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Exploring The Overall Equipment Effectiveness (OEE) In An Industrial Manufacturing Plant

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Abstract: This study intended to apply Overall Equipment Effectiveness (OEE) as a performance measurement tool to measure the effectiveness and performance of the machines in the selected manufacturing plant. For the purpose of this study, three machines were selected from the manufacturing plant. Apart from this, the issues and factors affecting the OEE figures were discussed as part of the findings. A case study approach was chosen to conduct the study. This study employed quantitative method to conduct the analysis part of the study where empirical data will be computed to provide typical information for decision making. The primary findings of this study were the possible factors that dominantly affect the equipment effectiveness in the selected manufacturing plant. These findings were used to serve as a guideline to improve the existing problem for the selected machines. Ultimately, it was recommended that the selected manufacturing plant employs OEE as their primary performance measurement tool.

Keywords – Overall Equipment Effectiveness, performance measurement tool, manufacturing plant.

I. INTRODUCTION

As noted by Huang et al (2003), due to intense global competition, companies are striving to improve and optimize their productivity in order to remain competitive. Fleischer et al (2006) stated that the competitiveness of manufacturing companies depends on the availability and productivity of their production facilities. The condition has triggered the need for a rigorously defined performance measurement system that is able to take into account different essential components of productivity in a manufacturing process.

Nakajima (1988) had launched a total productive maintenance (TPM) concept to offer a quantitative metric namely the Overall Equipment Effectiveness (OEE) for measuring productivity of individual equipment in a manufacturing plant. The quantitative metric (OEE) can identify and measure losses of crucial parts in a manufacturing process namely availability rate, performance rate and quality rate. The evaluation using OEE supports the betterment of equipment effectiveness and its productivity. Huang et al (2003) reported

that the OEE concept is becoming increasingly popular and has been widely utilized in industries over the world as a quantitative tool essential for measurement of productivity especially in the semiconductor manufacturing operations.

According to preliminary study noted that OEE began to be recognized as a fundamental method for measuring plant performance in the late 1980s and early 1990s during the emergence of maintenance benchmarking, introduction of Total Productive Maintenance and the founding of the Society for Maintenance Reliability Professionals.

It is therefore with these statements that OEE was chosen for this study to measure the effectiveness of the equipment or machines within an industrial manufacturing plant

A. Background of Study

According to Malaysian Industrial Development Authority (MIDA, 2005), manufacturing is the largest economic drive in Malaysian industrial development contributing 32% of overall economic and specifically 79% of the total exports to other

countries in comparison to other contributing sectors. Achievement for better economic pursuit in Malaysia is greatly influenced by manufacturing industries and hence, focuses and attention should be allocated for the industry to further improve and main the development.

In conjunction with the stated report that electronic and semiconductor products is Malaysia's most dominant manufacturing industry for exporting, Company F had been chosen for this study. Company F is situated at the Parit Raja industrial area in Batu Pahat, State of Johor Darul Takzim. The Japanese-base company's product focuses on two key areas of electromechanical components – relays and keyboards, and their parts thereof. Company F manufactured products to be exported to countries such as Japan and China.

B. *Problem Statement*

Researches or literature related to OEE in Malaysia is very limited, thus, it can be implied that OEE is still new to Malaysia Industry context. As Malaysia is growing rapidly towards industrialization, it is not hard to foresee the importance of implementing an effective method to improve the productivity and contributes to the growth of industries. Despite the difficulty to obtain literature or references on OEE in Malaysia context, OEE was still chosen as the study. The success of this study would be beneficial to the library of knowledge relative to OEE in Malaysia context.

A preliminary interview has been conducted with the production manager of Company F to identify if any problem related to production persists. According to the production manager, Company F does face some productivity issues in the recent months. Few operating machines do not achieve the productivity level they needed. The production manager also expressed the need for the immediate identification of the root causes that impede the productivity. Hence, an OEE measurement is suggested to Company F to tackle the problem.

C. *Study Questions*

- i. How to explore the current performance and effectiveness of an industrial manufacturing plant's equipment?
- ii. What causes the fluctuation of the Overall Equipment Effectiveness figures in an industrial manufacturing plant?

D. *Objectives of Study*

- i. To explore the current performance and effectiveness of an industrial manufacturing plant's equipments using the Overall Equipment Effectiveness as a performance measurement tool.
- ii. To identify the factors that determines the Overall Equipment Effectiveness in an industrial manufacturing plant.

E. *Scope of Study*

An industrial manufacturing plant has been selected for the purpose of this study as suggested by final year project title: A Study of the Factors Affecting the Overall Equipment Effectiveness (OEE) in an Industrial Manufacturing Plant. The company selected for the study is situated in Parit Raja industrial area from Batu Pahat, Johor Darul Takzim as to reason with the financial constraints and time constraints of the study.

Apart from that, the selected company is limited to those having major equipment utility to carry out their manufacturing process. The study is focused on the equipment effectiveness related activities and limited to the production area of the selected plant. The findings obtained from the study cannot be generalized and can only be recommended as a suggestion or improvement to the selected plant.

F. *Significance of Study*

This study applied the use of Overall Equipment Effectiveness extensively to play as a performance indicator measurement tool and also to identify predominant factors affecting the overall performance of the machines in an industrial manufacturing plant. The study is to showcase the practicability of OEE in measuring a plant's performance and outline the capability and usefulness of OEE as a benchmark tool for continuous improvement.

As studied, OEE provides clear visibility on the performance status in a manufacturing plant and a powerful lever of control. Thus, it is hoped through the comprehension of this study, the selected company will apply OEE in their manufacturing plant for a better measurement of performance. It is also hoped that the findings of the study provides a potential guideline or suggestion to the studied plant to improve its equipment effectiveness and efficiency.

Lastly, the study is hoped to be used as a reference or guideline to other manufacturing plant and also a source for future study in fields relevant to OEE. It is hoped that this study on OEE contributes to the library of knowledge relative to OEE and will be embodied as a part into the body

of knowledge or the mass collection of literatures of this context since there are less study on this context being conducted in Malaysia.

II. *LITERATURE REVIEW*

In this chapter, information or literature related to Overall Equipment Effectiveness (OEE) has been reviewed thoroughly for a clear and comprehensive understanding of the OEE measurement itself. This chapter reviews the overview of OEE, the purpose of OEE, the chronic and sporadic disturbances in the measurement, the six big losses and taxonomy of OEE, the components in OEE measurement and the example of calculation, the ideal OEE figure, the 1% OEE improvement effect and the previous study done. The reviews provide extensive knowledge related to OEE from the development of OEE as a measurement tool to its theoretical concept to its application and functions in industry.

A. *Overview of OEE*

OEE measurement tool was developed from the Total Productive Maintenance (TPM) concept launched by Nakajima (1988). OEE is defined as a measure of total equipment performance, which is the degree to which the equipment is doing what it is supposed to do (Williamson R.M., 2006). Bulent Dal, et al (2000) stated that OEE is used for tracing and tracking improvements or regression in equipment effectiveness over a period of time. Production losses, together with other indirect and hidden costs, constitute the majority of the total production costs (Ericsson J., 1997). Nakajima (1988) suggests that OEE was a measure that attempts to reveal these hidden costs.

B. *Purpose of OEE*

The OEE measurement can be applied at several different levels within a manufacturing environment. Firstly, OEE can be used as a benchmark for measuring the initial performance of a manufacturing plant in its entirety. In this manner the initial OEE measure can be compared with future OEE values, thus quantifying the level of improvement made. Secondly an OEE value, calculated for one manufacturing line can be used to compare line performance across the factory, thereby highlighting any poor line performance. Thirdly, if the machines process work individually, an OEE measurement can identify which machine performance is worst, and therefore indicate where to focus TPM resources (Bulent Dal, et al, 2000).

C. *Chronic and Sporadic Disturbances*

Losses are caused by activities that absorb resources but create no value. Therefore, it is crucial to understand and measure disturbances to the manufacturing process (Bulent Dal, et al, 2000). Johnson and Lesshammar (1999) stated that the losses are due to manufacturing disturbance and classify the disturbance as either chronic or sporadic according to their frequency of occurrence. Chronic disturbances are defined as small, hidden and are as an outcome of several concurrent causes. On the other hand, sporadic disturbances are more significant as they quickly and have large deviations from the normal state. Sporadic disturbances are more significant as they occur quickly and as large deviations from the normal state. Sporadic disturbances occur irregularly and their dramatic effects are often considered to lead to serious problems. However, research evidence suggests that it is the chronic disturbances that result in the low utilization of equipment and large costs because they occur repeatedly (Nakajima, 1988).

D. *The Six Big Losses*

As discussed, OEE was designated to identify these losses. It is essentially a bottom-up approach where an integrated workforce strives to achieve OEE by eliminating the six big losses (Nakajima, 1988). The six big losses are categorized as breakdown, waiting, minor stoppages, reduced speed, quality defects and start-up losses. Breakdown and waiting are downtime losses considered for availability rate, minor stoppages and reduced speed are speed losses considered for performance rate and quality defects and start-up losses are quality losses considered for quality rate.

E. *Components in OEE*

The components in OEE is:

..... (2)

Availability refers to the machine or cell being available for production when scheduled. Availability component in OEE measurement is concerned with the total stoppage time resulting from unscheduled downtime, process set-up and changeovers, and other unplanned stoppages (Bulent Dal et al, 2000).

..... (3)

Performance rate takes speed loss into account which includes all factors that caused the process of the equipment to operate less than the optimum speed. Performance is determined by how much waste is created through running at less than optimal speed.

..... (4)

Table 1
The Different of Lost Opportunity Cost

Actual units/ hours	700	717.9	17.9
Revenue generated per hour (RM)	7,000	7,179	179
Lost opportunity cost in revenue per hour (RM)	3,000	2,821	- 179

Quality rate in OEE measurement takes account of quality loss. Quality loss as defined in the literature is the factors that produced pieces that do not meet the quality standards, including pieces that require rework.

..... (5)

F. *Ideal OEE Figure*

Nakajima (1988) suggested that ideal values for the OEE component measures are:

- i. Availability in excess of 90 percent;
- ii. Performance efficient in excess of 95 percent;
- iii. Quality in excess of 99 percent.

Such levels of availability, performance and quality as suggested would result an ideal OEE scores of approximately 85 percent. The literature concerning appropriate levels of availability, performance and quality is vaguely defined (Bulent Dal, et al, 2000).

G. *The 1% OEE Effect*

From the table, the 1% increase of OEE can generate an extra RM 179 per hour rate. From another perspective, it can be viewed as a reduce in loss due to waste by RM 179 per hour rate, which is RM1,432 for an eight hour shift per day, and a sum of RM 7,160 reduction in loss for a week.

H. *Previous Study*

	Current	After 1% changes	Difference
OEE (%)	54.6	55.6	1
Performance rate (%)	70	71.79	1.79 %

Ir. K. Batumalay and Dr A. S. Santhappraj conducted a research on applying OEE through TPM in Malaysia. The outcome of the research shows the predominant TPM pillars (autonomous maintenance, focussed maintenance, planned maintenance, quality maintenance, training & education, safety, health & environment, office TPM, and development management) indeed has impact on the OEE.

Tom Pomorski (1997) conducted a research on the use of OEE and the major equipment loss analysis to optimize the performance of constraint tools at Fairchild Semiconductor, South Portland, Maine. The research successfully used OEE management to elevate constraint tool performance and to identify and address improvement opportunities through TPM loss analysis. The research stated that OEE looks at the entire manufacturing environment measuring, not just the equipment availability, but also the production efficiency loss that resulted from scrap, rework and yield losses. Meanwhile, the analysis of equipment effectiveness loss provides the user with improvement opportunities for the operation.

In another research, Patrik Jonsson and Magnus Lesshammar (1999) identifies the six requirements: four dimensions (what to measure) and two characteristic (how to measure) of an overall manufacturing performance measurement system. They evaluated three manufacturing company performance with OEE and expresses that the greatest contribution of OEE is that it is a simple yet comprehensive measure of internal efficiency. The researcher also stated that it can work as an important indicator in a continuous improvement process.

Bulent Dal et al (2000) present a practical analysis of operational performance measurement at airbags international Ltd (AIL) with OEE. The researchers discussed the potential benefits of developing OEE as an operational measure and contrasts AIL's performance with other application of OEE. The adoption of OEE as the primary

performance measure for the weaving department at AIL has highlighted a number of weakness. Utilizing OEE, both the operators and management became fully aware of what constitutes waste, and how such activities could be controlled and managed more effectively.

C.J. Barner et al (2003) defined OEE and explore the purpose of this concept in modern operations. Their work discussed OEE as a total measure of performance that relates the availability of the process to the productivity and quality of the product. In their research, they also stated that the concept of OEE was appropriate to all operations containing plant and machinery. It was discussed that OEE can be used with an internally focused benchmark where an organization set improvement objectives. The research has shown that the most successful method of employing OEE is to use cross-functional teams aimed at improving the competitiveness of business.

Lastly will be the research conducted by Ki Young Jeong and Don T. Philips (2001) presenting a methodology for constructing a data collection system and developing the total productivity improvement visibility system to implement the proposal OEE and related analyses. In the research, it is stated that accurate estimation of equipment utilization is very important in capital-intensive industry since the identification and analysis of hidden time losses are initiated from these estimates.

III. METHODOLOGY

Methodology was performed to ensure that all the data and information obtained during the data collection phase were suitable to meet the requirement of the study objectives. A case study protocol was structured in this chapter as a guideline to conduct the overall flow of the study. The protocol is to be created prior to the data collection in a single case study. Robert K. Yin (2003) presented the protocol as a major component in asserting the reliability of the case study. A typical protocol should have the following sections:

- ① An overview of the case study (Objectives, issues, literature review)
- ② Field procedures (credentials and access to sites and sources of information)
- ③ Case study questions (Specific questions that the investigator must keep in mind during data collection)
- ④ A guide for case study report (Outline, format for the narrative)

A. Study Design

The purpose of research design is to answer the research questions where every method has a special feature of technical and data analysis (Mohamad Najib, 1999). This study was attempted to provide an independent assessment of the applicability of OEE as a performance measure in an industrial manufacturing plant. Therefore, a case study approach is appropriate and chosen as the study design. Robert K. Yin (2003) noted that case studies are suitable to obtain the real data or collect information through interactive methods to achieve the objectives and answers to the research questions.

This study utilized quantitative method in the data analysis. Prior to the analysis, data collected were in two forms, primary and secondary data. Primary data was obtained by conducting cordial interview with the production manager to acquire more knowledge on the issues occurred in the production line while secondary data collected were such as production times, production downtime, preventive maintenance duration and other required data in the OEE measurement.

B. Case Study Protocol

The case study protocol constructed is to ensure the process of the study to conduct smoothly. Each item in the flow depends on the successful completion of the previous item. It is therefore important not to skip a single step to ensure the successfulness of the study. The list of items in case study protocol in sequence:

- i. Preliminary interview with the production manager
- ii. Identify objective and scope of research
- iii. Literature review
- iv. Data collection – Primary data and secondary data
- v. Data analysis –Quantitative analysis using Microsoft Excel
- vi. Discussion and conclusion

C. Interview

The interview is a two-way conversation that gives the interviewer the opportunity to participate actively in the interview (Robert K. Yin, 2003). Interview is one of the most important sources of case study evidence. The interview can focus more directly on areas that are related, at the same time being insightful and providing perceived causal inference.

The respondent that involved in the interview section was the production manager.

Selected interviewee was considered to be involved in the performance measurement process and operation process of Company F. The type of interview was face to face interview which involved direct meeting with the interviewee. It was an unstructured interview which is informal and do not offer a limited, pre-set range of answers for a respondent to choose. The questions were adapted to meet the respondent's intelligence, understanding or belief. Through the process of interview, the issues or problems existed in Company F and the operations of the selected machines were better understood.

D. Secondary Data

Table 2
Category of Data Collected

Working hours	The number of working hours as according to full work schedule. The full work schedule consists of working hours for different shifts and days of operation.
Number of units produced	The number of units produced per week.
Planned Downtime	Planned downtime includes time for rest interval, planned maintenance activities, waiting or idling time and initial testing time.
Unplanned Downtime	Unplanned downtime includes stoppage time due to unexpected events and changeover and set-up time.
Machine Time	The length of time for machine to produce each time.
Units scrapped	Quantity of defect products per week

The data collected from Company F were as categorized in the table 2. Much of the data obtained were not suitable for direct application into the OEE formula and needed to be

reconfigured in order to be useful for OEE measurement.

IV. Data Analysis

A spreadsheet was prepared to simplify the OEE calculation. The spreadsheet was designed to follow the production process of the machine from beginning till end listing the potentially lead to losses. The four week's data for each machine A, B and C were entered into the spreadsheet which includes:

⌚ Total shift time per day (min)	⌚ Actual operating time (min)
⌚ Machine time (sec)	⌚ Planned operating time (min)
⌚ Days of operation per week	⌚ Actual output (units/hour)
⌚ Units produced (units)	⌚ Theoretical output (units/hour)
⌚ Rest Interval (min)	⌚ Units scrapped (units)
⌚ Maintenance activities (min)	⌚ Quantity produced (units)
⌚ Waiting/idling time (min)	⌚ Availability rate (%)
⌚ Initial testing time (min)	⌚ Performance rate (%)
⌚ Stoppage time (min)	⌚ Quality rate (%)
⌚ Changeover and set-up time (min)	⌚ OEE rate (%)

There were a series of fixed reports that have been generated from the spreadsheet. The reports consist of availability analysis report, performance analysis report, quality analysis report and OEE analysis report. Graphical representations of the data were created to display a clearer picture of the three specific machines' performance in Company F.

A. Data Analysis

In this chapter, there are altogether three Overall Equipment Effectiveness (OEE) analyses; each for one piece of production equipment. As mentioned before, three machines were selected from Company F for the conduct of this study. The machines are as follows:

- i. Westech MRV-II-STW – Model 7881 (Gear Link Alignment Machine) as machine A.
- ii. Robo Cylinder RCM-PM-01 (Housing Riveting Machine) as machine B.

- iii. Munekata H/W-76xx-H501 (Switch Panel Riveting Machine) as machine C.

B. *Availability*

Availability of the equipment is the amount of time it is available for production. In another perspective, it is also a measure of how big the downtime losses are. Downtime considered appears in two categories, either planned or unplanned. In this study, planned downtime for the three machines includes duration for rest interval, maintenance activities, waiting and idling time, and initial testing time. Meanwhile, unplanned downtime includes stoppage time and changeover and set-up time. The percentage of each element in planned and unplanned downtime will be represented in pie chart to better illustrate the proportion among each other.

Figure 1 Planned and Unplanned Downtime for Machine A

Figure 2 Planned and Unplanned Downtime for Machine B

Figure 3 Planned and Unplanned Downtime for Machine C

Figures above show the planned downtime and unplanned downtime of each machine taken into consideration for the calculation of availability. Using the data, availability rate for each machines were computed and compared in the figure below.

Figure 4 Availability Rates for Machines A, B and C

On average, machine A shows the best availability score with an outstanding 95.76 percent availability rate while machine C is the second best showing 94.93 percent availability rate tailed closely by machine B, 94.92 percent. All the three machines have achieved an excellent availability score exceeding the world class OEE score for availability (90%). Hence, no major issue arises from the availability of the three machines.

C. *Performance*

The performance rate of equipment is the comparison of its actual production output to its

theoretical production output. During a production cycle, inputs are transformed into output. Ideally or theoretically, equipment should perform at speed of theoretical production output. However, this is impossible in real situation as many hindrances may hinder the equipment from performing ideally. Following are the figures showing the comparison between the actual output and theoretical output for each machine.

