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THE IMPACT OF OVERALL EQUIPMENT EFFECTIVENESS ON PRODUCTION LOSSES IN MOGHAN CABLE & WIRE MANUFACTURING

Abstract: *OEE is one of the most popular methods of evaluation of the performance in the manufacturing process to identify and eliminate the causes of production losses. This study has a significant importance due to demonstrating the existing loss and identifying indicators of OEE and their impact on production losses. The main purpose of this study is to minimize the losses of equipment by utilizing the available resources. For this purpose, Moghan Cable & Wire Manufacturing Company was selected as a case study. After collecting equipment data, a questionnaire was designed that its validity was approved by group of experts and its reliability was calculated by using Cronbach's alpha method which was equal to 0.901. Data were analyzed by Structural Equation Model, in order to examine the relationship between variables. The results showed that the high levels of overall equipment effectiveness have a significant impact on the reduction of production losses.*

Keywords: *OEE, Production Losses, Performance, Quality, structural equation modeling*

1. Introduction

Measurement of the performance is one of the basic principles in the management and its measurement is very important because it identifies the gap between the actual, optimal and expected performance. To this end, the key performance indicators are selected carefully and then they identify the parts that their performances need to be improved. (Weber and Thomas, 2005) Also, today, regarding the dramatic advances in the field of manufacturing machinery and equipment, major part of assets of factories have been concentrated in this sector which is the main source of added value as well. With the stop and breakdown of the machinery, consequently, production process of the value added will be also stopped. Three main specifications of quality, price and delivery time are considered for each product (Tucker, 2004) and equipment has impact on all of these criteria. Also achieving objectives, such as increased productivity, health and safety, quality and the like, in industries, all depend on the effective performance of the devices and equipment. The capability of industries in manufacturing products with lower costs and higher production also depends on efficient performance of equipment and devices. Overall equipment effectiveness is one of the

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key performance indicators in total productive maintenance and shows how effectively operate the machinery.

Total productive maintenance is a holistic approach of an organization towards the improvement of the efficiency and decay of life of machinery and nowadays, throughout the world, total productive maintenance is used to increase the capability of equipment. Total productive maintenance consists of a series of objectives for reducing losses and improving production and design procedures and maintenance of processes to avoid future problems and to achieve these goals, it uses the overall effectiveness indicators of equipment (Motavalian, 2007, pp. 24). Overall equipment effectiveness coefficient is a comprehensive measuring tool of manufacturing equipment of factory that employs the methodology of reducing manufacturing machinery and implementation of continuous improvement of production and at first utilizes the corrective measures in the best way to limit the equipment that can have a negative impact on production and finally corrective measures are extended to other parts of the factory. In any production process, there are six types of wastes that reduce the effectiveness of the machinery (Ahuja and Khamba, 2008), which include:

Breakdowns: are unexpected and sudden breakdowns that stop the device and then the device will not have any output.

Setup and adjustment of losses: To change the procedure of machine, it needs to stop a few hours or a period. The time period between the terminations of the production of last safe product up to next safe product production is called the stagnant time.

Losses resulting from the movement without producing or small and short-term stoppages: In this type of lesions, because of simplicity of defect, it is easily fixed by the operator. But if during a shift of production the lags occur frequently, then they would have adverse effects on the efficiency of the equipment.

Losses resulting from the slowdown: the difference between the nominal capacity and actual production capacity which should be zero.

Losses caused by quality and rework: a product that does not reach the desired qualitative criteria of production, even if it is to be modified and reworked.

Startup losses: Usually in the early hours of production, the obtained product does not reach the desired quality, this lesion is hidden and it is often considered as an inevitable loss that can be unexpectedly large. (Motavalian, 2007, pp. 38-39)

These 6 losses are classified in three categories that breakdown of machinery and the startup of equipment are placed in the category of downtime of machinery, small stops and low production speed are in the category of loss of speed and rework and startup losses are placed in the category of quality loss. And the main reason of implementation of overall equipment effectiveness is to reduce or eliminate the reasons for these losses and increase efficiency in the production process. (Parihar *et al.*, 2012)

2. Literature review

Researches have been conducted in this regard that emphasize on the importance of using indicators of overall equipment effectiveness that we are going to mention some of them briefly.

In another study entitled as "implementation of overall equipment effectiveness", the purpose was to implement the overall equipment effectiveness in a small manufacturing company and no measuring instrument was used in this company. This index helped to identify the problems related to the rate of availability and performance and also by relying on this indicator and the obtained results, the management of this company was able to detect root causes of losses caused by downtime and reduced speed. Results of this study showed that after

the full implementation of this indicator, the rate of performance and availability was improved by 79%, but the rate of quality was unchanged. (Raguram, 2014)

In another study which was conducted in Ground Force of Islamic Republic of Iran Army as "Increasing the equipment effectiveness in Ground Force of Islamic Republic of Iran Army by using the methods of preventive and predictive maintenance and total productive maintenance", various methods of maintenance and also identification of items that can increase the effectiveness of the equipment of Ground Force of Islamic Republic of Iran Army units and also the type of effect of each on the increase of equipment effectiveness have been examined. For this purpose, indicators and standards related to preventive maintenance (periodic and scheduled lubrication, cleaning, adjustment, repair and replacement), predictive maintenance (measurement of loss, and inspection and control of technical conditions) and total productive maintenance system (sound and healthful motivation and morale, fair competition and environmental conditions) were identified and then the impact of each of them on overall equipment effectiveness was evaluated. The statistical results obtained from this study indicated that there is a direct positive relationship between preventive maintenance, predictive maintenance and increase of the effectiveness of the equipment of Ground Force of Islamic Republic of Iran Army units. It was also found that among the three independent variables, total productive maintenance had the greatest impact and preventive maintenance had the less effect on increasing the equipment effectiveness of Ground Force of Islamic Republic of Iran Army. Considering that the total productive maintenance system is based on manpower, it was concluded that investments in human capital, such as increasing motivation and boosting morale, has an important role in increasing the effectiveness of the equipment of Ground Force of Islamic Republic of Iran Army units. (Karbasi *et al.*, 2011)

In another study, entitled as "Assessment of the overall equipment effectiveness in the continuous process of production of insulation in cable production unit", overall equipment effectiveness index was calculated and the limitations and problems in the production unit of this unit were identified. In this study, the amount of overall equipment effectiveness index in the process of production of insulation was calculated and it was equal to 52.93% that the main reason for the gap between this index in the insulation production unit of factory and their world class values was the level of performance factor that its amount was 68.67%. Also in this study, the main causes of production losses were examined in the mentioned unit that the most important of them include: change of basket, startup time and change of print wheel, low number of extruders, change in color, semi-skilled operators, low speed for different classes of copper and the risk of smoke from the substance of Hercules for the health of operators. To reduce these losses, the implementation of new techniques and tools, using skilled staff and standardization of speed in the production line were proposed. (Nayak *et al*., 2013)

Other research was carried out under the title of "Assessment of overall equipment effectiveness in a continuous production process of gas condensates stabilization factory in Assaluyeh" in which the index of overall equipment effectiveness was calculated and then its value was compared with world class values. The results of this study show that although the gas refinery of Assaluyeh works throughout the week without any pause and break, but considering the planned maintenance, units of this refinery cannot provide service at some times. The reasons for the lack of service in the factory and the main weaknesses of each factor i.e. availability, performance and quality have been identified. Studies conducted on the index of overall equipment effectiveness in the unit A of refinery, in this

study indicate that the main weaknesses of this unit are thee lack of servicing of platforms, scheduled maintenance and stoppages of machines, delay in finishing repairs, low quality product production during startup and reworks, fluctuations in gas demand by customers and lack of facilities for the storage of gas, which has caused fluctuations in input values to refineries. Similarly, the weaknesses were identified in unit B of the refinery which includes stoppage of equipment due to poor quality of output, planned stops, stoppage due to lack of servicing platforms, stoppages due to power outages, defective manufactured products, reworks, production of low quality products during the startup and fluctuations in gas demand by customers. The results of this research show the gap between the world class and the overall equipment effectiveness in this process that the main reason of this gap is the poor performance of these units. The level of performance in unit A is 21.63% lower than world class and it should be increased up to 96.13%. Also the level of performance in unit B is 25.96% lower than world class and it should be increased up to 96.25%. Another objective of this study was to identify and measure the six big losses that the most important losses in units A and B, were respectively reduced speed due to customer demand and sudden downtime and finally it was suggested that better planning and coordination with customers can reduce major losses in these units. (Zandieh and Nilipuor Tabatabei, 2012)

In another study that was conducted by Baluch and Abdullah (2012) under the title of "Measuring overall equipment effectiveness in palm oil production plant in Malaysia" the level of overall equipment effectiveness was calculated for this factory. For this purpose, in a period of time, the degree of availability of equipment was calculated according to real-times of production. The reasons for the decline in access and stops were equipment breakdown, lack or absence of input materials and low number of operators. Also performance rate and quality rate were calculated. This study showed that the decrease of performance rate of this factory is due to the size of the input products, the number of slots and the quality of materials. The results of this study showed that the sudden and unplanned breakdowns are the main reason for the reduction in the availability of equipment. For this purpose, in order to increase the level of this indicator, it has been proposed to pay more attention to availability of engineers and operators, access to critical and essential spare parts, as well as access to raw materials. Also in order to improve performance, more emphasize must be centered on the daily maintenance and redesign of product to reach the ideal speed. Increase of quality is also possible through making improvements in maintenance procedures and improving the quality of the raw material. (Baluch and Abdullah, 2012)

In other research entitled as “Correlating Failure Mode Effect Analysis (FMEA) & Overall Equipment Effectiveness (OEE)” that was conducted by Ahire, Relkar, the objective was to investigate the relationship between measures of FMEA, that is, severity rate of risk (intensity of risk), the rate of occurrence of risk and the rate of probability of risk detection and all the parameters of OEE i.e. availability, performance rate and quality rate. For this purpose, during different months, the amount of each FMEA measures and overall equipment effectiveness in in one of the industries, which was selected as a case study, were calculated. After calculating and collecting amounts, the correlation between FMEA standards and standards of overall equipment effectiveness was assessed by using correlation and regression tests. The results of this study showed that if PRN increases, the rate of availability will be reduced. Also, in general, results showed that low levels of PRN cause an increase in the overall equipment effectiveness. (Ahire and Relkar, 2012) Considering the mentioned issues, in

many industrial factories, there are some problems in the production lines like the rate of planned and unplanned stops and there are also problems regarding the quality of products that the main reason of these problems are the equipment and machinery of factory. Although the devices and equipment of the factories have an important role in the production of organization and are considered as one of the most important competitive advantages, but despite this fact, in most of factories, no sufficient attention has been paid to the effectiveness of the equipment and production losses that are caused by improper functioning of the equipment. Therefore, the present study has been conducted to demonstrate the existing loss and identify indicators of overall equipment effectiveness and their impact on production losses of Moghan Cable & Wire Manufacturing Company and the main objective of this study is to explain the hypothesis that "overall equipment effectiveness has a significant influence on production losses."

3. Research method

Statistical population of this study consists of all managers, specialists and operators associated with the production and maintenance unit of Moghan Cable & Wire Manufacturing Company that in general, 200 people of company are able to respond to the questionnaire. Due to limitation of population, in this study, a simple random sampling method is used. