

# Man to Machine Ratio (M2M) Technique for Labor Productivity Improvement

Rohana bt. Abdullah  
Faculty Manufacturing Engineering  
Kolej Universiti Teknikal Kebangsaan Malaysia  
Ayer Keroh, Melaka  
06 233 2548  
rohana\_abdullah@kutkm.edu.my

Prof.Dr.Razali Muhammad  
Faculty Manufacturing Engineering  
Kolej Universiti Teknikal Kebangsaan Malaysia  
Ayer Keroh, Melaka  
06 233 2420  
mohdrazali@kutkm.edu.my

## ABSTRACT

Tough global competition requires every manufacturer to be creative on ways to reduce every aspects of their manufacturing cost and to improve productivity. Labor cost is among the key cost contributors that the manufacturers are focusing on. Labor productivity improvement is all about getting more units out with the same or lesser amount of labor input.

This paper describes the development of a work measurement technique called Man to Machine Ratio (M2M) which is a methodology to measure and improve labor productivity for the backend semiconductor production line. M2M is derived through combining the existing method of process mapping, the established Maynard Operational Sequence Technique (MOST) predetermined time standard and the derivation of an equation to measure the labor utilization percentage. Case studies were carried out on the application of the new technique in order to attain the existing labor utilization on the key process operators. The study results were used to identify labor productivity improvement and waste elimination projects in order to achieve the optimum labor utilization goal for the company.

## Keywords

Work measurement, man to machine ratio, labor productivity improvement

## 1. INTRODUCTION

Based on a report produced by a research firm Gartner Inc, the semiconductor market has recently grown 25.7 percent annually in the Asia-Pacific region alone. With so many players in the semiconductor business, it is critical for businesses to reduce the operating cost and improve the profit margin. Performance metrics are used to measure a company's success. Among the important and commonly used performance metrics are on-time delivery, quality, productivity, resource utilization, inventory turns and customer incidents [1], [2].

Productivity has become an important aspect in an organization nowadays because high productivity means higher profit margin for a company. According to Stevenson [3], productivity can be defined as a ratio of a measure of output to a measure of resources used for the input and can be generally expressed as:

$$\text{Productivity} = \text{output/input}$$

Traditionally, the focus on productivity improvement was mainly on how to increase the utilization of the capital. But slowly, companies are adopting Lean culture where the drive is to eliminate waste everywhere in the organization. Waste in Lean is defined as anything other than the minimum amount of equipment, materials, parts, space and worker's time, which are absolutely essential to add value to the products or service [4].

Due to the rising labor cost factor, labor is now becoming more valuable asset to an organization and has a big opportunity to be improved. In Lean Manufacturing, labor contributes to the motion, waiting and overproduction types of waste [5]. Eliminating labor wastes means improving productivity. Hence, the various types of productivity techniques commonly used are:

- i. Questioning technique
- ii. Pareto Analysis
- iii. Family Tree Analysis
- iv. Cause & Effect Diagram
- v. Work Study

The most relevant productivity method to measure worker's performance is work study. Work study is a systematic examination of human activities in order to improve the efficiency. Sometimes, the actual term of "work study" has been replaced by phrase of "continuous improvement of work". This is due to the on going monitoring improvement and quantifies work on a continuous basis [6].

Work study includes methods study and work measurement. Method study is use to improve method of doing job while evaluation of effectiveness measured by work measurement. The objective of method study is to improve in productivity for company or organization. Figure 1 shows the work study categories and the relationship between work method and work measurement.

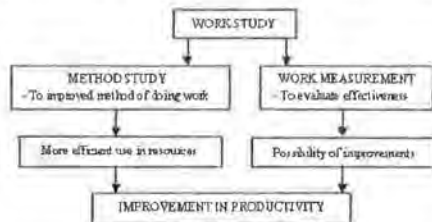


Figure 1: Relationship between work method and work measurement

Work method techniques can be divided into 2 categories. The first category is defined as the traditional methods designed since the late 1970's consisting of process chart, man to machine chart and work sampling. Another category is the more recent or modern methods where simulation using computer software, mathematical modeling and touch time analysis are used to measure and analyze work elements.