Figure 5 Actual and Theoretical Outputs for Machine A

Figure 6 Actual and Theoretical Outputs for Machine B

Figure 7 Actual and Theoretical Outputs for Machine C

Figures above also show the data for actual output and theoretical output of which will be compared to compute the performance rate. Using the data, performance rate for each machine were computed and compared in the below figure.

Figure 8 Performance Rates for Machine A, B and C

On average, machine C performed the best among the three machines with 96.43 percent. Machine A is performing slightly lower at 95.46 percent while machine B performed the worst at 85.77 percent. The poor indicator shows that machine B has some performance issues and need to be attended to.

D. *Quality*

Quality factor takes rejected items due to quality defects into consideration. These defect items produced are considered as losses to production, hence it is taken consideration into the computation of OEE under quality factor. Quality rate for each machine were computed and illustrated in the figure below.

Figure 9 Quality Rates for Machine A, B and C

From the figure, it is obvious that machine C is producing at the highest quality rate, 99.03 percent on average. Meantime, machine B has slightly

lower quality rate at 98.69 percent. Machine A which only has a quality rate of 97.07 percent is the lowest among the three machines. Only machine C achieved the world class OEE score for quality (99%). Machine B and especially machine A are indicating a very weak quality rate, hence attention must be prioritize to resolve.

E. *Overall Equipment Efficiency*

OEE is a quantitative measure that comprise of three ultimate factors which is the availability rate, performance rate and quality rate. By looking into all these three elements, the different kinds of wastes or losses are taken consideration for. Hence, it is a more comprehensive measurement to keep track of the current performance. OEE is the product of the three stated factors. By multiplying together the result obtained for each availability rate, performance rate and quality rate in the subchapter before, the OEE rate can be computed. The figure below shows the computed OEE rate for each machine.

Availability	95.77	94.91	94.93	90.00
Performance	95.46	85.77	96.43	95.00
Quality	97.07	98.69	99.03	99.00
OEE	88.73	80.35	90.65	85.00

By comparing the OEE of machine A, B and C to the world class OEE, weaknesses can be spotted immediately. Machine A did achieve an excellent OEE rate but there is a sign of low quality yield in the result. Machine A had a low quality performance of 97.07 comparing to the world class OEE. For machine B, it has a major problem in its performance. As interpret from the result, machine B has an approximately 10 percent room for improvement in its performance. Not only that, efforts must be made to pull its quality a little higher so Company F can enjoy better productivity. Machine C had the best OEE score among the three machines with all the factors achieving the world class OEE rate.

Figure 10.OEE Rates for Machine A, B and C

As shown in the figure, machine C has the highest OEE rate over the weeks while machine B has the lowest OEE rate. Machine A is doing excellent with an average of 88.46 percent OEE rate.

V. *DISCUSSION AND CONCLUSION*

F. *Benchmarking World Class OEE*

In this section, the findings from chapter four will be thoroughly discussed here. The following subchapters, discussions were done to answer the study questions stated for this study.

As mentioned in the literature before, Seiichi Nakajima, the founder of OEE had also set a world class OEE score for the users to benchmark. The world class OEE is set at a minimum score of 90 percent for availability rate, 95 percent for performance rate, and 99 percent for quality. Multiplying these factors together obtained a minimum score of 85 percent world class OEE rate. In the following table, each factor of OEE and OEE rate itself for machine A, B and C is compared to the world class OEE rate. This step is crucial to identify the origin of weakness in the machine.

A. *Availability Issues*

The concept of availability was related to downtime, it is realized that downtime could be minimized by placing an emphasis on planned downtime. Emphasizing on the length of rest interval can provide the machine operator sufficient rest for the continual of work at optimal condition. In case of insufficient rest, problems such as unforeseen stoppage time and delay or prolonged changeover and set-up time may occur. Unforeseen stoppage time can be due to many reasons from serious cases to the minor ones.

