A FRAMEWORK FOR IMPROVING MANUFACTURING OVERALL EQUIPMENT EFFECTIVENESS

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ABSTRACT: The main motivation for improving productivity is to develop and implement manufacturing methods and concepts that provide stable, flexible and low cost production with high quality levels. However in the pursuit of increasing competitiveness may lead to plant downtime; which must be minimized wherever possible. Overall equipment effectiveness (OEE) is a metric to measure equipment performance and effectiveness and therefore, reduce equipment cost of ownership (COO). OEE topic has become progressively popular and widely used as a research discussion in operation management. However, OEE framework for previous studies was developed on a piecemeal basis. This paper presents a new and complete conceptual framework that illustrates the most important factors that influence and contribute to OEE improvement. The comprehensive framework is able to provide effective guidance and direction to industry practitioner on how to improve OEE.

KEYWORDS: *Overall Equipment Effectiveness (OEE); Overall Equipment Effectiveness Improvement (OEEI) Framework; Maintenance; Productivity; Total Productive Maintenance (TPM)*

1.0 INTRODUCTION

In today's competitive market place and complicated manufacturing industry, the performance of overall equipment effectiveness and efficiency plays an important role to determine operation competitiveness of the organization as well as the degree of success accomplished in the organization[1]. Semiconductor manufacturers required flexible manufacturing methods to achieve high manufacturing productivity. Over the past twenty years, the Malaysian manufacturing sector has achieved outstanding performance in contributing to the nation's gross domestic product growth and successfully attracted an enormous amount of foreign direct investment to this country [2].

In today's manufacturing industry, the equipment utilization and installed capacity is still low and the main reasons for these are low equipment effectiveness, very limited shop floor involvement in autonomous maintenance and little evidence on small group activities participation in continuous improvement [3]. The equipment throughput can be calculated as the output divided by the machines hour or capacity utilized [4].

In order to apply the principles accurately, the basic factors that influence OEE must be clearly understood. This paper uses a hypothetical manufacturing system to describe the basic elements that contribute to OEE and explain in detail the existence of each factor. This framework also could be used to educate the organization in these basic concepts. This paper also presents a comprehensive framework that demonstrates the factors that contribute and influence OEE. The framework also provides the action to change each factor and their inter-relations. The proposed framework is comprehensive enough to provide guidance and assistance to industry practitioners on how to improve OEE while being general enough to be applied in most manufacturing circumstances.

2.0 LITERATURE REVIEW

There were numerous researches done previously on OEE improvement framework. Nguyen et al. [5] proposed a framework for improving productivity using both value stream mapping and OEE in lean manufacturing. From the framework, OEE is the first element to be considered. If the demand can be achieved, it is not necessary to implement value stream map. Otherwise, value stream should be considered to achieve the target.

Mansour and Ahmad [6] proposed a framework for evaluation and improvement of workover rigs in oilfields. The framework defined a series of work procedure that supplied a practical maintenance system for their workforce based on the twelve steps as described in [12]. The framework focuses on maintenance system and approach to improved OEE.

Wudhikarn [7] proposed a new quantification framework by using Analytical Network Process (ANP) with OEE foe enhancing the shortcoming of the original OEE and other adapted assessment. He presented a concept and initial work in term of developing how to assign weighted OEE where the three main OEE parameters carry different weightage in OEE calculation.

Vijayakumar and Gajendran [8] developed an OEE framework by emphasizing 5S and Total Productive Maintenance (TPM) as the critical success factors in OEE improvement activities. By doing correctly on the 5S and TPM, the main production losses such as defects, mistakes, delay, wastage and accident can be eliminated and a case study was carried out and shown that OEE improved by 20 % in an injection moulding company.

Hernández et al. [9] defined a framework by applying lean tools and six sigma approach in manufacturing in order to improve OEE. Case study in a polystyrene foam for packaging company proved that availability and performance elements improve after applying the lean tools such as Single Minutes Exchange Die (SMED) and Pareto Analysis.

Puvanasvaran et al. [10] developed a macro framework that integrating the quality tool such as value stream mapping, failure mode effect analysis and single minutes exchange die in OEE improvement. The proposed framework is focusing on applying quality tool to reduce non value added process in operation and improving the utilization of the equipment purchased.

Garcia et al. [11] presented a continuous improvement framework by incorporated Lean manufacturing fundamentals and OEE which operated by a wireless device system to support the real time equipment performance measures. They argued that the real time and accurate data is crucial in order to provide information in OEE improvement. Through the integration of information technology and lean manufacturing tool in OEE improvement, the real time data able to provide the most accurate information for the practitioners in order to provide precise and right solutions.

Most of the researchers provided piecemeal information and activities in OEE improvement. The next section provides the comprehensive Overall Equipment Effectiveness Improvement (OEEI) frame work to provide complete guidance to manufacturing practitioners.

Based on the six large losses measured by [12], which is a function of availability (A), performance (P) and quality rate (Q) expressed as

$$\text{OEE} = \text{A} \times \text{P} \times \text{Q} \tag{1}$$

where

$$\text{A} = \frac{\text{Operating time (h)}}{\text{Loading time (h)}} \times 100 \tag{2}$$

$$\text{Operating time} = \text{Loading time} - \text{Down time} \tag{3}$$

$$\text{P} = \frac{\text{Theoritical cycle time (h)} \times \text{Actual output}}{\text{Operating time (h)}} \times 100 \tag{4}$$

$$\text{Q} = \frac{\text{Total prodution parts} - \text{Defects amount}}{\text{Total production parts}} \times 100 \tag{5}$$

Figure 1 presents the overall equipment effectiveness improvement (OEEI) framework. The framework can be described as a flowchart with five levels. Level 1 stated the motivation of the framework as the improvement or increase in OEE. Level 2 presents the main three main elements for the increase in OEE. The equipment availability is the percent of time the equipment is in a good condition to perform its intended function during the period of total time. This calculation indicates the effectiveness functionality of production equipment from a business point of view. The performance rate is the ratio of actual operating time to loading time. The standard operating time is the time required for the equipment to produce the parts at the standard production rate. To calculate the standard operating time is subtracting performance time losses from the operating time. The last element is quality rate. It calculated as the proportion between number of good products and total production amount by SEMI E10 [13]. The level 3 is the main top three major losses contribute to OEE. In this level, it just categorise the three major losses into down time loss, speed loss and quality loss. Level 4 further breakdown to detail extended from level 3. Level 5 specifies the actions implements that will increase the OEE for each factors which shown in level 4. Level 6 presents important changes that might require enabling some of the actions in level 5.

Based on all the explanations and definitions, one or more of the three main components must be increased in order to improve OEE. By following the flow from left to right, remedies that will increase each element can be identified. The motivation of the flow is provide a systematic and structured way to examine the appropriate actions that can be implementing in order to improve OEE and the relationships within these entire actions list. In the following sections will briefly discuss how to improve each important component of OEE. The basic definition of the terms are referring to SEMI [14] and SEMATECH [15].

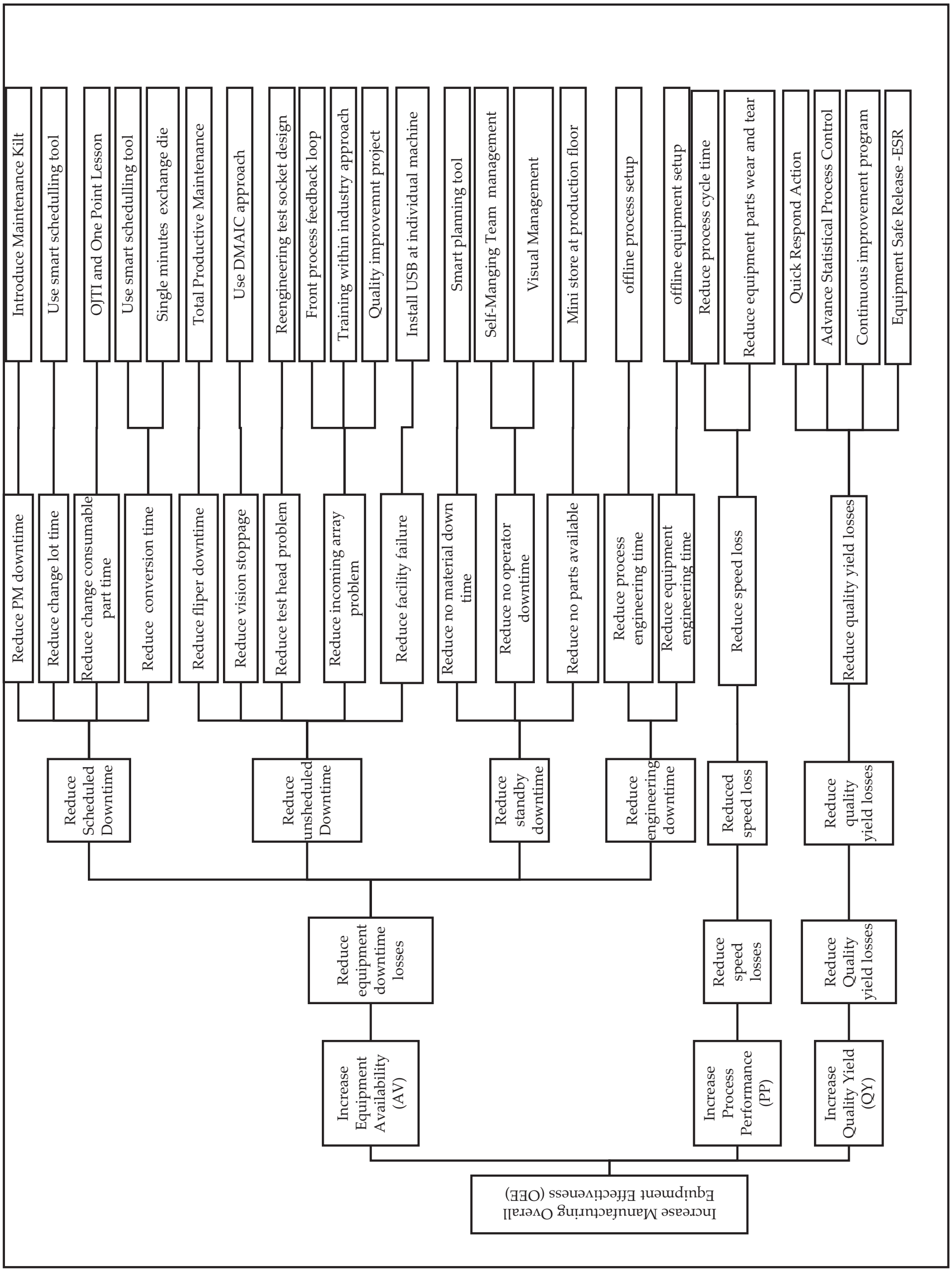

Figure 1: Overall Equipment Effectiveness Improvement Framework

2.1 Reduce Un-scheduled/ Unplanned Downtime

Level 4 of Figure 1 indicates that the unscheduled time reduction can be accomplished by reducing the tool failure rate and frequency, process failure and facility failure. The tool/equipment failure frequency can be achieved by implementing world class maintenance management such as planned maintenance concept, preventive maintenance approach, predictive maintenance approach and Total productive Maintenance (TPM). The maintenance function becomes crucial and important due to its role in keeping and maintaining high equipment availability, performance efficiency, product quality and on time delivery [16]. The main motivation to adapt the above maintenance strategy is to avoid breakdown maintenance which causes long equipment down time and affecting production throughput. Based on the framework and research done by Marquez et al. [17], the technique and model able to improve maintenance effectiveness and hence reduce equipment down time.

The implementation of Maintenance Kit (MK) methodology manages to optimise the unscheduled downtime. The main motivation of MK is ensure all the parts supposed to replace are replace according. The principle of MK is the new parts taken out are used in the machine during servicing and the used parts are marked with red pen & re-inserted into the relevant position of the sponge for quantity accountability, after servicing, used parts are quantified. Each drawer is filled up again with new parts, ready for the next service. MK is in a form of mobile-cabinet. Each drawer comprises of parts for each station/module of the equipment.

2.2 Reduce Scheduled/Planned Downtime

The schedule downtime is a period of time in hours or in percentage where the machine is not available in order to perform its intended task due to scheduled downtime activities. The planned downtime included maintenance delay, preventive maintenance, set-up, tool conversion and change of consumable parts.

All the scheduled downtime procedures are clearly defined and planned in the respective process. The entitlement downtime required for each activity is well-defined and approved by all parties. The waiting time resulting from the delays in the process also included.

By implementing TPM able to improve equipment scheduled down time. Activity such as study the part replacement frequency and life span is one of the pillars in TPM methodology. Single minutes of Exchange Die (SMED) concept can be applied in order to reduce the tool conversion time required and hence reduce the schedule downtime. Perfect setup approach with the main indention of optimises the set-up time required and doing the thing right at the first time. Using intelligent scheduling tool enables the operator smartly plan when the best change tool activity is and enhance the visibility of the administrative process. The 'Training within Industry' (TWI) and 'On Job Training' (OJT) methodologies able to ensure all shop floor staff are able to perform all production tasks efficiently.

2.3 Reduce Non-scheduled Downtime

Non-scheduled Time (NSDT) is a period of time in hour or the share of Total Time (TT) in percentage, when the equipment is not scheduled to be utilized in production.

To reduce the non-scheduled time, management must schedule the training hour by stagger approach and resulted the production line not necessity to shut down the whole production line. The production still can operate by utilizing the remaining staff in the production.

2.4 Reduce Standby Downtime

Standby Time (SBY) is a period of time in hour or the share of Operations Time (OT) in percentage other than non-scheduled time, when the equipment is in a condition to perform its intended function, people, material and facilities are available, but it is not operated.

To reduce standby time losses, management adopt 'cold steel' concept by shutting or warm shutting down few equipment so that production can fully utilize the lesser number of equipment. By doing this, the operator will fully focus on the optimum number of equipment needed especially during demand soft period. The no material can be minimizing by using smart planning tool to ensure material available all the time.

2.5 Reduce Engineering Downtime

Engineering Time (ENG) is a period of time in hour or the share of Operations Time (OT) in percentage, when the equipment is in a condition to perform its intended function (no equipment or process problem exist), but is operated to conduct engineering experiment.

In order to reduce engineering time loss, the engineering time slot must plan in such where the equipment incurs minimum conversion. Besides this, if the engineering activities involve big amount of conversion, some of the activities can do carry out off line by adopt plug-and-play concept to reduce engineering set-up time needed.

2.6 Reduce Speed Loss Downtime

Speed losses categories into two; one is equipment minor stoppages and the other is reduced speed. The minor stoppages are mainly due to material flow, stoppage due to components jams and material miss-feeds. Hence, the actual machine speed is slower than the design or intended speed. TPM implementation is one of the enabler in order to reduce speed losses downtime.

Total productive maintenance might shift the paradigm of a company's traditional maintenance system from being reactive to becoming a more proactive concept by maintaining the equipment in 'tip top' condition [18]. Reactive maintenance concept is based on traditional practices where operators will wait until the equipment is breaks down before reacting. Based on Davis [18], this approach is very inefficient and ineffective, therefore requiring an alternative approach to reduce and minimize production losses, which led to the emergence of proactive maintenance approaches. TPM is the maintenance approach where able to provide total solution to improve equipment performance [18]. Production equipment may also be inspected for signs of deterioration during preventive maintenance work and hence this will prolong the life span of equipment [19].

2.7 Reduce Quality Losses

The quality losses in OEE calculation refers to the production reject and start-up scrap. Some equipment require warm up time and certain adjustments to obtain optimum output (Start-up Rejection occurs during this start-up time) [8]. The production reject losses referring to when products produced are not conforming to the specification (Reject during steady state production)[8].

In this section, the factors that contributing to the increase of OEE is presented. The OEEI framework is describing in detail. The factors changes that will increase each components of OEEI are discussing. The next session will provide an overview of the research methods to be employed in this study.

3.0 METHODOLOGY

The research method used for this research is case study or field research. Field research is one of the techniques used for qualitative data collection [20]. It includes the use of interviews, observation, document review and secondary data analysis.

In this study, the equipment performance data are obtained from the 'total fabrication monitoring' (TFM) data base. TFM is a comprehensive software system used to collect equipment data for improvement in Global Semiconductor. A total of 11 testers were integrated and connected to the TFM software to enable engineers and managers to identify performance issues and make room for further improvement.

The case study carried out at one of the well know semiconductor manufacturing firm in Malacca. The company focuses on three major divisions which are automotive, industrial electronics and chip card and security applications. In automotive division, this company serves as the world's second largest chip supplier to this industry.

This study focused on the testing, which is the bottleneck process under the scope of this study. The tester equipment provide integrated high-speed electrical final test for discrete, radio frequency and power devices. The company decided implement TPM in testing process.

Currently the equipment experienced low throughput and low overall equipment effectiveness (OEE) during production. The main reason for the low OEE is mainly due to the high machine downtime during operational periods. The team decided to apply the framework developed and follow step by step to improve the OEE. The current OEE of the equipment is at 63 % and the planned OEE is 75 % by reducing the equipment downtime from 15 % to 7.8 %, performance efficiency improved by 2 % and quality performance improve by 1 %. Figures 2 to 4 demonstrate step by step on how to apply the proposed OEEI framework to improve overall OEE in the test process.

a) For availability improvement

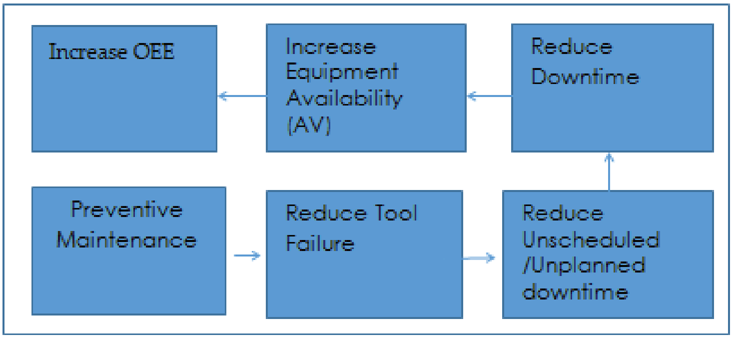

Figure 2: Flow Chart to Improve Availability

b) For performance efficiency improvement

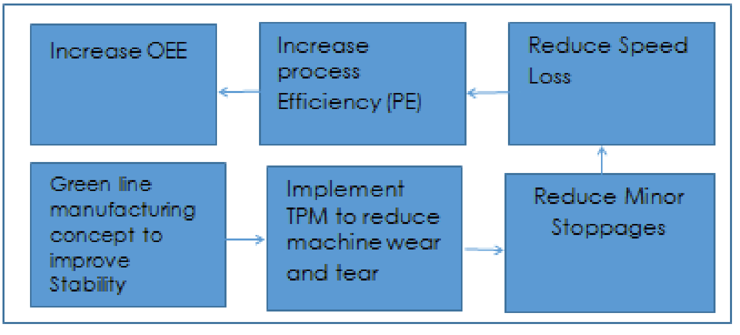

Figure 3: Flow Chart to Improve Performance Efficiency

c) For quality improvement

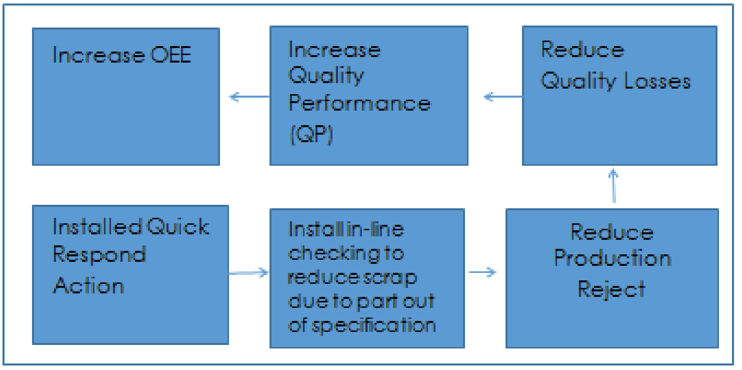

Figure 4: Flow chart to Improve Quality Performance

4.0 RESULTS AND DISCUSSION

As a pilot run purpose, the case study only partially implement the elements in the OEEI framework. The results are presented here. The losses trend for unscheduled downtime specifically for tool failure was monitored. Figure 5 shows the unscheduled downtime trend for tool failure loss which improved by an average of 7.8 % effective from week-11. Equipment unscheduled downtime improved from 15 % to 7.8 % which is aligned to the set target. The main action was to implement a new type of socket to improve the material robustness in terms of mechanical accuracy, life span and handling method which will reduce the maintenance trouble shooting time.

Figure 6 demonstrates the trend of performance efficiency for speed loss. The speed loss was reduced significantly after implementing TPM which resulted in a reduction of machine part wear and tear. The speed loss also improved from 5.3 % to 3 % beginning week-11. Figure 7 shows the quality performance trend improvement. The production rejection rate reduced after quick respond action was rolled out at test area. The yield has improved from 95.1% to 96.9% started from week-11.

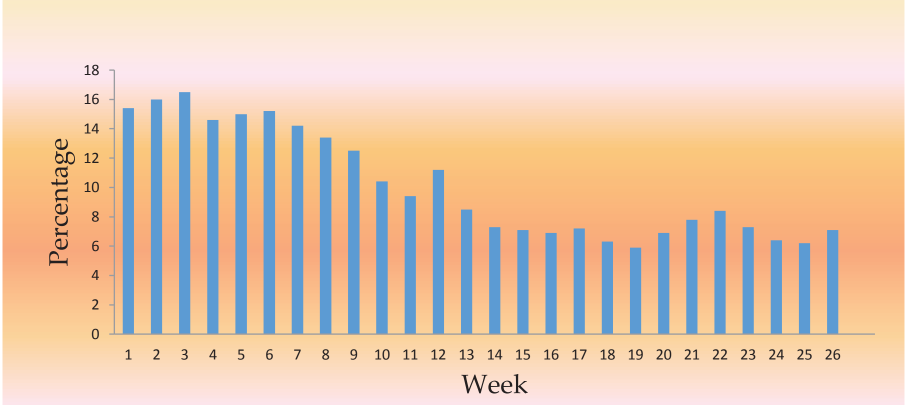

Figure 5: Unscheduled Downtime for 11 testers

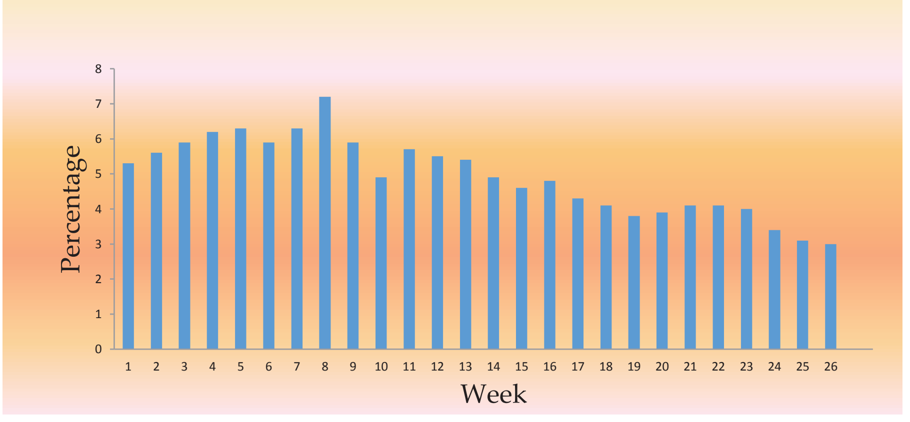

Figure 6: Speed loss for 11testers

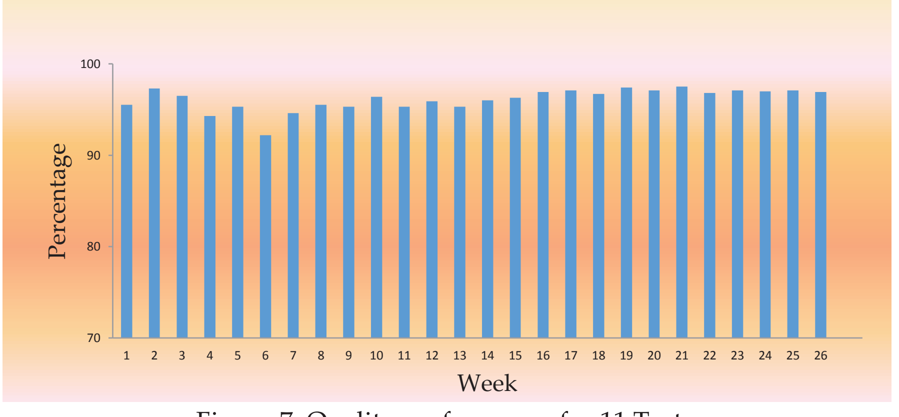

Figure 7: Quality performance for 11 Testers

OEE is the most effective metric to measure equipment effectiveness. Figure 8 shows OEE improved from 63 % to 75 % by applying the OEEI framework. The main contributions to the improvement of OEE and other production performances were the reduction of un-scheduled down time, process performance and increased in quality performance. The shop-floor operators performed autonomous maintenance which will reduce equipment breakdown rate.

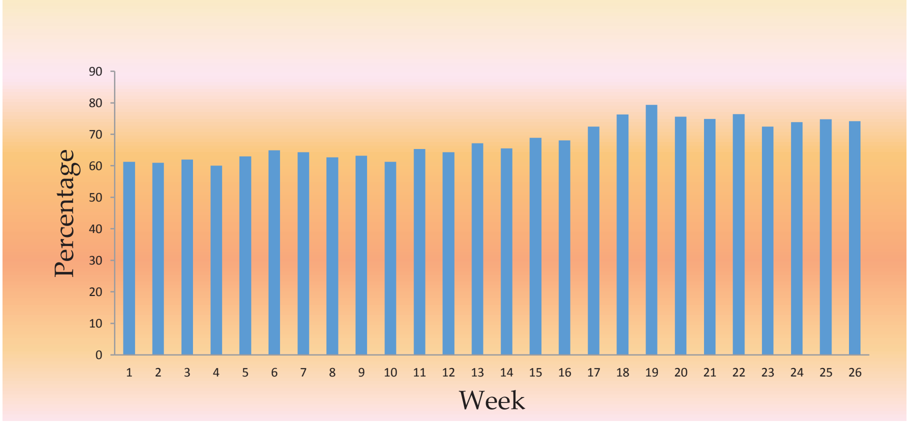

Figure 8: OEE trend for 11 Testers

5.0 CONCLUSION

Overall equipment effectiveness (OEE) improvement in manufacturing industry can be a complicating and confusing task due to large number of factors that can contribute and influence each other. This paper provides detailed steps to demonstrate the fundamental contributors that influence OEE and illustrates why each factors impact occurs. This paper outlines a new framework for OEE improvement (OEEI). Implementing the OEEI resulted in an improvement of 7.8 % unscheduled downtime, 2 % in performance efficiency and 1 % in quality performance. This proposed framework can also be used as the training material for engineers, managers, supervisors or even operators on how to improve OEE in the bottleneck process. The proposed framework provides an easy-to-follow tool that the managers can utilize to implement an action list in order to improve the OEE in their organization.

The proposed OEEI framework serves as a guide to the engineer and manger in order to improve OEE within short period of time. All defined actions listed at level six in the framework can be implemented to improve OEE; the decision lies with the managers to decide on which area to prioritize and focus on. The presented framework is an applied framework which is adaptable for different manufacturing industries.

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