Comparison of Overall Equipment Effectiveness in Continuous Production Line of Isomax unit of Esfahan Oil Refining Company (EORC) with World Class Manufacturing

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Abstract

Overall Equipment Effectiveness (OEE) is a measuring index which indicates how the equipment works. It not only shows the number of the manufactured products, but also indicates when the machineries really work and what percentage of the products are sorted out as quality ones. As a result, OEE can be considered as the health index of a process or equipment. The effectiveness index interprets the most frequent and the most important energy dissipation sources and classifies them into three main categories as downtime, speed and defect losses in order to specify in which state a producing system is and how it can optimize the losses. In this study, the difference between overall equipment effectiveness of the Isomax unit of EORC and its world class manufacturing standard was determined and the difference causes has been analyzed through three main elements: accessibility, performance and quality of the Isomax unit. To do so, the available information in EORC during 2008 to 2010 has been employed. The results suggest that asset productivity ratio, equipment performance ratio and quality ratio of Isomax unit differ from world class by +6%, -24% and -3.5%, respectively. Quality control and design capacity maximum output rate minimize such difference considerably.

Keywords: OEE, TPM, Quality, Equipment Performance, Asset Productivity, Overall Line Effectiveness, World Class Manufacturing

1. Introduction

As a key measuring criterion for total productive maintenance (TPM), the overall equipment effectiveness (OEE) was introduced first by Nakajima. Ever-increasing development of industrial technologies makes necessary the evolution of the advanced maintenance and repair systems. Total Productive Maintenance (TPM) is one of the most advanced maintenance and repair systems which it is applied collectively by all employees of the company. Accordingly, a program called TPM, defined by Japan Institute of Plant Maintenance (JIPM) on 1971, is used. The program has been defined to achieve five main goals, one of which is the equipment effectiveness. Maximizing equipment effectiveness is realized through minimizing/removing six major losses. Measuring OEE in a factory can be manifested in several forms and its function is determined based on the environmental condition, factory equipment and production methods which lead to generation of various OEE models in turn.

Although Various OEE measuring models identify the three following main elements/factors, they differ in terms of usage modes:

Accessibility: Performance effectiveness makes equipment accessible for producing activities.

Performance level: performance effectiveness implements a producing activity when equipment is accessible and is able to perform tasks.

Quality: performance effectiveness generates units adaptive with product qualitative criteria when equipment is involved in producing activity.

If access rate, quality rate and performance rate are defined as 90%, 99.9% and 95% respectively according to the world class criterion, then an overall rate as large as 85% is achieved via multiplying them by each other. Relying on the effectiveness index, the most important energy dissipation sources can be sorted out in three classes as downtime losses, speed losses and defect losses; hence, six major losses of a producing system including equipment failures, set-up and adjustments, idling and minor stoppage, reduced speed (actual designing vs. designed), start-up quality losses and in-process quality losses are specified separately.

2. Problem Statement

Since quality of OEE index covers most quality management requirements in quality management debates and also given the sensitivity of the refinery plants and the necessity to achieve the bottleneck point of the continuous production lines and to solve these problems, it seems reasonable that this system works with the lowest downtime and [its] highest possible capacity, so using an equipment effectiveness analysis system can be useful to prevent occurrence of any downtime or wreckage. Presently, suffering from the current international sanctions against Iran, it seems completely reasonable for Iranian oil industry to do its best to protect such capitals and keep them safe against dissipation and wasting. To do so, achieving a good OEE index across the refinery units through a proper method which can evaluate all production lines of a refinery unit seems necessary. This study is about to offer a proper method and to achieve some correct values to be used for comparing refinery units with other companies as well as the world class rates and for defining the necessary objectives for development and improvement. According to the recent studies on oil and petrochemical industries, no similar work has been conducted within Iran so far; thus, this study is practically an essential demand for the oil industry, so it analyzes the ISOMAX operational unit accordingly.

The following questions are posed and analyzed aiming to analyze and evaluate TEEP rate of Isomax unit of EORC based on its constituting components.

The main question of this study is: how much is the TEEP rate in the continuous production line of Isomax unit of EORC?

This question can be divided into three subsidiary questions by separating components of TEEP:

1. How asset productivity (AP) may affect the TEEP in the ISOMAX operation unit of EORC?
2. How equipment performance ratio may affect the TEEP in the ISOMAX operation unit of EORC?
3. How production quality or quality ratio may affect the TEEP in the ISOMAX operation unit of EORC?

Given the outlined questions, this study intends to come to the conclusion that which one of the mentioned factors of the Isomax operational unit of EORC predominates the TEEP.

3. Methodology

The available and actual documents of the production line including operation department, engineering and mechanized services department have been used to collect the required data for the study. Afterwards, they were summarized, sorted out and arranged in order to specify system requirements and then inspiring by the specified requirements forms, tables and calculation instructions have been designed in proportion to requirements of our research. Eventually, all of the obtained results were analyzed as Figures using Minitab software. The time frame of this study is limited to 2008, 2009 and 2010.

4. Data Collection

All monthly reports of the mentioned unit in association with the operational daily reports were used and examined during data collection stage and the essential information was elicited monthly from total raw data of the operational unit.

Converting the collected data into a similar and certain measuring unit was essential for evaluation and calculation purposes. Kilogram was selected as the basic measuring unit which is worked out by multiplying the volume by fluid density.

5. How to calculate

The calculation results gained from the received raw data of ISOMAX producing unit of EORC are:

1. Nominal performance indicating nominal speed and nominal production rate of machines in the continuous production line.
2. Performance rate: actual performance / nominal performance x 100.
3. Quality rate gained by dividing health output value in total output of the production line.
4. Planned downtimes were introduced as the total planned repairs and idling machines times.
5. Loading time: This parameter is measured by subtracting the planned downtime from the total time.
6. Abrupt losses or emergency downtimes or delays including the whole production downtimes comprising of instrumentation, electrical, mechanical and process downtimes.
7. Unplanned downtimes were introduced as total sum of the abrupt downtimes, set-up and adjustments times and delay times of materials.
8. Operation time: It is calculated by subtracting the loading time from the unplanned downtimes.
9. Access rate: it is calculated by dividing the operation time in the loading time.
10. Asset productivity (AP): it is calculated by dividing the operation time in the total time.
11. Overall equipment effectiveness is gained from multiplying AP, quality rate and performance rate to each other.

The obtained data from the production line are employed using eq.1 to calculate the applied TEEP value:

(1) TEEP = (equipment access time) x (performance rate) x (quality rate)

The asset productivity is used instead of the access time, because producing process of ISOMAX operation unit of EORC is a continuous process; regarding its formula at the ideal condition, all equipment must be available during the whole calendar hour, henceforth eq.2 is used and the effective overall equipment effectiveness is analyzed.

(2) TEEP =(Asset productivity) x (Performance ratio) x (Quality ratio)

6. Data Analysis

Subsequent to the measuring stage, the data should be analyzed. To do so, the obtained information was scrutinized using EXCEL and Minitab software. Initially, correlation rate of TEEP along with access, performance and quality ratios were examined by the regression analysis. Given the high correlation rate, TEEP rate in the production line was studied. Then, the TEEP states during various months were controlled by means of controlling Fig.s. Wherever TEEP rate dropped, main causes of stoppages were marked and analyzed.

6.1. Analysis of the first question of the study:

(How asset productivity may affect the TEEP in the ISOMAX operation unit of EORC?)

Here, impact of asset productivity of the ISOMAX producing unit of EORC on the TEEP is fathomed. Initially, we need to test the correlation between data and their normality. According to Fig. 2, the correlation between AP and TEEP is high because R-squared value is equal to 95.5%.

Insert Fig. 1 Here: Correlation between AP and TEEP

Insert Fig. 2 Here: Testing normality of AP data

Pearson's correlation coefficient is 0.979 and the correlation equation is calculated as

AP= 5.748 + 1 X TEEP. Since AP is one of TEEP parameters, its variations should affect the effectiveness value, it can be observed very clearly in Fig. 3. Changing AP, as a result of the downtime changes, would change TEEP values in turn. For example, the TEEP rate in April 2010 has changed outstandingly in response to the critical repairs and the planned downtimes.

Insert Fig. 3 Here: variations of both AP and TEEP

In order to analyze AP variations, downtimes of Isomax unit of EORC have been summarized in table 1.