Table 3 Factors of OEE and World Class Rates

Factors of OEE	A (%)	B (%)	C (%)	World Class OEE (%)

One of the serious scenarios is when the machine operator caught in accident. When that occurs, the machine will be halted from operation. The length of time it took for the machine to regain its operation is defined as unplanned stoppage time. There are many factors that can potentially induce such happening; it can be personal reason or even management reason. What causes the stoppage time

maybe due to the fatigue or stress level of the operator. In which case, the portion of planned downtime must be carefully planned as it is essential to determine the unplanned downtime. Even though, the occurrence of unplanned downtime cannot be controlled but it can be pretty much reduced by implementing some preventive measures. Other serious cases maybe electric supply shortage, raw material shortages, machine malfunction or any cases that took long time for operation to recover. For the case of machine malfunction, preventive maintenance activities time allocated in planned downtime is responsible to make any maintenance to prevent such scenario from happening as much as possible.

Minor cases are defined by the short length of time it took the operation off. Examples can be toilet emergency, a short stoppage for picking up emergency calls or some other event that causes minor stoppages. It can also be disciplinary causes such as taking a short break during work time for smoking. At times, minor stoppages are caused when supervisor dropped by to give some talks or follow up with the operator. This kind of stoppage must be carefully determined whether it is unplanned or planned. A planned stoppage would be the briefing done every morning or at any specific planned time. However, if any abrupt briefing or lecture is given during working time, it is considered as minor stoppages depends on the length of time.

A sufficient rest interval time also prepares the operator mentally and physically ready for a machine changeover and set-up. The time required for machine changeover and set-up are fixed in the manual or handbook. However, in the real world, it is often influenced by all sorts of reason that causes the prolongation. One of it is definitely the mental and physical readiness of the operator to perform the changeover and set-up at the optimal speed. Emphasizing on daily maintenance also provide a smoother machine changeover and set-up. If machines are not regularly maintained, time maybe consumed for the difficulty in set-up during a machine changeover. Sometimes, time can also be consumed for locating the source of problem during a difficult machine changeover or set-up.

B. *Performance Issues*

The factors that cause a performance issues for the three machines in Company F are machine wear, substandard material and operator inefficiency. Machine wear is among the reason that constantly causes performance issues. Over the time, machine will wear as a result of frequent use or heavy use. Until a certain period, a machine will be completely worn out and required a new replacement. Before it is completely worn out, the

worn machine that is still utilized for production will definitely impedes the production speed and therefore induces a performance loss. Worn machine usually causes minor stoppages during production or are producing at a slower pace. Depending on machine and level of machine wear, some machine only requires constant maintenance such as lubricating or cleaning to keep the machine from worn out while others may require replacement of parts or even the whole equipment.

Another factor that causes performance issue is the substandard material. On occasion, the raw materials supplied from external sources contained faulty material. The faulty material causes problem such as clogging the machine and resulted a performance loss in return. Minor losses of speed also inflicted when operator has to remove the faulty material manually and replace with a new one. A longer loss of speed will occur when operator has to retrieve new raw materials from stores or warehouse or the successive machine before.

Lastly, operator inefficiency is also one of the causes of performance loss, though not the major one. Many reasons can cause an operator to be inefficient. Among them will be fatigue, work stress, lack of training, lack of supervision or lack of motivation. It is important that operator can work at optimal condition so that the loss of performance can be minimal.

C. *Quality Issues*

Since Company F is a Japanese-based company, most of their machines do not have major quality problem. The defective yield is being minimized by a set of stringent policies. However so, quality rate should be lifted as near as possible to 100 percent. Slight decrease in quality rate implies slight increase in defective units being produced. These defects increase the cost for rework such as additional cost for energy and material handling. Hence, it is encouraged that Company maintain the current performance in quality yield or better if increase.

D. *Suggestion to Company F*

After the discussion on the issues of the three elements in OEE figure, several suggestions have come to mind for Company F. Since Company F's three machines do not faces any serious problem with availability, there will be no suggestion for improvement on availability.

It is noticed that machine B has a low performance rating of 85.77 percent. Hence, three suggestions will be given to Company F for implementation in curbing the problem.