Stop watch and predetermined time standards (PTS) are common methods used to measure work elements. PTS provides more consistent time standards and requires lesser time as compared to the stop watch method since the common basic movements, operator's rating and work variations are already taken into consideration. There are two types of PTS which are Method and Time Measurement (MTM) which is used to measure manual operator's activities and Maynard Operational Sequence Technique (MOST) which is more suitable to measure operator handling semi-automatic equipment. The standard time from MOST is based data gathering and data validation process since 1967 and therefore, ensures 95% confidence level on the data accuracy as compared to the conventional method of time study using the stop watch.

## 2. BACKGROUND

Denton [7] emphasized that it is important to measure relevant and specific things that the company wants. The existing work study techniques were insufficient to be used to measure the labor utilization and the man to machine ratio of the back-end semiconductor production line. Therefore, the purpose of the study is to develop suitable technique to be used to measure the labor utilization and to

determine the ideal man to machine ratio for the back-end semiconductor production line.

The scope of this research includes the evaluation of the existing work study techniques based on the key factors identified. This paper will also discuss on the development of the Man to Machine (M2M) technique which is designed to measure and identify improvements of labor utilization for the back-end semiconductor. To test the effectiveness of this M2M technique, case studies were performed at a semiconductor company's manufacturing processes. These case studies were conducted utilizing a systematic Lean Six Sigma project management approach.

## 3. METHODOLOGY

A thorough literature review to identify various methods and tools that have been used in performing the labor productivity study was conducted. Selected techniques were evaluated based on the criteria for a suitable method which are meeting the study objectives, cost, speed, skill set, accuracy and flexibility.

The variables that contribute to the measurement of the operator's utilization and the man to machine ratio were also analyzed from these techniques. Field observation on the operator's and machine's activities utilizing an existing technique was conducted to observe other variables that can be attributed to the analysis of labor productivity in a back-end semiconductor environment. The results from the field study combined with the analysis done on the existing techniques were used to develop a method called Man to Machine ratio or M2M.

Case studies were conducted to test the validity of a qualitative research. There are various types of case studies that a researcher can employ and this study applied the program effect case studies [8] since this approach involves identifying findings of specific interest which is the labor productivity measurement technique and then implementing this technique in a selected site to evaluate the effectiveness. In this study, the M2M will be tested on both the manufacturing operators and the non-manufacturing operators to test the applicability of this method in determining the labor utilization in both areas.

A Lean Six Sigma systematic project management approach was used when performing the case study. The DMAIC flow is defined as follows:

- i. Problem definition (D)
- ii. Data gathering (M)
- iii. Analysis (A)

- iv. Improve (I)
- v. Control (C)

## 4. RESULTS AND DISCUSSIONS

### 4.1 Development of M2M technique

Figure 2 shows the summary of different work study techniques and their applications obtained various through literature searches.

Traditional	Modern
Process Chart Left Hand/Right Hand Chart Man to Machine Chart Multi-machine Chart Simo Chart Work Sampling	Simulation software Touch Time Analysis Work Cell Load Chart

Figure 2: Summary of Work Study Techniques

The Process Chart, Multi-Machine Chart, Simulation and Touch Time analysis techniques were used to evaluate and not one were able to meet all the criteria. For example, the Process Chart is only able to measure the operator's utilization but not the man to machine ratio. The Multi-machine Chart is able to meet the objectives but is not an easy method to apply and maintain.

Apart from evaluating the existing techniques against the set criteria, the common variables used to measure the operator's utilization were also able to be extracted. These variables were detail work activities, the time element and the number of repetitions for each activity (frequency). The field study done utilizing the Process Mapping technique confirmed that these variables were the required data to get the operator's utilization. Hence, the operator's utilization can be defined as

$$\text{Operator utilization (\%)} = \frac{\text{Activity time} \times \text{Frequency}}{\text{Total Time}} \times 100$$

Where the activity time is the time taken by an operator to perform the task and the frequency is the rate of recurrence of an activity.

