

Work Study Architecture for Lean Waste Analysis to Achieve Optimum Man-Machine Configuration

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Abstract – To survive in the global marketplace, companies has adopted lean towards reducing wastes and improving their efficiency. Manpower study traditionally employs work study methods such as Process Mapping and Man-Machine Charts which are no longer suitable to be used in the complicated manufacturing environment such as in the electronics manufacturing facility. Thus, a modified work-study architecture is designed and applied at the process under study to optimize the man-machine configuration. This paper details out the development and implementation of the work study architecture to perform lean waste analysis at an electronic manufacturing company. The benefits observed from the implementation phase indicate that the lean waste analysis performed using this system has reduced the lengthy time that work-study usually takes, eliminated human error during analysis and improved the accuracy of data.

Index Term – Lean Waste Analysis, Work Study Architecture, Lean Manufacturing, Man-machine configuration

I. INTRODUCTION

The survival issues in the marketplace force manufacturers to focus on opportunities in a creative way to reduce their operating costs. Thus, lean manufacturing implementation has grown in popularity to assist improving company's performance and productivity. Lean manufacturing is also known as the most influential manufacturing paradigm of recent years that can be considered as a multi-dimensional approach that encompasses a wide variety of management practices in an integrated system to produce finished products at the pace of customer demand with little or no waste [1].

Before lean improvement can be suggested, the basic data needed must be ready by completing work study to prepare the standard time for the process under study. Hicks [2] explained that Ohno and Shingo from Toyota have applied many traditional work study techniques, which had contributed to the reduction of the manufacturing cycle time. They also utilized work measurement techniques such as stopwatch time study, predetermined time standards (PTS) and work sampling in their work. However, stopwatch time study was used as a general tool for determining standard work, but predetermined time standard system (PTS) provides a way to use the accumulated result from prior time studies. Thus, with the current emphasis on lean manufacturing, PTS such as

Maynard Operational Sequence techniques (MOST) are used to provide time value data consistently and quickly [3].

This paper reports on a project conducted at the back-end of a semiconductor manufacturing firm that aims to implement lean and seeks to complete work study in order to establish basic standard data for its operations. The production lines are semi-automated, which means one operator normally is required to perform activities such as cleaning, setup and loading before a machine can process the products. While waiting for the machine to process a batch or a lot of products, the operator will perform other functions such as inspection on finished products, data entry and preparing a new lot for the machine. Upon machine completion, the operator will perform the unloading activity. The operator will repeat the activities with some other machines. One operator will normally manage two or more machines in a shift. Due to rising labor cost, there must be a work study technique to determine the ideal numbers of equipment that can be allocated to one operator to ensure that the operator is fully utilized. In addition, the work-study analysis should provide information on wastes for lean improvement activities.

Initially, Process Mapping and Man-Machine chart were evaluated as the work methods to be used [4]. Process Mapping was only able to provide information regarding operator utilization. Man-Machine chart can provide both operator and machine utilization but it get to be very complicated when the operator is required to handle more machines. In addition, the process to perform lean waste analysis still needs to be done manually and can get to be very tedious. Thus, these two methods were unsuitable to be used in the electronics manufacturing to perform man machine configuration study and lean waste analysis. Conversely, the authors used the basic concepts of these two work techniques to derive a mathematical model for work study and develop an approach for waste analysis. In addition and to ensure data accuracy, Maynard Operational Sequence Technique (MOST) work measurement method was chosen over the stopwatch time study. In this paper, the authors share their experience in developing and implementing an integrated architecture of work study and lean waste analysis. The paper is organized as follows: in the following section, lean waste is explained. After that, the mathematical model development and the man to machine ration (M2M) are presented. The work study integrated architecture is presented in section III. Results and discussion are presented in section IV. Finally, the conclusions are presented in section V.

II. M2M DEVELOPMENT

In this section, first the lean seven-waste is introduced. Then the authors explain how man to machine ration (M2M) is developed.