1) *Replace a new machine*

As new machine seldom has problem of slowing down or stoppage, it will only leave the remaining deducted percentage for human error.

2) *Perform more frequent inspection and maintenance*

Suggestion made for Company F to perform daily inspection thoroughly for machine B and perform maintenance for any parts necessary to boost up the performance of the machine.

3) *Add third working shift*

The low performance rate causes machine B to be a bottleneck in a production system. The suggestion made to curb this problem is to add in another shift in midnight so as to create buffer units.

As obtained from data analysis in chapter four, machine A is identified with quality problem where it only produces at 97.07 percent quality rate only as compared to world class OEE score for quality, 99 percent. The fourth will be suggestion to improve quality rate.

4) *Effective data collection*

In this suggestion, data is suggested to be collected in hourly manner or any short period of time to allow real-time data collection. Pareto analysis is also suggested where it can effectively highlight the most common faults and their root causes can be examined.

The following is the last suggestion for Company F.

i) *Apply OEE as a key performance indicator*

In order for a successful implementation of OEE, it is imperative for Company F to collect data in real-time. Real time data provides Company F actionable data. OEE can be used to measure the improvement or the effectiveness of the corrective action taken.

ii) *Benefits of OEE*

⌚ *Simple yet powerful key performance indicator*

The simplicity of OEE calculation makes it a user friendly key performance indicator. OEE offers a simple quantitative metric to effectively **measure losses of crucial parts in a manufacturing process** namely availability rate, performance rate and quality rate. Through the clear information obtained from the result of the measurement of losses, OEE can also easily **identify complex production problems and initiate specific improvement**. This is not all what an OEE can do. OEE can also be utilized as a **measurement for improvement or maintenance performance**

carried out. Utilizing the OEE metric as key performance indicator also allow the operator or supervisor to **give the correct feedback to the upper management**. This in return allows upper management to make more accurate decision according to the feedback. Apart from that, the OEE metric is also able to integrate seamlessly into its process monitoring and control solutions. This system allows operators or supervisor to **monitor all instruments and components in the production line** easily.

⌚ *Cost-saving tools*

OEE is being used widely to help plant managers trim costs. The cost reductions that come with OEE are especially interesting during these recessionary times. OEE has been around a long time, dating back at least to the 1960s. However, recent developments in real-time OEE have given it more attention as a cost-saving tool.

VI. CONCLUSION

A great deal of knowledge about OEE has been accumulated. OEE as discussed in most pages of this chapter is the example of application in real situation. It is learned that OEE provides many benefits and with proper implementation, OEE can serve as a tool to elevate the company's competitiveness in the industry. Simply said, OEE is a simple yet powerful performance measurement tool, thus it is suggested to Company F for implementation.

A real-time OEE measurement generates clear daily information regarding of the level of effectiveness of a machine. It is imperative for Company F to collect real-time data in order to generate relevant and factual information as real-time data expedites the corrective action. Comprehensive OEE information also provides operators with continuous line notification and control, so that actions can be taken in time to preempt event that could result in downtime, poor product quality and lost revenue. When a production line achieves a strong OEE rating, it is an excellent indicator for highly productive processes, but continual optimization is paramount to realizing long term value.

VII. FUTURE STUDY

Since the present study is exploratory in nature and it is limited to a case study in a Japanese-based company, it would be beneficial for the future researcher to conduct the study in mode of multiple case studies where generalize-ability can be tested. The multiple case studies can be done on companies across the sectors or industries. Such participation of companies from diverse sectors or

industries will increase the significance or usage of the study.

It is also mentioned that the present study is conducted by collecting secondary data for the analysis. It would be beneficial and most recommended that the study can be conducted by analyzing primary data. Such data can be collected in real-time through field observation. By doing so, the study can gain more in depth information or knowledge on the related issues.

Last suggestion for future study is the formulation of new OEE by incorporating the element of profitability or costing. In the present study, OEE lacks in any notion of product profitability and costing. It would be beneficial to the industries if the suggested new OEE is formulated.

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