

# Overall Equipment Effectiveness Measurement By Weighted Approach Method

M. Maran, G. Manikandan, and K.Thiagarajan

**Abstract** — This research is intended to enhance the original Overall Equipment Effectiveness (OEE). Calculating plant/equipment OEE can be very helpful for monitoring trends (such as whether a given plant is improving OEE over time) or as a rough measure of where a given plant lies in the OEE benchmarking spectrum. OEE concept in TPM implementation truly reduces manufacturing complex problems into simple, intuitive presentation of information. It helps to systematically improve the process with easy-to-obtain measurements. The OEE is the process, which is acquired to specify an equivalent weight setting of every single element, even if, each concerning losses are totally different. Hence, the study proposes a weighted graph approach, to identify dissimilarity in weighting each OEE element. The proposed concept is used to find the OEE for the plant, as well as to set the target for the plant and the area to focus for their improvement.

**Index Terms**— TPM, effectiveness, weighted signed graph, OEE, performance improvement.

## I. INTRODUCTION

IN the highly competitive manufacturing environment prevailing at the global level, plants of any country or region should be benchmarked and maintained at world-class level. Failing to do that, a plant may be exposed to various difficulties. The results of implementation of Total Productive Maintenance (TPM) program increased plant efficiency and productivity significantly by means of eliminating the major losses. The important goal of TPM is the total elimination of all six major losses, including breakdowns, equipment setup & adjustment losses, idling & minor stoppages, reduced speed, defects & rework, spills, process upset conditions, startup and yield losses. The proposed algorithm gives the mathematical approach for computing the plant effectiveness, i.e. Overall Equipment Effectiveness (OEE). Measurement is an important requirement for continuous improvement processes. It is necessary to establish appropriate matrices for measurement purposes. Measurement is an important requirement for continuous improvement processes.

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It is necessary to establish appropriate matrices for measurement purposes. From a generic perspective, TPM can be defined in terms of OEE, which in-turn can be considered combination of the operation maintenance, equipment management, and available resources. The goal of TPM is to maximize equipment effectiveness, and OEE is used as a measure.

*OEE measurement is an effective way of analyzing the efficiency of a single machine or an integrated manufacturing system. OEE incorporates availability performance rate and quality rate and gives results. In other words, OEE addresses all losses caused by the equipment, not being available when needed due to breakdowns or set-up and adjustment losses, not running at the optimum rate due to reduced speed or idling and minor stoppage Losses and not producing first quality output due to defects and rework or start-up losses. A key objective of TPM is cost efficiency; maximizing Overall Equipment Effectiveness through the elimination or minimization of all these six losses by means of weighted signed graph method.*

The proposed work optimizes the six losses associated with the OEE by weighted signed graph approach. The methodology of using signed graph for the betterment of the TPM implementing organizations and other industries is discussed. Finally, this approach gives them the direction to work-on and fix their targets and OEE can be calculated as follows,

$$\text{Overall Equipment Effectiveness (OEE)} = A \times PR \times Q,$$

Where,

A - Availability of the machine. Availability is proportion of time a machine is actually available to out of time it should be available

P- Performance Rate i.e.,  $P=RE \times SR$

RE - Rate efficiency is actual average cycle time which is slower than design cycle time because of jams, etc. Output is reduced because of jams.

SR - Speed Rate is actual cycle time which is slower than design cycle time; machine output is reduced because it is running at a reduced speed.

Q - Quality rate, is percentage of good parts out of total production, sometimes called yield.

In other words, OEE can be expressed as

$$\text{OEE} = \text{Utilization (Availability)} \times \text{Rate Loss (Performance)} \times \text{Yield (Quality)}$$

All these figures are usually expressed in percentage and higher OEE translates into higher equipment efficiency from the equipment. Surprisingly, the OEE of most equipments ranges from 40%-60%, whereas the benchmark is 85%, world class [8]. As such, OEE has become the accepted

indicator to assess, how plants/factories actually manage their most expensive asset, the equipment, to produce saleable goods, with minimum losses and wastes.