Insert Table 1 Here: A three-year summary of downtimes (hour)
(Only months with downtime are shown)

Regarding direct involvement of downtimes in calculation of access times and APs, for analyzing drop causes it is necessary to analyze firstly behaviors and Fig.s of such times. Fig. 4 indicates all downtimes in comparison with the operation times and Fig. 5 shows Pareto chart for these downtimes.

Insert Fig. 4 Here: All downtimes in comparison with the operation time

Insert Fig. 5 Here: Pareto chart for downtimes during 2008 to 2010

According to the Fig. 5, 54% of downtimes belong to the unplanned downtimes and 17% were caused by process equipment shut downs, so set-up and adjustments periods can be declined by controlling such downtimes and the unit will find a better status. For more analyses and information please refer to Pareto charts 6, 7, and 8 which analyze each year separately.

Fig. 6 suggests that the most important cause of downtimes has been machinery downtimes in 2008.

Insert Fig. 6 Here: Pareto chart for unplanned downtimes in 2008

Fig. 7 suggests that the most important cause of downtimes has been process equipment downtimes in 2009.

Insert Fig. 7 Here: Pareto chart for unplanned downtimes in 2009

Fig. 8 suggests that 46% and 37% of downtimes were because of process equipment shut downs and set-up and adjustment failures, respectively in 2010.

Insert Fig. 8 Here: Pareto chart for unplanned downtimes in 2010

6.2. **Analysis of the second question of the study**:

(How equipment performance ratio may affect the TEEP in the ISOMAX operation unit of EORC?)

According to Fig.s 9 and 10, the Pearson's correlation coefficient was calculated by the software as 0.248, so it can be inferred that performance rate data are normal and have a weak but consistent correlation with TEEP.

The relation between TEEP and operational performance is OP= 67.55 + 0.05697 x TEEP and its R-squared value is equal to 6.1% which approves the weak correlation between TEEP and OP.

Insert Fig. 9 Here: Testing normality of OP data

Insert Fig. 10 Here: Correlation between the operational performance (OP) rate and TEEP

Fig. 11 shows that OP enjoys a fixed trend and has hence the lowest impact on the effectiveness

OP and TEEP Variations

Insert Fig. 11 Here: Operational performance and TEEP variations

6.3. Analysis of the third question of the study

(How production quality or quality ratio may affect the TEEP in the ISOMAX operation unit of EORC?)

Insert Fig. 12 Here: Correlation between quality rate and Total equipment effective performance

Regarding the Pearson's correlation coefficient, -0.039 measured by Minitab software, and normal performance rate, it can be concluded that there is not any correlation between TEEP and quality ratio. Thus TEEP is not affected by quality ratio which it is explained by relatively fixed rate of the quality ratio.

Fig. 13 shows very clearly the impact of the correlation and quality variations on TEEP. The fixed quality ratio has not affected the TEEP.

TEEP and Q Variations

Insert Fig. 13 Here: Quality and TEEP variations

Regarding the fact that effectiveness is comprised of three factors whose behaviors may affect the effectiveness output, Fig. 14 shows all factors simultaneously and finally variations are completely evident. Most effects are due to AP caused by downtimes. Thereafter AP has the most remarkable effect on TEEP.

Q, OP, AP and TEEP variations

Insert Fig. 14 Here: Variations of TEEP with all parameters

Insert Fig. 15 Here: Controlling chart of performance ratio

Insert Fig. 16 Here: controlling chart of quality ratio

Insert Fig. 17 Here: controlling chart of AP ratio

Fig.s 15, 16 and 17 show the unit in a desired status. Fig. 17 (quality) shows that the unit has found a better status in terms of production quality after substantial (planned) repairs. In fact these values are close to the international standards. The calculated and depicted values by Fig.s 15, 16 and 17 are AP: 96%, Q: 96.5% and OP: 71.5%.

Insert Fig. 18 Here: controlling chart of TEEP

As Fig. 18 shows the average obtained rate of TEEP is 66% which is lower than the international class by 19%.

7. Discussion and Conclusion

Three subsidiary questions were dealt with in order to achieve the answer for the main question: "how much is the TEEP rate in the continuous production line of Isomax unit of EORC**?**"

7.1. Results gained from analyzing the first subsidiary question (How asset productivity may affect the TEEP in the ISOMAX operation unit of EORC?)

According to Fig.s 1 and 2, the Pearson's correlation coefficient was determined as 0.979 which implies very high correlation and consistency with AP data. AP rate is normal, both the relation and effect are completely clear in Fig. 3. The wreckage times or the planned repair times (April 2010) show exactly this effect. Analysis of Fig. 5 showed the unplanned downtimes in TEEP as 54% for three years, out of which 17% and 12% were justified by process equipment shut downs and machinery equipment failure and the remaining was due to set-up times. Therefore, by controlling such downtimes we can decline set-up and adjustments times. As it can be seen in Fig. 17, the average AP rate of Isomax unit was 96% which is 6% more than that of its international counterpart.

7.2. Results gained from analyzing the subsidiary second question, (How equipment performance ratio may affect the TEEP in the ISOMAX operation unit of EORC?)

Pearson's correlation coefficient was determined as 0.248, relying on Fig.s 9 and 10 and the measured value by the software, so it can be concluded that the operational performance data are normal and have weak but consistent correlation with TEEP. Since Isomax unit continues production task through a relatively constant rate, OP has not been varied considerably hence it has not imposed major changes on TEEP. The average OP rate of Isomax unit was 71% which shows 24% decline rather its international counterpart.

7.3 Results gained form analyzing subsidiary third question, (How production quality or quality ratio may affect the TEEP in the ISOMAX operation unit of EORC?

There is a weak correlation between OP rate and TEEP rate (~0). Given the relatively constant variation of the quality rate of the Isomax unit, the quality has not experienced considerable variations and has not imposed major variations on TEEP. The average Q rate of Isomax unit was 96.4% which shows 3.5% decline rather its international counterpart.

8. Level of realizing the study objectives

The main objective of the study was achieving TEEP rate in the continuous production line of Isomax unit of EORC which was materialized and you can find it in the Fig. 18. It was equal to 66% for TEEP.

Controlling chart 18 (TEEP) shows that the obtained average value differs from the international class of TEEP by 19%.

1. *First subsidiary objective*: to realize this, AP rate has been measured as 96% which is 6% higher than the international class.
2. *Second subsidiary objective*: It was materialized by gaining 71% as the average value for OP rate. It is 24% lower than the international class.
3. *Third secondary objective*: It was materialized by gaining 96.5 % as the average value for Q rate. It is 3.5% lower than the international class.

Propositions based on findings of the study

Using productivity to conduct troubleshooting and to improve system is the main goal of analysis and calculation of productivity.

8.1. First subsidiary question

As the average accessibility rate of Isomax unit is 96% and is 6% higher than the defined international class, maintaining such condition is highly reasonable. Concerning dependence of the accessibility rate on various factors such as emergency and planned downtimes, they still should be kept under the control. Fig. 6 showed that machinery equipment failure during 2008 was the main cause for such downtimes which are mainly restricted to July 2008. Fig. 7 represented that process equipment shut down has been the main cause of such downtimes on 2009, which are mainly restricted into June, December and January 2009. Regarding Fig. 8, process equipment shut down has been the main cause for downtimes recorded on 2010 so application of the autonomous maintenance approach and proactive repairs are helpful to control the mentioned downtimes.

8.2. Second subsidiary question

As you observed, the average rate of operational performance for the Isomax unit was 71% which showed 24% decline rather the international class. Thus, the strategy to improve this average should be put atop agenda. To do so, referring to basis of the calculations makes evident that this issue is related to design capacity as well as operation arte of the capacity. Therefore, recognizing bottlenecks is very essential to improve this loss. Analysis of Isomax unit process helped us to the effective factors: amount of materials shall recycle across the process, input feed and hydrogen gas, as a result, defining and conducting research and practical projects on production process designing fields with the purpose to achieve performance average rate 95% can improve this rate.

8.3. Third subsidiary question

Our results showed that the average rate of quality is 3.5% lower than the international class and is equal to 96.4%. The waste amount of production is the main effective factor to either increase or decrease the quality rate, however production wastes due to production process of the Isomax unit, as large as the defined amount in unit design, is unavoidable. In fact such wastes are considered as products in turn and since decreasing wastes has been introduced as a way to enhance the quality, relying on renovation and technology development strategy is seemed necessary. Using any kind of technologic development entails increased skillful employees which should be carried out in association with other required fields of technologic revolutions, new technologies will affect the organization structure, skills, employees' relations and occupations. Thus, all of the mentioned items and the relevant fields must be analyzed precisely and the necessary changes and modifications should be applied on them to drag out optimum usages.

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Annexure

Figures and tables

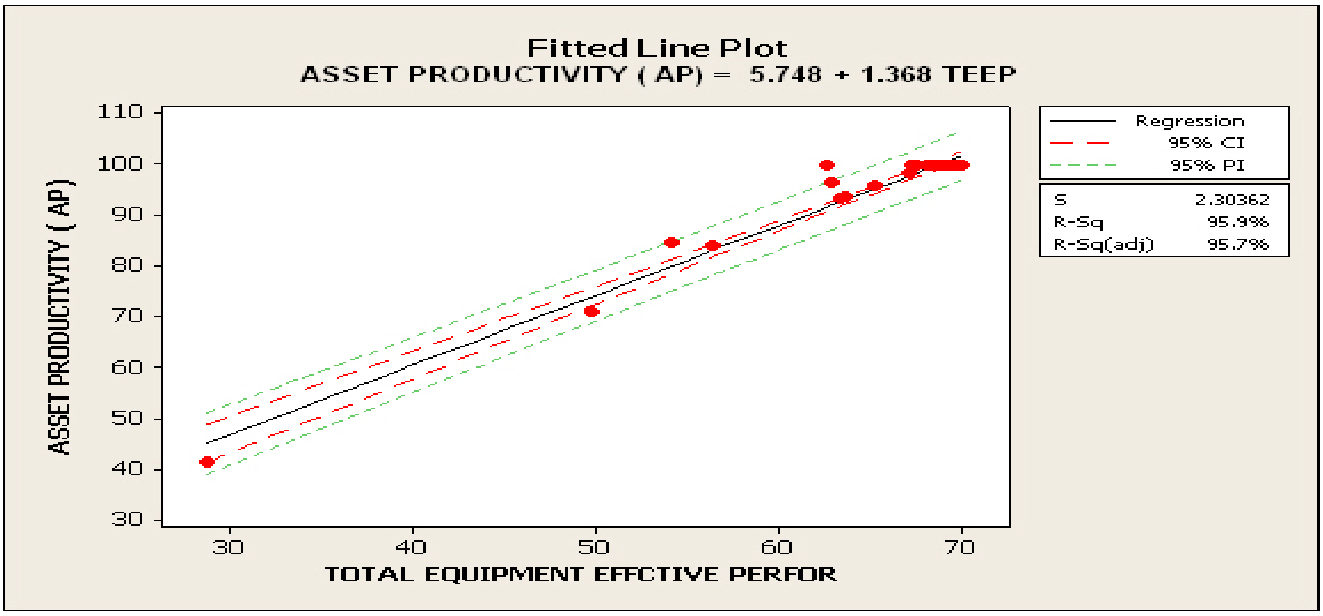

Fig. 1: Correlation between AP and TEEP

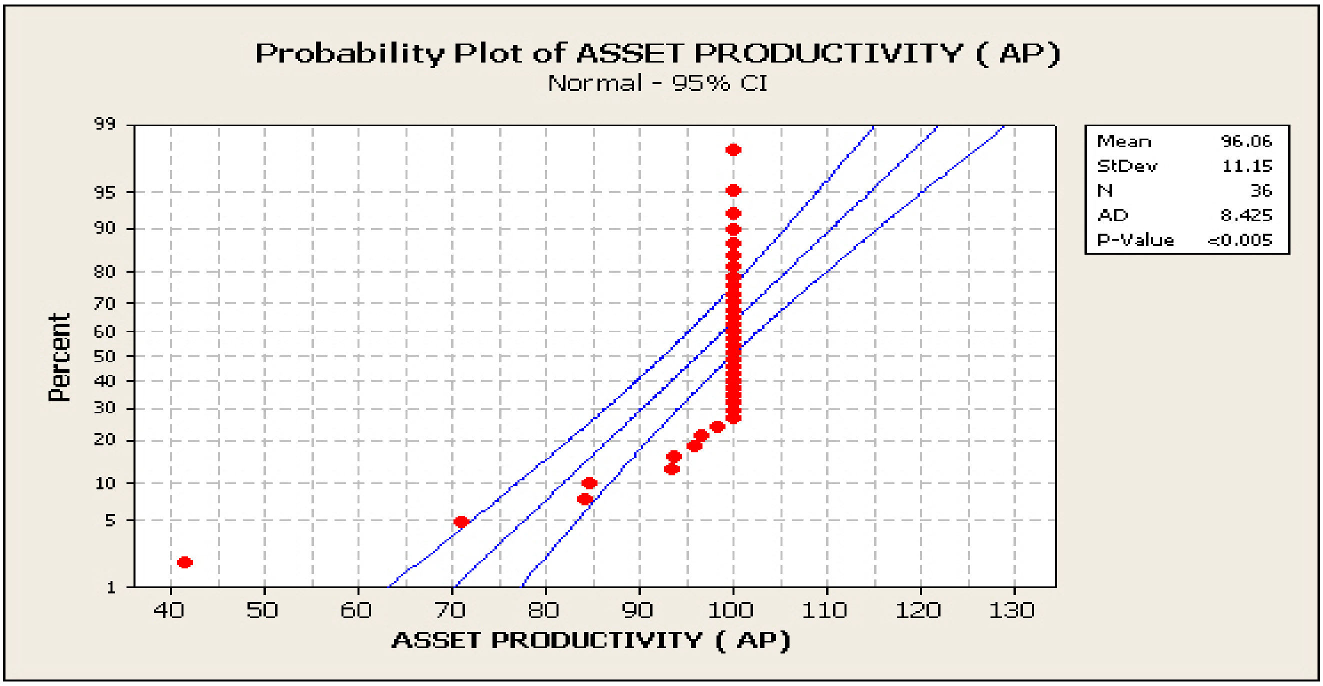

Fig. 2: Testing normality of AP data

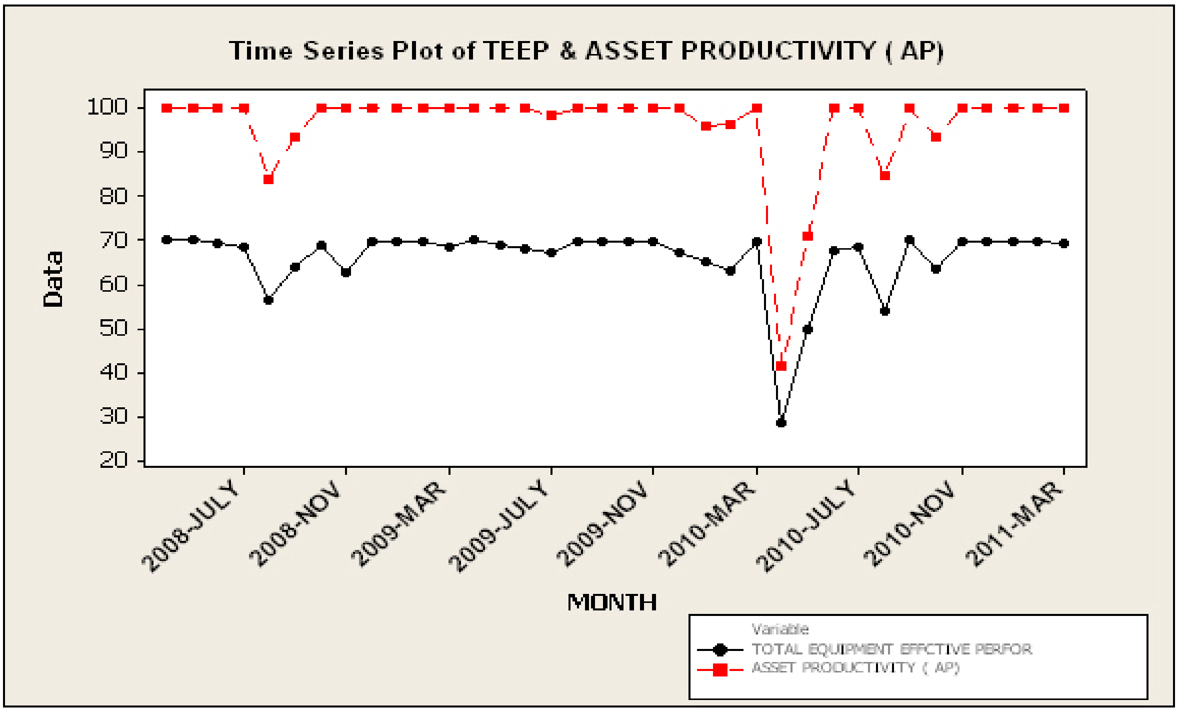

Fig. 3: variations of both AP and TEEP

Table 1: A three-year summary of downtimes (hour)
(Only months with downtime are shown)

Month	Planned stops	Emergency downtime due to process problem	Emergency downtime due to instrumentation problem	Emergency downtime due to electrical problem	Emergency downtime due to machinery problem	Lack of production and/or material circulation	Set-up and adjustment time	Operation time	Loading time
2008-AUG	0	0	0	0	119	0	0	625	744
2008-SEP	0	0	0	0	12	0	36	696	744
2009-JUL	0	13	0	0	0	0	0	731	744
2010-JAN	0	30	0	0	0	0	0	690	720
2010-FEB	0	25	0	0	0	0	0	695	720
2010-APR	437	0	0	0	0	0	0	307	307
2010-MAY	131	0	0	0	0	0	85	528	613
2010-AUG	0	115	0	0	0	0	0	629	477
2010-SEP	0	0	0	41	0	0	7	672	720

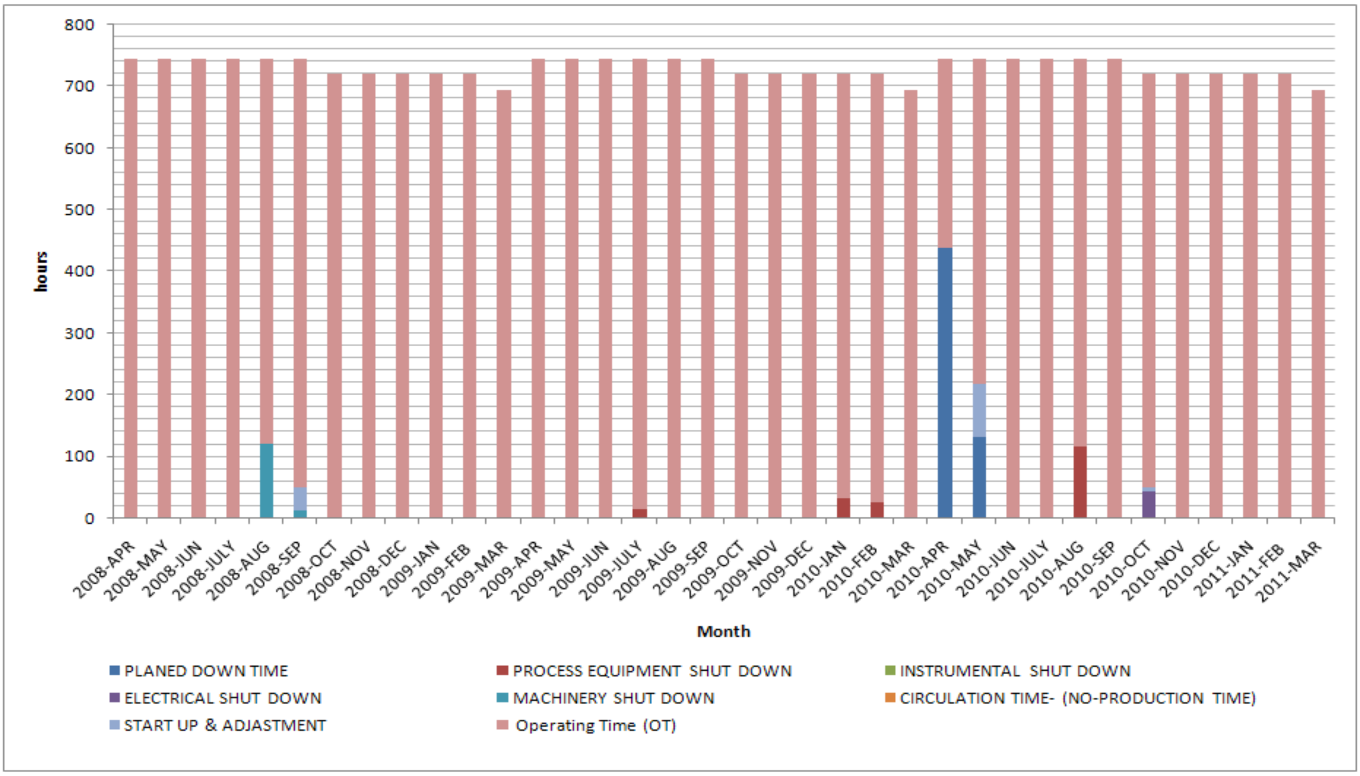

Fig. 4: All downtimes in comparison with the operation time

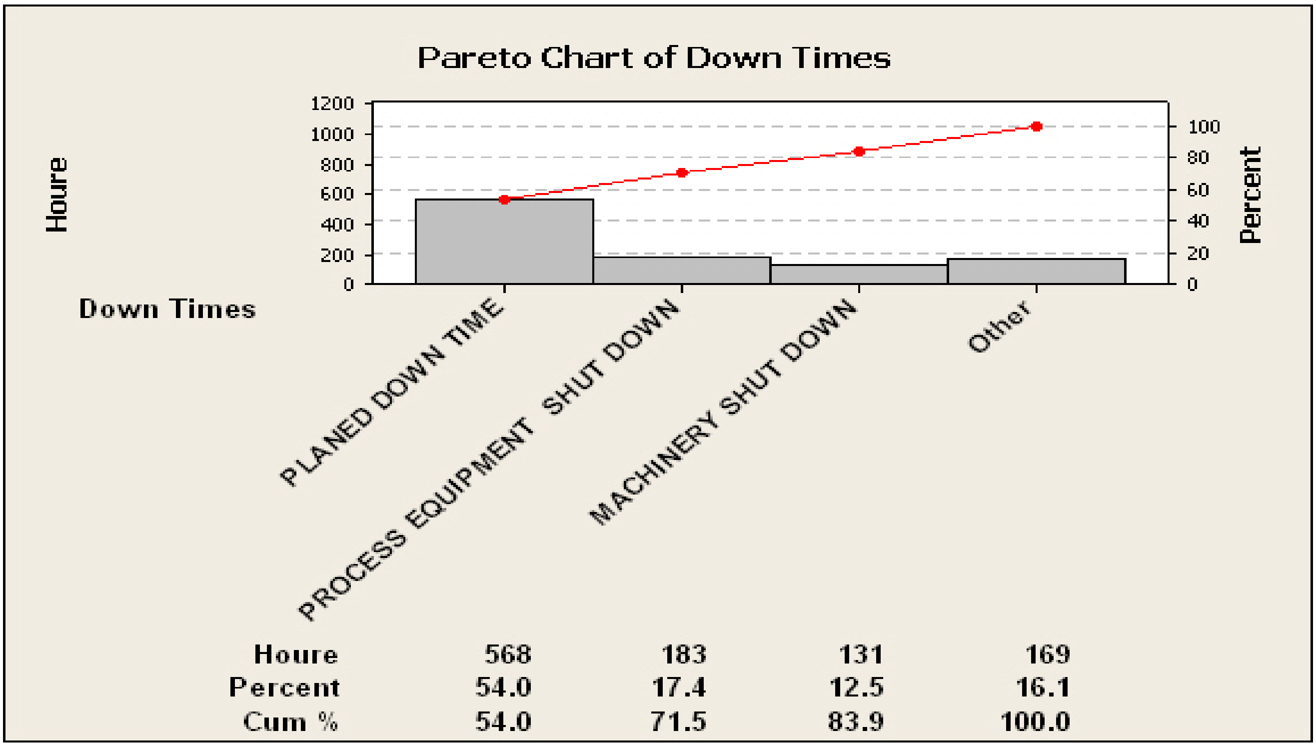

Fig. 5: Pareto chart for downtimes during 2008 to 2010

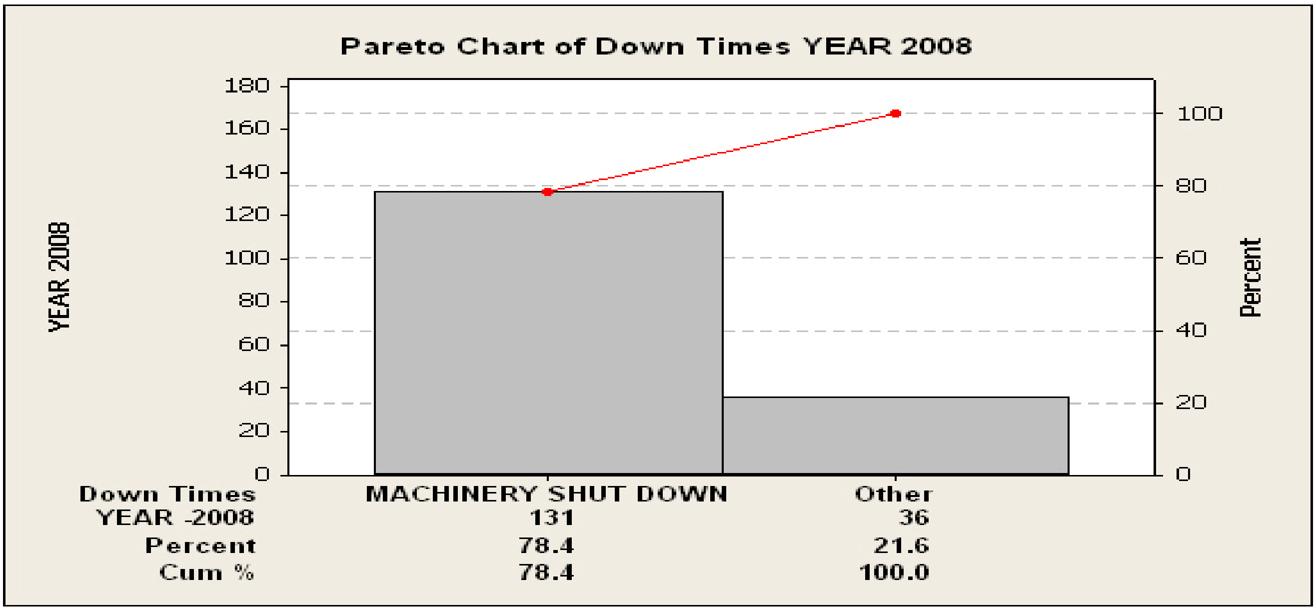

Fig. 6: Pareto chart for unplanned downtimes in 2008

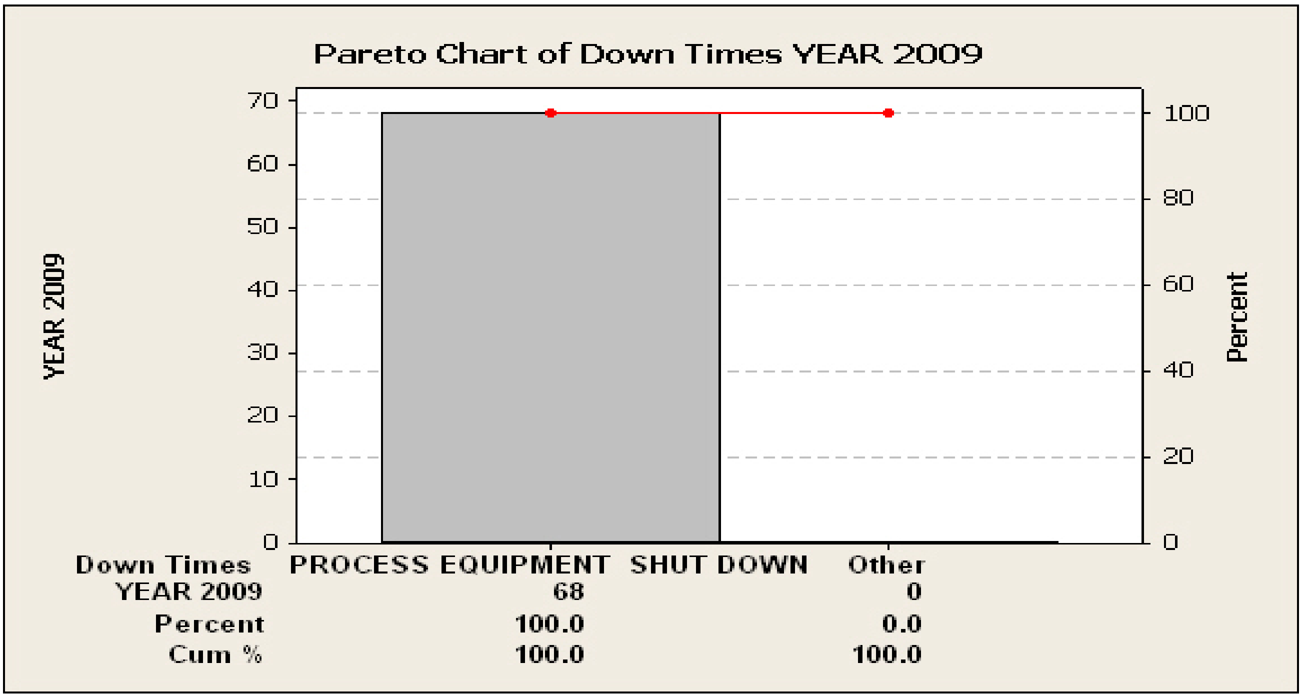

Fig. 7: Pareto chart for unplanned downtimes in 2009

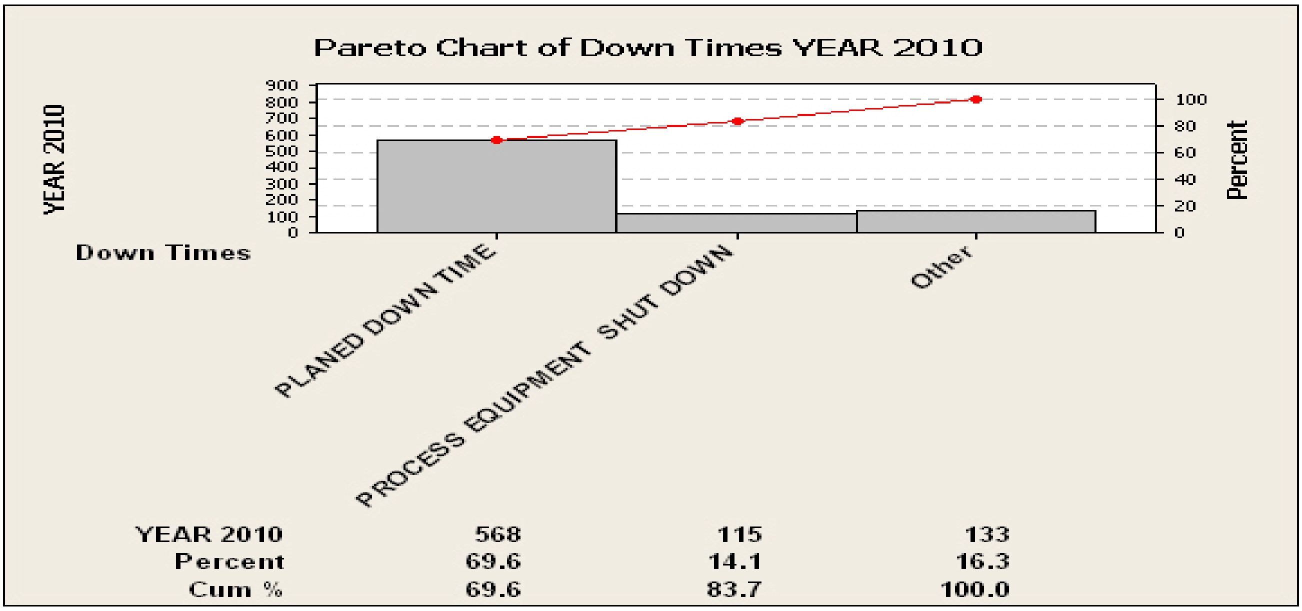

Fig. 8: Pareto chart for unplanned downtimes in 2010

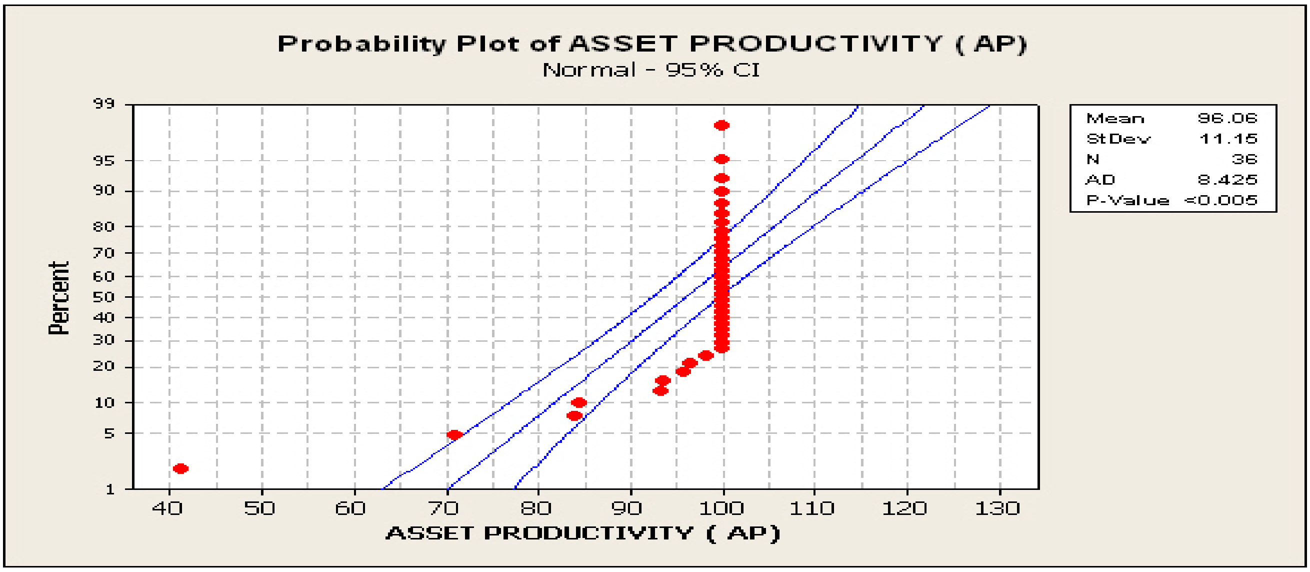

Fig. 9: Testing normality of OP data

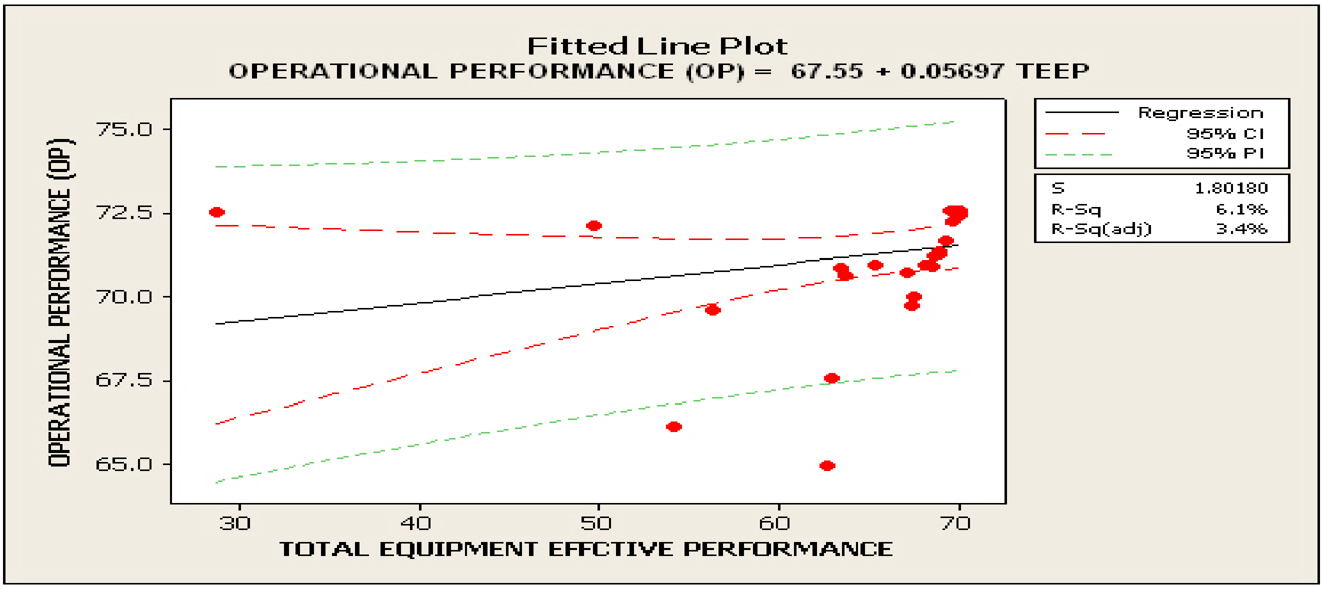

Fig. 10: Correlation between the operational performance (OP) rate and TEEP

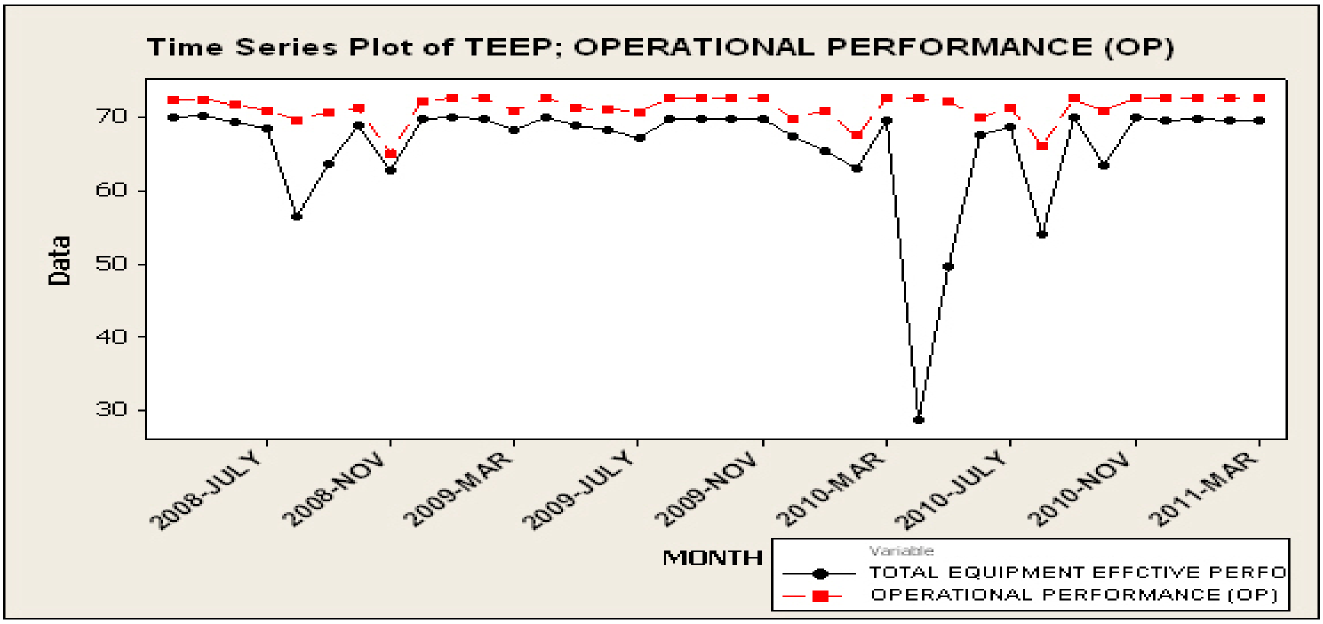

Fig. 11: Operational performance and TEEP variations

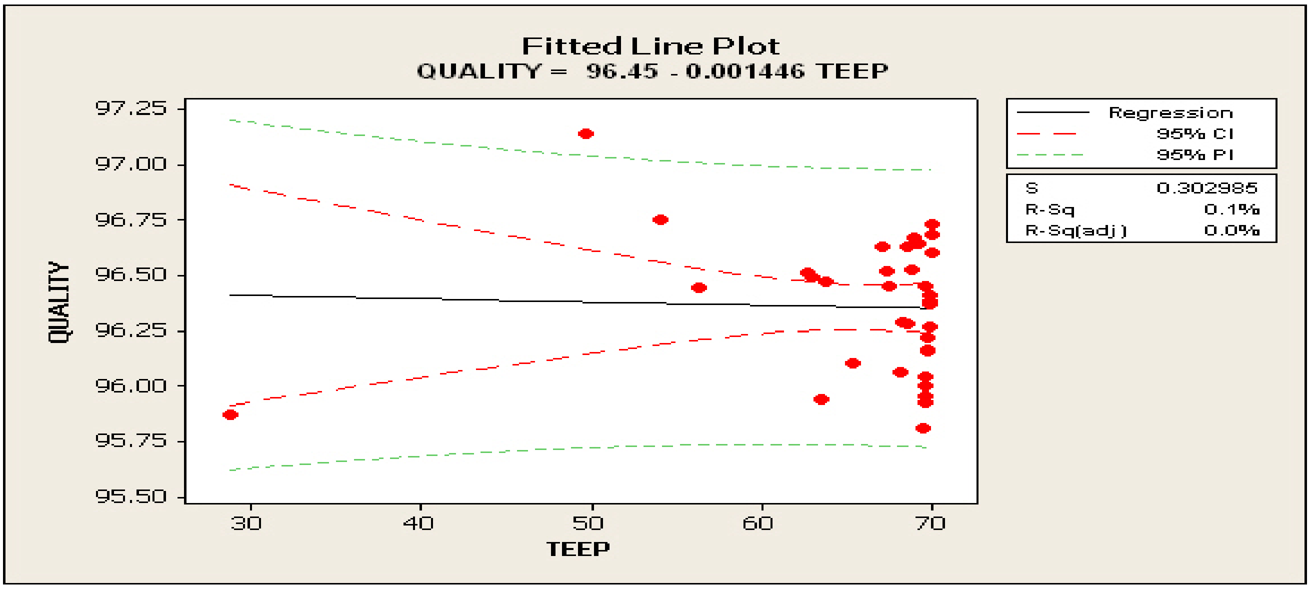

Fig. 12: Correlation between quality rate and Total equipment effective performance

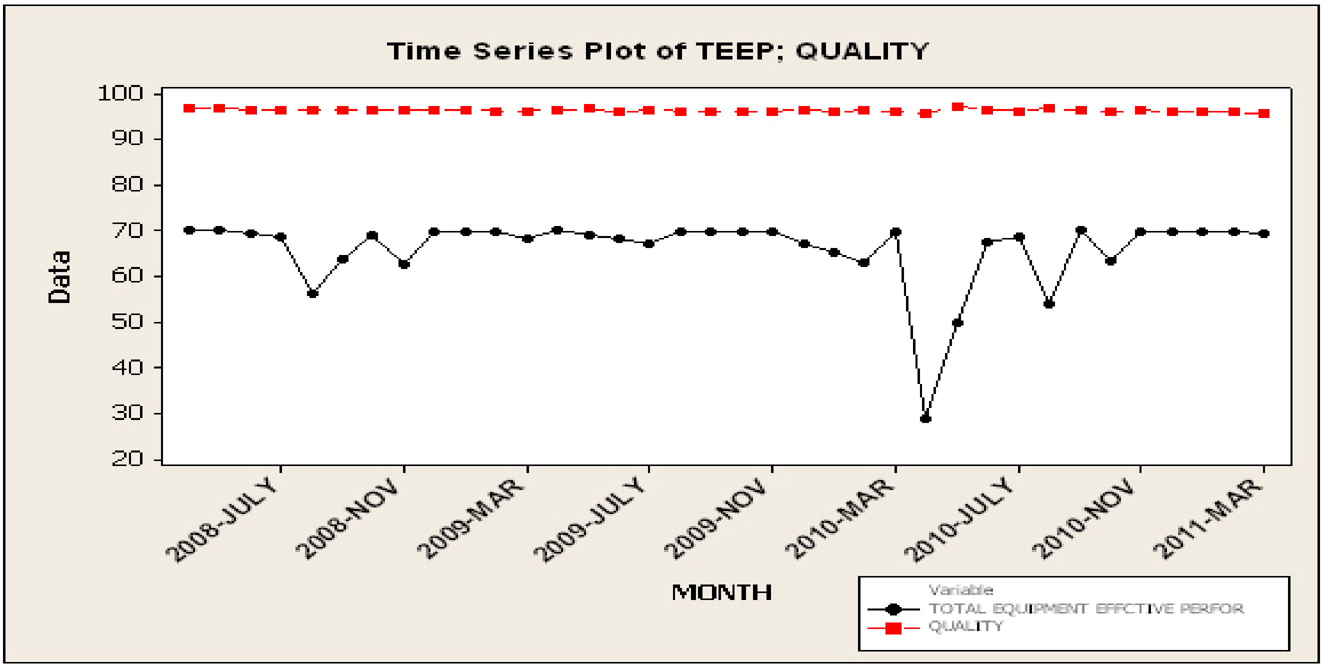

FIG. 13: Quality and TEEP variations

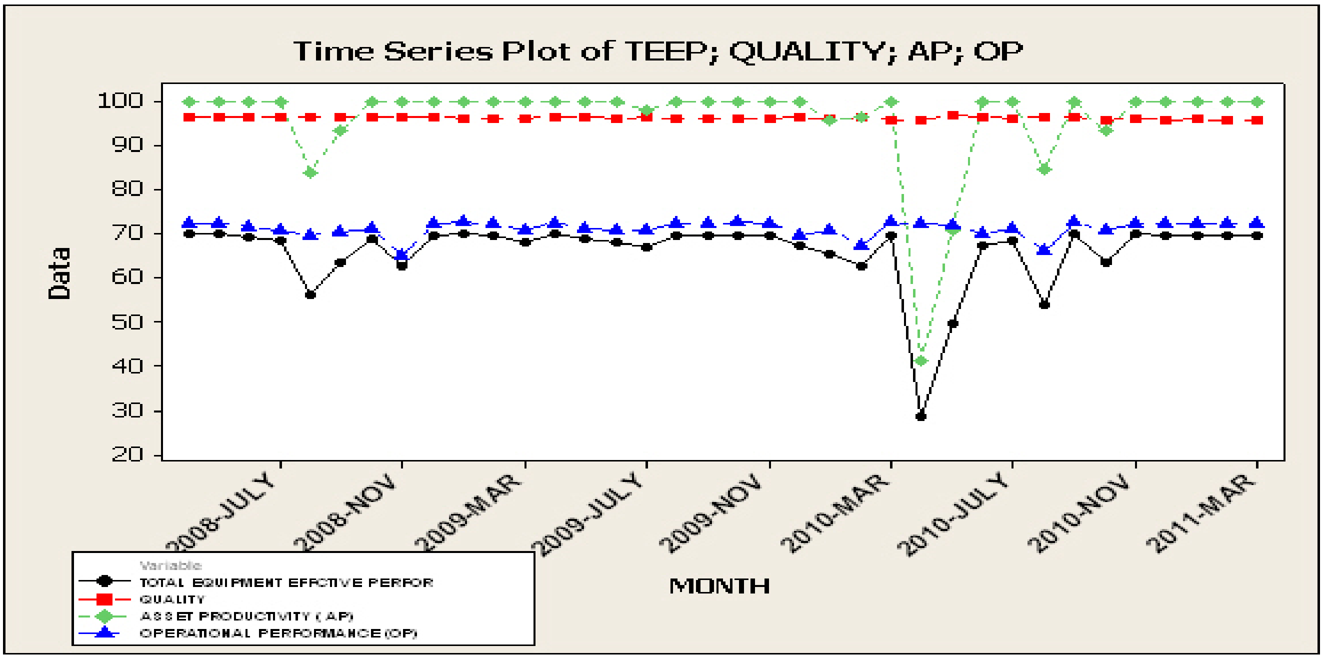

Fig. 14: Variations of TEEP with all parameters

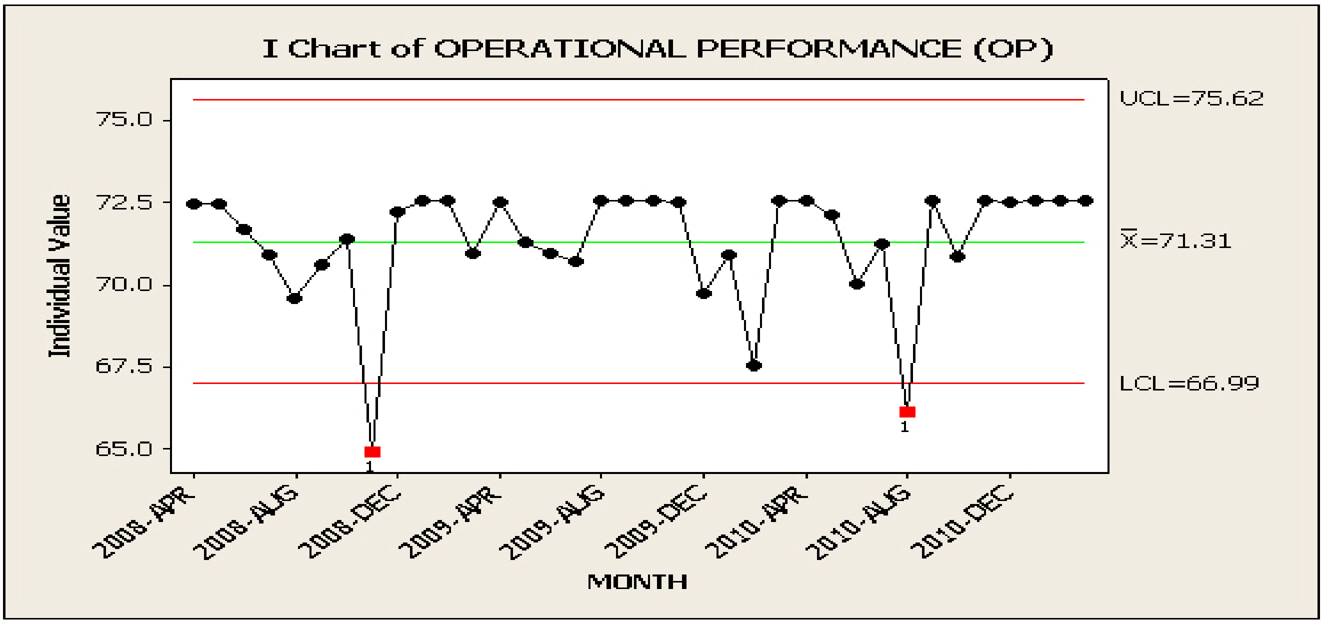

Fig. 15: Controlling chart of performance ratio

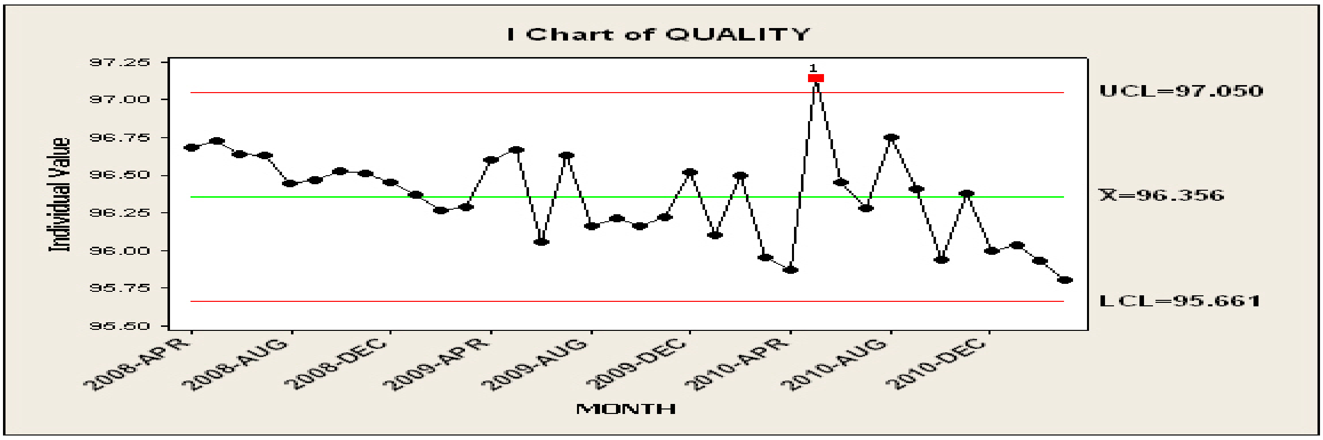

Fig. 16: controlling chart of quality ratio

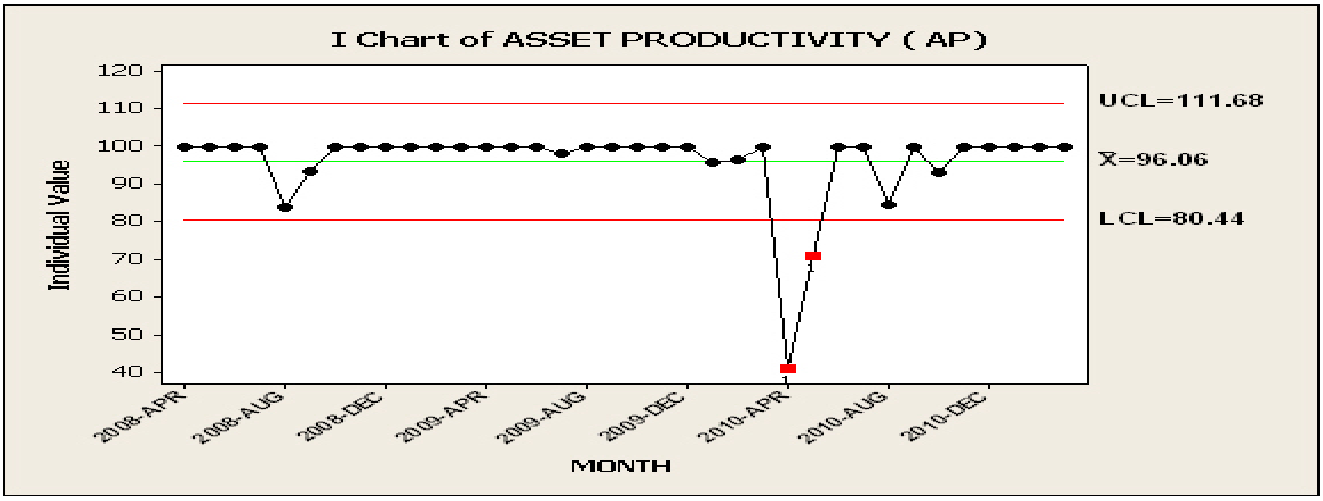

Fig. 17: controlling chart of AP ratio

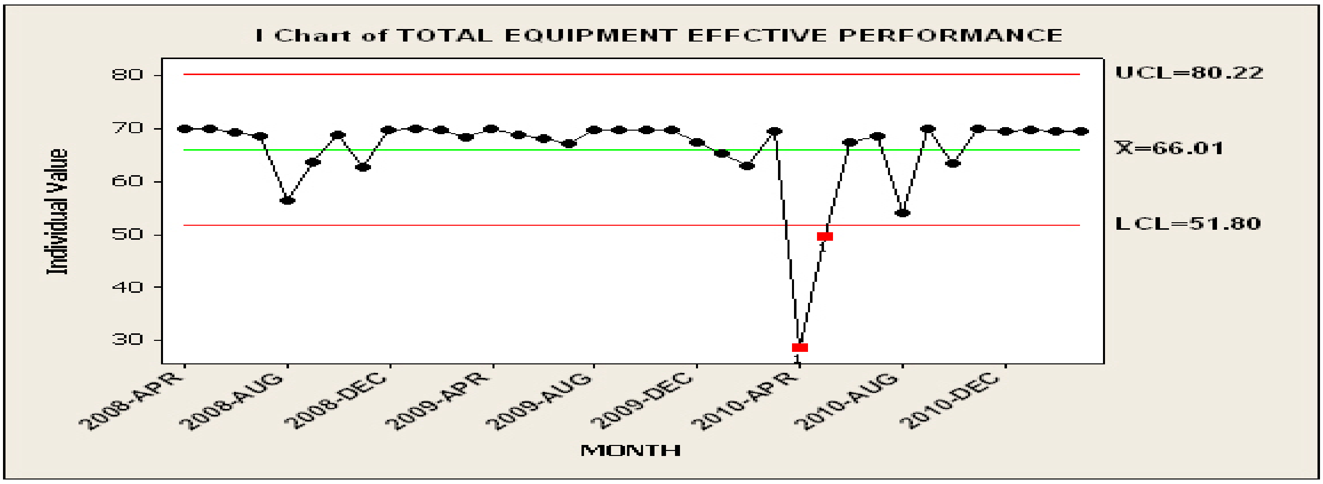

Fig. 18: controlling chart of TEEP