A. Lean 7 Types of Waste

The main idea of Lean concept is waste elimination. Technically, waste or 'Muda' is anything that does not add any value to the activity [5]. However, this focus on waste elimination can only be realized by taking consideration to the increase in the Value Added (VA) and the elimination of Non-Value Added (NVA) activities such as transportation, inventory, motion, waiting, over-production, over-processing and defect [6]. Figure 1 illustrates the 7 types of waste.

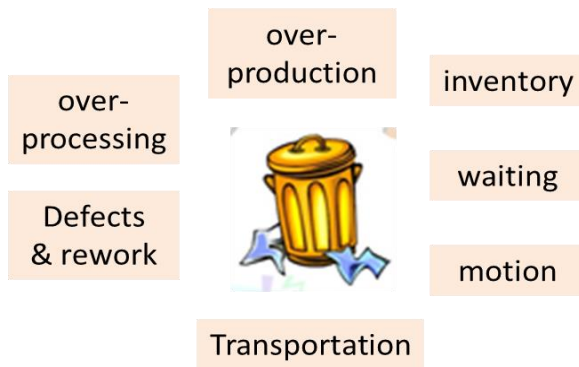


Fig. 1. The 7 types of wastes [6]

B. Work Study for Lean Analysis

Work study can assist manufacturing to capture the detail breakdown of the operational costs and provide information to assist management to ensure smooth workflow [7]. The work-study technique consists of the method analysis and work measurement analysis. The method analysis focuses on the study of existing work and identifying possible opportunities to make the work easier and more effective.

Lean manufacturing requires maps of the sequence of the process. This is done with the method study called process chart, which is capable of provide means for analyzing and improving the process which is imperative for lean manufacturing implementation. During a method study, jobs are divided into elements, which can be timed using stop watch or PTS such as MOST. MOST is a work measurement system which can be easily implemented and practically maintained [8]. It is a system to measure work, and concentrates on the movement of objects. The movement of objects follows certain consistently repeating patterns such as reach, grasp, move and positioning of the object. These sequences can be identified and arranged as a sequence of events manifesting the movement of an object. A model of this sequence is made and acts as a standard guide in analyzing the movement of an object [9,10].

Through the evaluation of the common work study tools such as Process Mapping and Multi Machine Chart, the first important element that contributes to the labor productivity determination is the operator's utilization or the time spent to perform a set of activities over a period of time [11]. Operator's utilization consists of the operator's activity time, the number of time each activity is repeated (frequency) and the time-frame in which the whole process is repeated. Hence, the operator's utilization can be computed using equation (1).

$$\text{Operator Utilization (\%)} = \frac{\text{Activity Time} \times \text{Frequency}}{\text{Total Time}} * 100 \quad (1)$$

where:

Activity Time = time taken by an operator to perform a task.

Frequency = rate of recurrence of an activity.

Total Time = Total working time of an operator in a shift.

Since the equipment used at the back-end semiconductor manufacturing line are semi-automatic, for a machine to process a lot of products, the operator will need to perform the machine setup, loading the unprocessed product on the machine and documentation on the shop order. This set of activities will be repeated when a new lot is started on the machine. Since the mode of operation machines dependent, the operator will be performing a set of tasks while the machine is processing a batch of products or a lot.

Through the evaluation of the Multi Machine Chart, the next key element found was the lot cycle time or the time taken for the machine to complete a certain quantity of product in a lot or lot size. The data regarding the lot cycle time can be obtained through measuring the time to process the lot using a stop watch. However, the lot cycle time can also be obtained when information on lot size, the number of units produced in one hour or Units Per Hour (UPH), and the Overall Equipment Efficiencies (OEE) are available from the manufacturing shop floor. The relationship between these variables is defined as shown in (2).

$$\text{Lot Cycle Time} = \frac{\text{Lot Size}}{\text{UPH} * \text{OEE}} \quad (2)$$

where,

Lot size = the set quantity of a unit to be processed.

Units per Hour (UPH) = Number of units processed in an hour.