When evaluating the Multi-machine chart, the important variables required to measure the machine time was able to be analyzed. The result shows that the machine time is the time to process a lot or known as a lot cycle time. The lot cycle time can also be obtained if information on lot size or the set quantity of units to be processed, the units per hour (UPH) and the Overall Equipment Efficiency (OEE) were

available. The relationships between these variables can be defined as:

$$\text{Lot Cycle Time} = \frac{\text{Lot Size}}{\text{UPH} \times \text{OEE}}$$

Since the mode of operation at the back-end semiconductor production line is machine dependent, the operator will be performing a set of task such as product loading, inspection and shop order recording while the machine is processing a batch or a product lot. Hence, the operator's utilization while the machine is producing a lot is able to be measured. In addition, the sum of each individual operator's activity utilization will provide the total utilization of an operator while manning a machine or known as M2M percentage.

$$\text{M2M (\%)} = \sum_{i=1}^n \frac{\text{Activity Time} \times \text{Frequency}}{\text{Lot Cycle Time}} \times 100$$

The number of machines that the operator is able to The existing process chart format was then modified using the Microsoft excel spreadsheet to include the additional information on MOST time analysis, activity frequency, lot cycle time and man to machine ratio. This new format is called the process mapping and M2M Form (Figure 3).



Figure 3: Process Mapping and M2M Form

### 4.2 Case Studies

The case studies were conducted at a leading semiconductor company located in Seremban, Negeri Sembilan. The back-end semiconductor facility was established in 1979 and currently has about three thousand employees. The operations are divided into four major areas and the company operates 24 hours a day and 7 days a week. There were four major areas selected for the study which were the assembly process (wafer saw and front end), back end process (mold, trim and form), final test process

designing work standards and operator cross training in order to increase the production throughput and ensure balanced work loads between operators. These activities will contribute to the overall improvements in the productivity of the production line and will help contribute to the reduction in cost and the increase in profit to the company. In the end, the company will be in the right track of its lean journey and towards achieving a high productivity, quality and safety of the employees.

## **6. ACKNOWLEDGMENTS**

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## **7. REFERENCES**

- [1] Sink, D.Scott (1991). The Role of Measurement in Achieving World Class Quality and Productivity Management. *Industrial Engineering Magazine*. Vol 23, No 6. 23-29
- [2] Engle, Paul (2005). The Metrics System. *Industrial Engineers Magazine*. Vol. 37, No.9.24.
- [3] Stevenson, William J. (1996). *Production/Operations Management. Productivity, Competitiveness, Strategy. The Irwin Series in Production Operation Management, Operation Management 5<sup>th</sup> Edition*, 40-44.
- [4] Canel, C., Rosen, D., Anderson, E.A. (2000). "Just In Time Is Not Just For Manufacturing: A Service Perspective". *Industrial Management and Data Systems*. Vol. 100, No. 2, 1-60.
- [5] Rawabdeh, Ibrahim A (2005). A Model for Assessment of Waste in Job Shop Environment. *International Journal of Operations and Production Management*. Vol 25, No 8, 800-8226
- [6] Brown, Stephen (1994). Role of Work Study in TQM. *The TQM Magazine*. Vol.16, No3.9-15.
- [7] Denton, Keith D. (2005) Measuring Relevant Things. *International Journal of Productivity and Performance Management*. 278-287
- [8] Wikipedia Encyclopedia.  
<http://en.wikipedia.org/wiki/Research>

and the support function. Each of the study followed the lean six sigma DMAIC project management methodology

#### 4.2.1 Define (D)

Detail information on the process and equipment were obtained and recorded. The layout of the equipment was also necessary to determine the location and the distance between one workstation to another. In addition, the current ratio of man to machine and the material flow information were also gathered during this stage.

#### 4.2.2 Measure (M)

The operator's work activities and frequency were recorded using the process mapping and M2M chart for the purpose of measuring the labor utilization. MOST predetermined time standards were assigned to each work element. For the equipment information, the lot size, UPH, breakdown data, set-up time were gathered through factory shop floor system, log book and time study techniques.

#### 4.2.3 Analyze (A)

Utilizing the M2M equation, the current operator's utilizing and the ideal man to machine ratio can be determined. The example of the M2M result is depicted in Figure 4.