The OEE is not that which gives one magic number; it gives three numbers other than OEE, which are all useful individually as the situation changes from day to day. In addition, it helps to visualize performance in simple terms - a very practical simplification. The OEE is probably the most important tool in continuous improvement program in manufacturing industry. Through the Pareto analysis the operators can observe, where they lose most of the production (The 6 Major Losses as mentioned in above).

Significant improvement can be evident within a short period by means of eliminating the six equipment losses with result of enhanced maintenance activities and equipment management

Increasingly, companies working in process manufacturing environments are discovering a surprisingly effective framework from which to tackle the continuous improvement challenge: the “Six Big Losses” approach. Developed in the 1970’s by the Japan Institute of Plant Maintenance (JIPM), the Six Big Losses framework enables manufacturers to examine their efficiency problem with an unprecedented level of granularity According to JIPM, the OEE is based on three main aspects; each element concerns with different losses as shown in the table 1.

Performance Aspects	Relating Losses
1. Availability Rate (A)	<ul style="list-style-type: none"> <li>▪ Equipment failure /breakdown losses</li> <li>▪ Set-up and adjustment losses</li> </ul>
2. Performance Efficiency (P)	<ul style="list-style-type: none"> <li>▪ Idling and minor stoppage losses</li> <li>▪ Reduced speed losses</li> </ul>
3. Quality Rate (Q)	<ul style="list-style-type: none"> <li>▪ Defect and rework losses</li> <li>▪ Start-up losses</li> </ul>

## II. OVER VIEW OF THE PAPER

Section I presents Introduction, Section II presents weighted graph method of OEE, Section III deals with flow diagram of the proposed scheme, Section IV presents ratings for the factors of OEE & estimated results as well as experimental results and Section V presents concurrent application for industry. Finally Section VI presents opportunity for further enrichment.

## III. OEE - WEIGHTED APPROACH

In proposed system, OEE is considered as a signed graph, where each factors BD, SA, MI, RS, RL & SL are assigned with weight ratings based on the loss percentage. Signed weight (++, +-, -+, --) is attached to each factors of the graph based on the combination of above contributing factors for A, P, Q & OEE. Depending upon the BD, SA,

MI, RS, RL & SL ratings A, P & Q are calculated. Similarly based on A, P & Q ratings OEE is estimated.

### WEIGHTED RATING FOR A, P & Q

In a weighted graph, A1, A2, A3 and A4 are considered as the loss ratings, where  $A1 < A2 < A3 < A4$ . (i.e., A1 is the lowest loss level rating and A4 is the highest loss level rating) [7].The ratings for the basic six parameters differ from one another based on user. In the subsequent ranking scheme, more weightage is given for BD i.e., up to 10% loss, where as other parameters have less weightage of 2 to 3%.

#### 1. BD - Breakdown (in %):

- a.  $A1 = 0 \text{ to } \leq 1$
- b.  $A2 = > 1 \text{ to } \leq 5$
- c.  $A3 = > 5 \text{ to } \leq 10$
- d.  $A4 = > 10$

#### 2. SA - Setup adjustment (in %):

- a.  $A1 = 0 \text{ to } \leq 0.5$
- b.  $A2 = > 0.5 \text{ to } \leq 1$
- c.  $A3 = > 1 \text{ to } \leq 2$
- d.  $A4 = > 2$

#### 3. MI - Minor / Idling stoppages (in %):

- a.  $A1 = 0 \text{ to } \leq 1$
- b.  $A2 = > 1 \text{ to } \leq 2$
- c.  $A3 = > 2 \text{ to } \leq 3$
- d.  $A4 = > 3$

#### 4. RS - Reduced speed (in %):

- a.  $A1 = 0 \text{ to } \leq 1$
- b.  $A2 = > 1 \text{ to } \leq 2$
- c.  $A3 = > 2 \text{ to } \leq 3$
- d.  $A4 = > 3$

#### 5. RL - Reject / Rework losses (in %):

- a.  $A1 = 0 \text{ to } \leq 0.5$
- b.  $A2 = > 0.5 \text{ to } \leq 1$
- c.  $A3 = > 1 \text{ to } \leq 2$
- d.  $A4 = > 2$

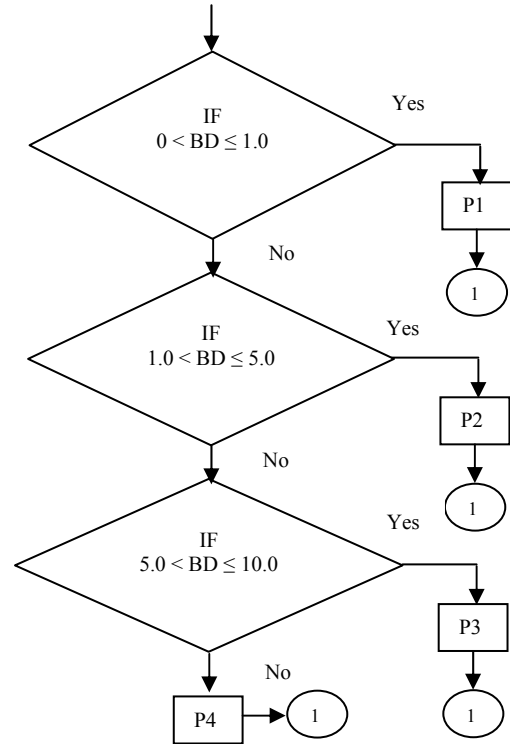
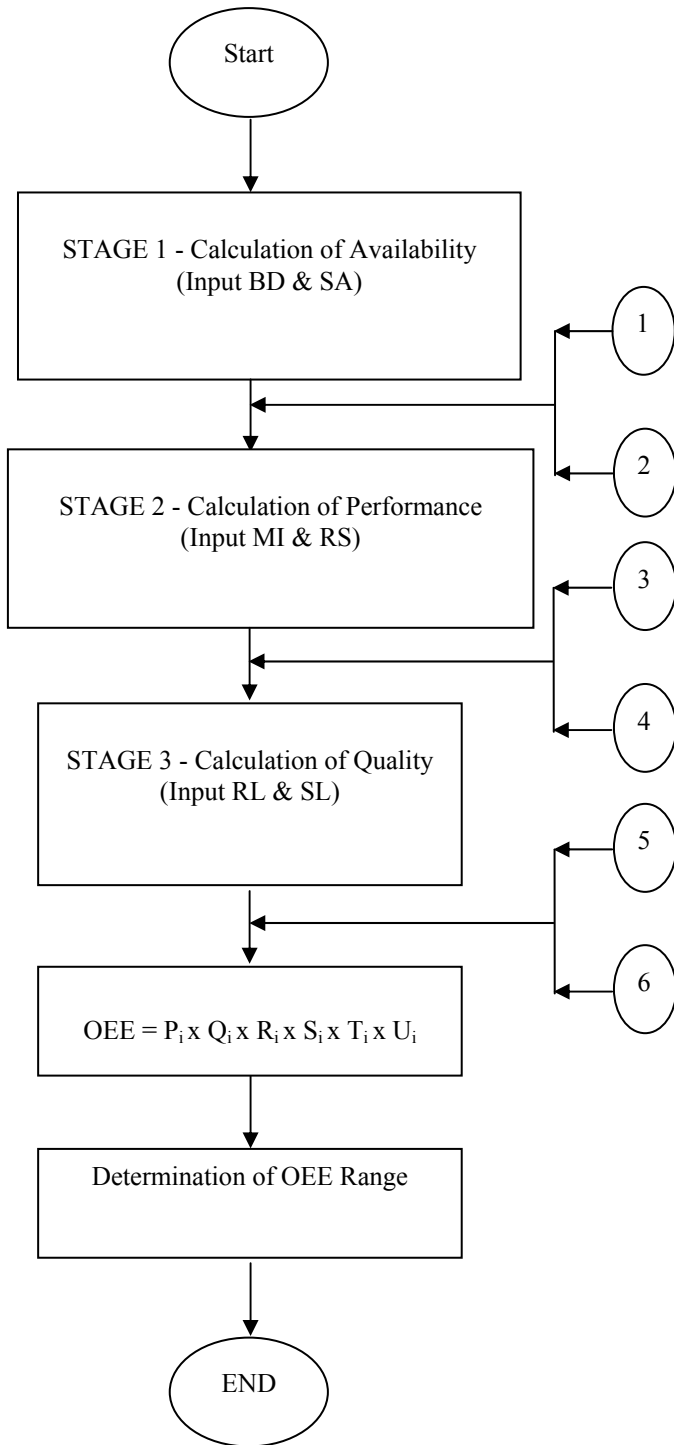
#### 6. SL - Start-up losses (in %):

- a.  $A1 = 0 \text{ to } \leq 0.5$
- b.  $A2 = > 0.5 \text{ to } \leq 1$
- c.  $A3 = > 1 \text{ to } \leq 2$
- d.  $A4 = > 2$

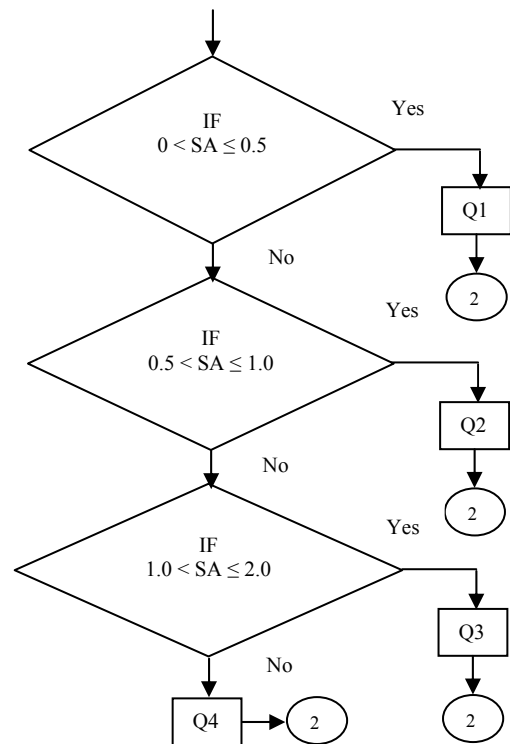
## IV. PROGRAM DEPENDENCE GRAPH

- a) In the following program dependence graph, stage 1 calculation of availability with the inputs BD & SA with constrain limit shown in Fig. 1.1 & 1.2.
- b) In stage 2, calculation of performance with the inputs of MI & RS with constrain limit shown in the fig 2.1 & 2.2.
- c) In stage 3, calculation of quality with the inputs of RL & SL with constrain limit shown in the fig 3.1 & 3.2.
- d) Determination of OEE using formula  $OEE = P_i \times Q_i \times R_i \times S_i \times T_i \times U_i$ .

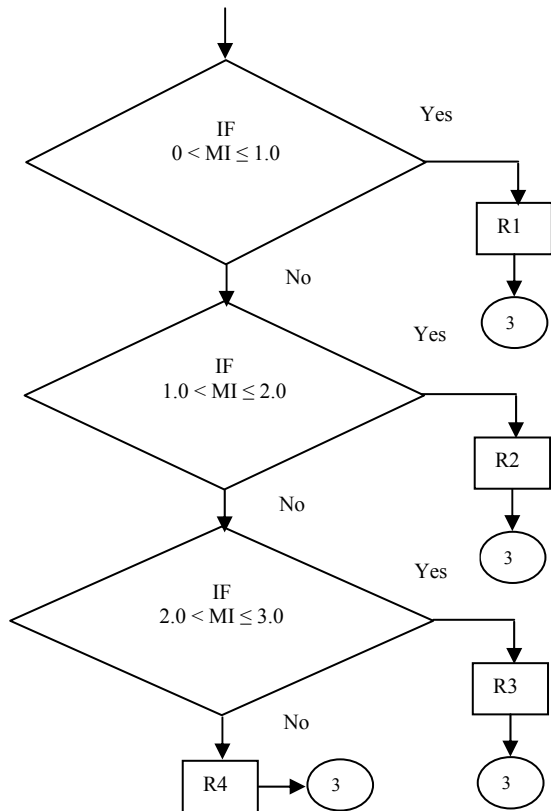
STAGE 1 (Fig 1.1):



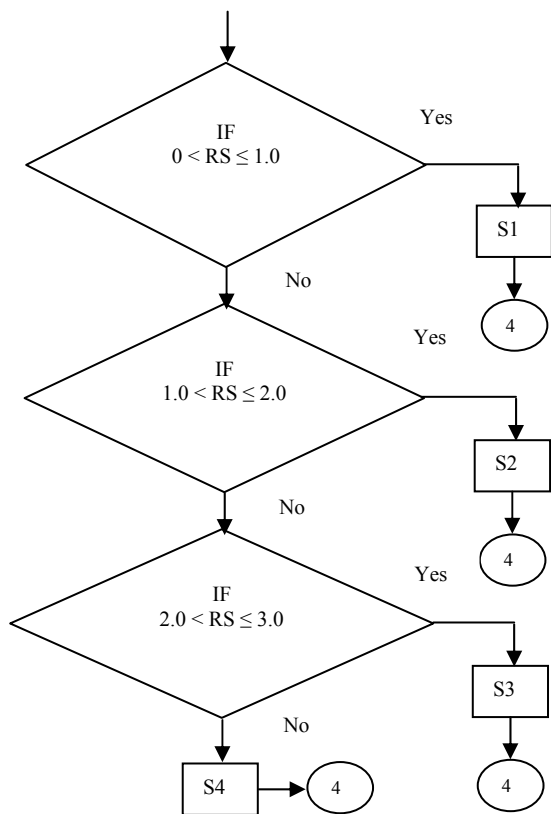
(Fig 1.2):



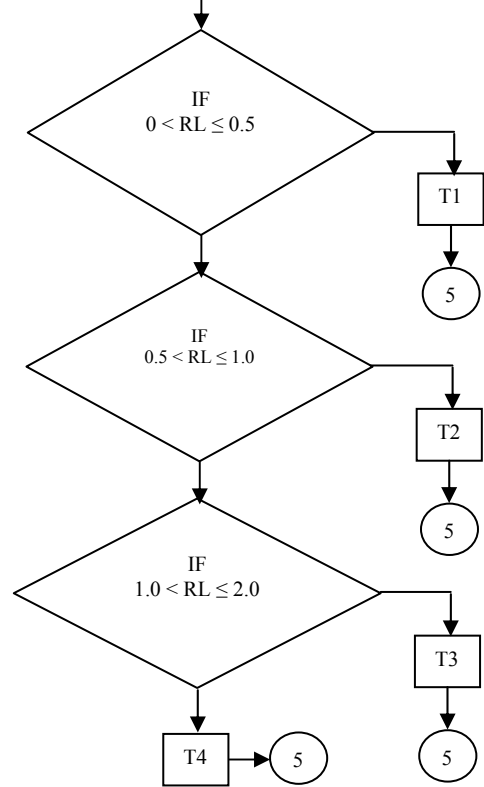
STAGE 2 (Fig 2.1):



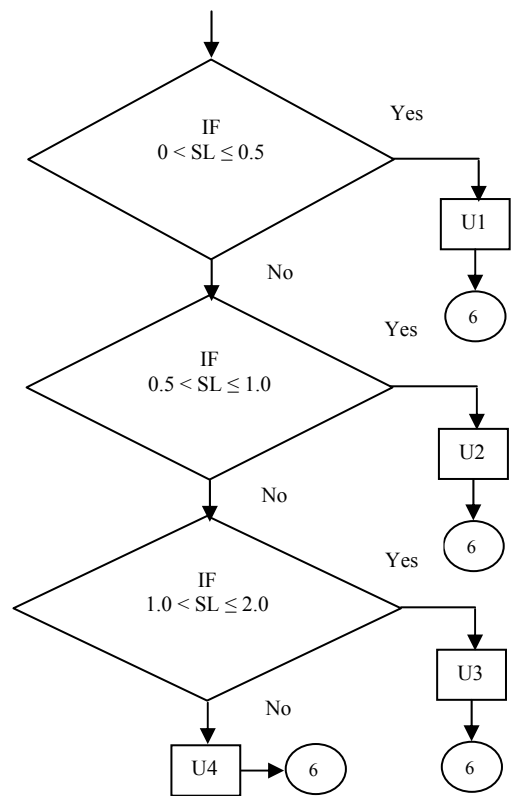
(Fig 2.2):