OEE = Overall Equipment Efficiency.

Equation (1) explains how to determine the operator utilization. However, since many of the activities are done repetitively for each lot, the labor utilization can be sampled based on the lot cycle time because it represents the utilization of the labor handling a machine in a shift. Figure 2.0 shows the concept of the operator utilization where the M2M (%) indicates the percentage utilization of the operator.

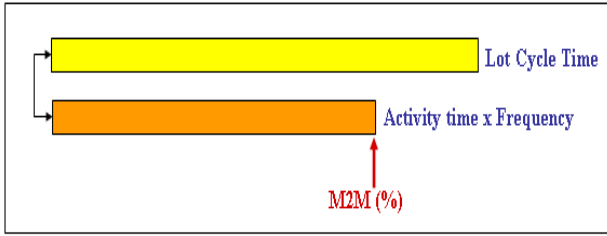


Fig. 2. Concept of Operator Utilization [10]

Since the operator needs to perform activities within a lot cycle time, every individual activity time interval must be multiplied by the frequency and then the summation of the product of activity time interval and its frequency of occurrence has to be computed. If this summation is divided by the total lot cycle time, the man to machine ratio (M2M) can be computed using (3).

$$M2M(\%) = \sum_{i=1}^n \frac{\text{Activity Time}_i \times \text{Frequency}_i}{\text{Total Time}} * 100 \quad (3)$$

where,

- i = number of activity time and the frequency
- n = total number of activity time and the frequency

III. THE INTEGRATED ARCHITECTURE

A. Work Study Framework

The work-study framework considers the factors to be used as the inputs such as the operator activity and time value, frequency and the lot cycle time of the product. These values are then used as the variables in the mathematical formula to process the outputs such as the operator utilization. The lean analysis will involve the determination of the man to machine configuration (M2M) and the classification of the 7 types of wastes. Figure 3 provides the work-study framework used in this study.

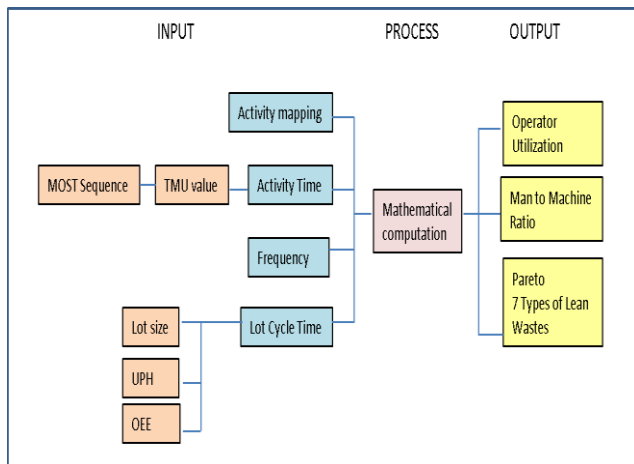


Fig. 3. Work Study Architecture

B. Work Study System Architecture

The work-study framework is then used to design the architecture for the Work Study System. Figure 4 shows the work-study system architecture which consists of the user interface design, the navigation design, the input design and the output design. In the input design, the data entry page enables the user to add or delete information. The information entered will then be stored. The system will provide the user with the results of the operator utilization and the M2M in the summary worksheet. Moreover, the histogram and Pareto Chart provide the user with alternatives to view the seven-wastes. User is also provided with a user manual as a guideline in the usage of the system.