Activity	Time (sec)	Time (min)	Frequency	Waste cycle time (min)	M2M1	M2M2	M2M3	M2M4	M2M5	M2M6
1. Pickling/soaking	300	5	1/week	14.40	0.21%	0.21%	0.21%	0.21%	0.21%	0.21%
2. Preparation (beginning of shift)	11	0.17	1/shift	14.40	0.09%	0.09%	0.09%	0.09%	0.09%	0.09%
3. Wire mesh (empty style)	27.30	0.45	1/shift	14.40	0.19%	0.19%	0.19%	0.19%	0.19%	0.19%
4. Machine set up (beginning of shift)	33.20	0.55	1/shift	14.40	0.23%	0.23%	0.23%	0.23%	0.23%	0.23%
5. Die change	300	5	1/shift	14.40	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%
6. Wire run	30.04	0.50	1/shift	14.40	0.21%	0.21%	0.21%	0.21%	0.21%	0.21%
7. Machine start	151.56	2.53	1/shift	14.40	1.67%	1.67%	1.67%	1.67%	1.67%	1.67%
8. Wire work	9.30	0.15	1/shift	14.40	0.06%	0.06%	0.06%	0.06%	0.06%	0.06%
9. Inspection	43.36	0.72	1/shift	14.40	0.27%	0.27%	0.27%	0.27%	0.27%	0.27%
10. Fill up post-req (beginning of shift)	12.00	0.20	1/shift	14.40	0.08%	0.08%	0.08%	0.08%	0.08%	0.08%
11. Fill up post-req (end of shift)	6.00	0.10	1/shift	14.40	0.04%	0.04%	0.04%	0.04%	0.04%	0.04%
12. Shift power (end of shift)	3.00	0.05	1/shift	14.40	0.02%	0.02%	0.02%	0.02%	0.02%	0.02%
13. Shift power (end of shift)	12923.4	215.39	1/shift	14.40	89.65%	89.65%	89.65%	89.65%	89.65%	89.65%

Figure 4: Example of the M2M result

#### 4.2.4 Improve (I)

By analyzing the result of the study, opportunities for improvement were able to be identified and implemented plans were developed through the continuous improvement team. The team consisted of the process engineers, section heads and industrial engineers (IE).

For example, a Pareto analysis at the die bond and wire bond process was done and various potential improvements were identified. As a result, additional computers for entering the lot information were placed in the production line and were able to reduce 20% of the operator's movement.

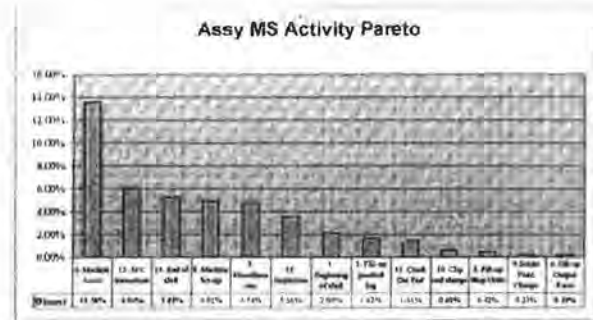


Figure 5: Pareto Analysis on Assembly Work Study

#### 4.2.5 Control (C)

In order to ensure all the projects identified were implemented, the team was required to present their progress to the steering committee headed by the company's general manager every quarter. With the success of the pilot area, the project was extended to the other operations. Once the improvement was done, each area IE was required to recalculate the M2M for the improved process and continuously work together with the team to identify further opportunities and eventually achieving the company's goal of improving the productivity through optimum utilization of labor.

## 5. CONCLUSIONS

The Man to Machine (M2M) technique is an improved work study technique that is developed to provide a work measurement practitioner with cost effective, easy, fast, accurate and flexible tool to measure the labor productivity at the back end semiconductor process. By utilizing the M2M method, current and ideal labor utilization can be determined and opportunities can be identified to further improve labor productivity and reduce manufacturing cost. Detail labor activities are able to be mapped to identify value added and non-value added activities in order eliminate waste and improve the production throughput while still considering the ergonomic factor and the product quality.

The result of the improvement of the cycle time will contribute to the increase in the speed of delivery to the customers. Thus, the company will be able to confidently identify the actual number of employees they need to employ and can concentrate on the training to ensure each employee they hire provides high productivity and performance to the company.

By employing the M2M method, human wastes such as motion and idling were able to be identified. In addition, the data obtained from the work study can be used for