to the fund sponsor, Ministry of Higher Education (MoHE) throughout the research period. The Fundamental Research Grant Scheme (FRGS) provided is coded FRGS_12015TK03FKP02F00279. Furthermore, the acknowledgement is given by the author to the Universiti Teknikal Malaysia Melaka for the support and encouragement throughout the research period.

References
Agrawal, S., Gautam, A., Chauhan, D.K., Tiwari, L.M., and Kapoor, S., A flow shop scheduling problem with transportation time and separated setup time of jobs, *Procedia Engineering,* vol. 38, no. 2012, pp. 1327-1332, 2012

Bokrantz, J., Skoogh, A., Ylipaa, T., and Stahre, J., Handling of production disturbances in the manufacturing industry, *Journal of Manufacturing Technology*, vol. 27, no. 8, pp. 1054-1075, 2016.

Bondhare, G., Pawar, A., and Deshpande, G., Productivity improvement in cable assembly line by MOST technique, *International Journal of Advance Industrial Engineering*, vol. 4, no. 2, pp. 50-55, 2016.

Ferradas, P.G., and Salonitis, K., Improving changeover time: a tailored SMED approach for welding cells, *Procedia CIRP Elsevier,* vol. 7, pp. 598-603, 2012.

Henry, J.R., Achieving lean changeover: putting SMED to work, Boca Raton, CRC Press, 2013.

Karasu, M.K., Cakmakci, M., Cakiroglu, M.B., Away, E., and Demirel- Ortabas, N., Improvement of changeover times via taguchi empowered SMED/ case study on injection molding production, *Measurement*, vol. 47, pp. 741-748, 2014.

Kumar, B.S., and Abuthakeer, S.S., Implementation of lean tools and techniques in an automotive industry, *Journal of Applied Science*, vol. 12, no. 10, pp. 1032-1037, 2012.

Low, S.N., Chong, S.H., Sim, H.Y., Razalli, S., and Kamruddin, S., Measurement of overall performance effectiveness in setup improvement, *Journal of Industrial Engineering,* pp. 1-7, 2014.

Madhav, R., Marnewick, A., Nel, H., and Pretorius, J.H., Managing changeover waste in manufacturing plants when using single minute exchange of dies, *Proceedings of the Internationl Conference on Industrial Engineering and Operations Management*, pp. 231-242, Rabat, Morocco, 11-13 April, 2017.

McIntosh, R., Culley, S., Gest, G., Mileham, T., and Owen, G., An assessment of the role of design in the improvement of changeover performance, *International Journal of Operations & Production Management,* vol. 16, no. 9, pp. 5-22, 1996.

Mohamed Esa, M., Abdul Rahman, N.A., and Jamaludin, M., Reducing high setup time in assembly line: a case study of automotive manufacturing company in Malaysia, *2nd Global Conference on Business and Social Science-2015,* vol. 211, pp. 215-220, Bali, Indonesia, 17-18 September, 2015.

Puvanasvaran. A.P., Mei, C.Z., and Alagendram, V.A., Overall equipment efficiency improvement using time study in an aerospace industry, *The Malaysian International Tribology Conference 2013,* vol. 68, pp271-277, MITC, 2013.

Puvanasvaran, A.P., Teruaki, I., Teoh, Y.S., and Yoong, S.S., Examination of overall equipment effectiveness (OEE) in term of maynard's operation sequence technique (MOST), *American Journal of Applied Sciences*, vol. 13, no. 11, pp. 1214-1220, 2016.

Puvanasvaran, A.P., Teruaki, I., Teoh, Y.S., and Mahamud, N.S., Hidden wastes in overall equipment effectiveness (OEE) under the study of maynard's operation sequence technique (MOST), *Proceedings of the 2016 Internationl Conference on Industrial Engineering and Operations Management*, pp. 1563-1568, Kuala Lumpur, Malaysia, 8-10 March, 2016a.

Schmidt, M., Munzberg, B., and Nyhuis, P., Determining lot sizes in production areas – exact calculations versus research based estimation, *3rd CIRP Global Web Conference,* vol. 28, pp. 143-148, 2015.

Stefansdottir, B., Grunow, M., and Akkerman, R., Classifying and modeling setups and cleanings in lot sizing and scheduling, *European Journal of Operational Research,* vol. 261, no. 2017, pp. 849-865, 2017.

Tanjong Tuan, S., Karim, A.N.M., Emrul Kays, H.M., Amin, A.K.M.N., and Hasan, M.H., Improvement of workflow and productivity through application of maynard operation sequence technique (MOST), *Proceedings of the 2014 International Conference on Industrial Engineering and Operations Managemenet*, pp. 2162-2171, Bali, Indonesia, 7-9 January, 2014.

Wong, Y.C., and Wong, K.Y., A lean manufacturing framework for the Malaysian electrical and electronic industry, *Proceedings of the 3rd International Conference on Information and Financial Engineering,* vol. 12, pp. 30-34, IACSIT Press, Singapore, 2011.

Zhang, H., Hu, M., Zong, F., Yin, B., Ye, D., He, Q., and Wang, Z., Wafer damage issue study by heavy Al wire wedge bonding, *Microelectronics International*, vol. 31, no. 2, pp. 129-136, 2014.

Biographies

Puvanasvaran A/L A. Perumal is a professional engineer graduated in Mechanical Engineering. He has been working as a Senior Engineer for over six years in National Semiconductor Melaka. He joins Academic Field in Universiti Teknikal Malaysia Melaka as a Lecturer in the year 2002 and now he is an Associate Professor. Beside involved in Teaching and Learning Activities for undergraduates and postgraduate students, he actively involved in research work. One of his main contributions during his doctorial study is thru attached with “Aero Composite” Manufacturing Company in Malaysia from 2005 to 2008. The scope of work includes planning and implementing Lean concept for above company in general and developing new framework to enhance problem solving capability among employees in eliminating wastages at the Kitting department as a pilot study. This new framework (People Development System) was developed by him and successfully adopted by the company to include under their Lean House as a foundation pillar. In addition, he has presented various papers with focus on Lean Integration related to his current study in journals and conferences internationally. Therefore, he is experienced in Lean Integration and implement Lean Integration concept in the industry.

Yoong Sai Sieng is currently pursuing his master degree in Universiti Teknikal Malaysia Melaka. He finished his degree as manufacturing engineering at the same university. He is also a graduate research assistant of Associate Professor Ir. Dr. Puvasvaran A. Perumal.

Tay Choo Chuan is an associate professor in the Universiti Teknikal Malaysia Melaka. He joins this university in the year 2004 as a lecturer. He has involved in the teaching and learning activities for undergraduates and post-graduate students. Besides that, he also involved in the research and his areas of research interest are group theory, optimization and quality control.