STAGE 3 (Fig 3.1):



(Fig 3.2):



SIGNED GRAPH METHOD FOR OEE

TABLE 2

AVAILABILITY RATING BASED ON BREAKDOWN AND SETUP ADJUSTMENT

BREAKDOWN (BD)	SETUP ADJUSTMENT (SA)	AVILABILITY (A)
+	+	+
+	-	+
-	+	-
-	-	-

TABLE 3

PERFORMANCE RATING BASED ON IDLING, MINIOR STOPPAGES AND REDUCED SPEED

IDLING & MINIOR STOPPAGES (IM)	REDUCED SPEED (RS)	PERFORMANCE (P)
+	+	+
+	-	+
-	+	-
-	-	-

TABLE 4

QUALITY RATING BASED ON DEFECT / REWORK AND STRAT-UP LOSSES

DEFECT / REWORK (DR)	STRAT-UP LOSSES (SL)	QUALITY (Q)
+	+	+
+	-	+
-	+	-
-	-	-

TABLE 5

OEE RATING BASED ON AVILABILITY, PERFORMANCE & QUALITY RATINGS

AVAILABILITY (A)	PERFORMANCE (P)	QUALITY (Q)	OEE
+	+	+	++
+	+	-	+ <sub>-</sub>
+	-	+	+ <sub>-</sub>
-	+	+	+ <sub>-</sub>
+	-	-	+ <sub>-</sub> *
-	+	-	-+
-	-	+	-+
-	-	-	--

\* Availability is having major impact on the OEE. In most of circumstances, A (+) ranking gives better OEE, in spite of both P (-) & Q (-) ratings

TABLE 6

EXPRIMENTAL RESULTS

Here we assumed Values for A, P & Q, and for various vales of A, P & Q, OEE was calculated

AVAILABILITY (A)	PERFORMANCE (P)	QUALITY (Q)	OEE
95	98	99	92.2
95	98	97	90.3
95	97	94	86.6
90	98	98	86.4
93	96	96	85.7*
88	98	94	81.1
87	91	92	72.8
86	90	90	69.7

## VI. REAL TIME APPLICATION

O.E.E. data collection, analysis and reporting provide the principal basis for improving equipment effectiveness by eliminating the major equipment-related losses. The weighted OEE method is presented and the analytical hierarchy process has been applied for setting the weight of all the factors namely BD, SA, MI, RS, RL & SL. The potential of the proposed method can be applied for new as well as existing industries. OEE data very quickly leads to root-cause identification and elimination of losses. Overall Equipment Effectiveness continues to gain acceptance as an effective method to measure production floor performance. Capturing reliable production floor information is critical for producing reliable OEE focused progress of the plant or equipment. It will be optimal tool for plants implementing TPM.

This weighted approach and OEE results will be benchmarking tool to gauge manufacturing system, especially maintenance management system. OEE helps manufacturer to improve productivity and get better visibility into their operations and also allow them to take sound management decisions.

## VII. CONCLUSION AND FUTURE WORKS

We may apply this methodology through algorithmic approach to get computational work, the values of OEE categorized through fuzzy logic method on A, P & Q to get optimization.

No manual data collection or manual compilation for OEE calculations is the first step in improving both the accuracy of OEE reports as wells as reducing the cost to produce the reports through neural network. The utility of artificial neural network models lies in fact that, they can be used to infer for future purposes.

## VIII. LIST OF ACRONYMS

TPM	Total Productive Maintenance
OEE	Overall Equipment Effectiveness
PE	Plant Effectiveness
A	Availability
P	Performance Rate
Q	Quality Rate
JIPM	Japan Institute of Plant Maintenance
BD	Break-Down
SA	Setup Adjustment
MI	Minor / Idling stoppages
RS	Reduced Speed
RL	Reject / Rework Losses
SL	Start-up Losses

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