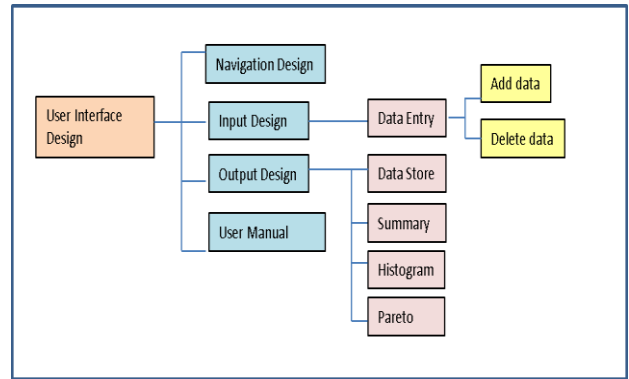


Fig. 4. Work Study System Architecture

IV. RESULTS AND DISCUSSION

As per the work-study system architecture that has been introduced earlier, the first activity to be executed is to design the system navigation flow using Microsoft Excel spreadsheet (Figure 5). The template control panel is designed where a user can choose which spreadsheet the user wants to view. The second worksheet will consist of the data entry where a user will be required to input the work-study information such as the operator activity, MOST activity sequence, etc. The data will then be stored in the Work Study Template residing in the data store template. Upon completion of the data entry, the user will automatically be provided the operator utilization, man to machine ration and lean waste analysis information in the summary, histogram and Pareto worksheets.

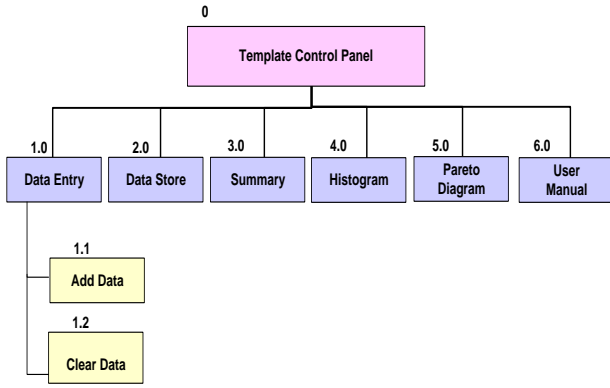


Fig. 5. Work Study System Navigation Design

A. Template Control Panel

The work-study system development first involves the Template Control Panel (Figure 6). Next, the system Data Entry Interface is designed, which includes the Data Store Output Interface, Summary Interface and the Pareto Diagram Interface. The results of each interface are illustrated in Figure 7, Figure 8, Figure 9 and Figure 10 respectively.



Fig. 6. Work Study System Navigation Design

B. Data Entry Interface

The input design interface describes and illustrates the user interface for the user to enter information. Figure 7 shows the information required to be included in the data entry worksheet such as the activity, and the MOST activity sequence options to be entered by the user related to the activity under study. This MOST sequence option can be the general move, control move or the tool-used move.

Fig. 7. Data Entry Input Interface

C. Data Store Interface

The data storage will be generated based on the data entry input interface. This spreadsheet provides the user with the work-study template consisting of all the information entered in the data entry worksheet and allows the user to view and validate the information entered in the data entry worksheet. Figure 8 provides an example of the data store worksheet.

BACK TO ADD DATA
BACK TO CONTROL PANEL

DATA STORE

Activities	Most Sequence	RF	CF	Activity time TMU	Activity time (min)	Frequency/cycle (in ratio)	Lot cycle time (min)
9. Solder paste change							
Pick-up allen key & unscrew/remove jig	A10B1G1 A1B0P1 U10				360	0.216	0.33333
remove syringe fin jig	A10B1G1 M1X0H1 A10				240	0.144	0.33333
remove tube fin gauge	A10B1G1 M1X0H1 A10				240	0.144	0.33333
press dispense button to dispense the solder	A10B1G1 M1X10H1 A10				250	0.15	0.33333
Monitor the solder flow	A10B1G1 M1X0H1 A10				0	0	0.33333
Remove tube fin gauge	A10B1G1 M1X0H1 A10				240	0.144	0.33333
pick-up allen key & jig	A10B1G1 A1B0P1 U10				360	0.216	0.33333
Screw jig on	A1B0P1 A10						0.33333
	A10B1G1 A1B0P1 R1						0.33333
Pick up pen and mark the 1f	A1B0P1 A10				270	0.162	0.33333
Close the m/c guard	A10B1G1 M1X0H1 A10				240	0.144	0.33333
Press button to run m/c	A10B1G1 M1X0H1 A10				240	0.144	0.33333
					2,202	5.3333	

Fig. 8. Data Store Output Interface

D. Summary Interface

The summary interface allows the user to obtain the information regarding the operator utilization and the man to machine ratio for the process under study. Figure 9 shows an example of the summary worksheet where the entire utilization of the operator is reported in the total value and the man to machine ration is provided in the (M2M) columns. For example, from Figure 9, the operator utilization of the process is 18% when performing activities such as from tool preparation, pre-mold activity, machine buy-off until unloading.

SUMMARY

No	ACTIVITY	MZM-1(%)	MZM-2(%)	MZM-3(%)	MZM-4(%)	MZM-5(%)	MZM-6(%)
1	Tool Preparation	0.395	0.790	1.185	1.58	1.975	2.37
2	Pre-Mold Activity	0.3325	0.665	0.9975	1.33	1.6625	1.995
3	Machine Buy off	0.500	1.000	1.500	2.000	2.500	3.000
4	Loading	0.6775	1.355	2.0325	2.71	3.3875	4.065
5	Documentation	0.2438	0.488	0.7314	0.9752	1.219	1.4628
6	Positrol Log	0.086	0.172	0.258	0.344	0.43	0.516
7	Shop Order	0.235	0.470	0.705	0.94	1.175	1.41
8	Unloading	0.535	1.070	1.605	2.14	2.675	3.21
	TOTAL	3.0048	6.0096	9.0144	12.0192	15.024	18.029

Fig. 9. Summary Output Interface

BACK TO CONTROL PANEL

HISTOGRAM MZM

HISTOGRAM TMU

PARETO DIAGRAM TMU

activities, time values and activities frequency are determined. A work-study system is then developed based on the work-study framework design which eliminates the need for user to perform lean waste analysis. The work-study system architecture was tested using real-life data from a back-end semiconductor firm. The results indicate that the proposed integrated architecture has reduced the lengthy time that work-study usually takes and improved the accuracy of the results. Future works include the use of simulation modeling to investigate the impact of the results on the overall improvement of the production line.

E. Pareto Diagram Interface

The Pareto Diagram Interface provides automatic results on classification of value added, and non-value added activities or wastes occurring in the process. Figure 10 shows an example of the lean waste analysis in the form of Pareto Chart.

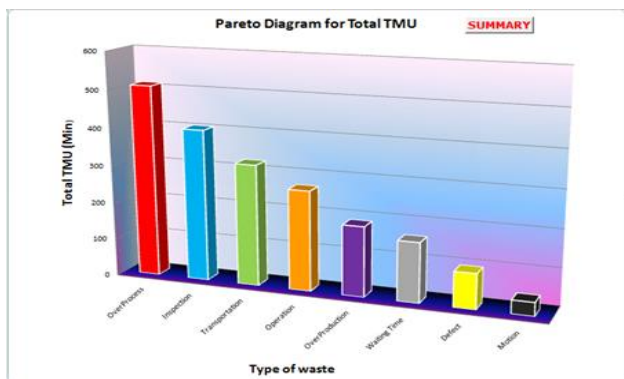


Fig. 10. Pareto Diagram Output Interface

With the work-study system, the user only needs to enter the information using the data input interface. The process of determining the MOST activities sequence has also been simplified. Upon completion of data entry, the related calculation such as total TMU, time value conversion, build Pareto Diagram and Histogram, the result of the operator utilization and man to machine configuration is performed by the work-study system. User will automatically be provided with a Pareto Chart of the types of wastes occurring in the process. Therefore, the IE is provided with information on the areas that require improving the activities. Consequently, the user enjoys a great benefit that significantly reduces the tedious task of data analysis and the risk of performing human error.

IV. CONCLUSION

This paper presents an architecture that integrates work study technique with lean waste analysis for electronics manufacturing environment. The proposed architecture includes designing the work-study technique for back-end semiconductor where important factors such as operator's

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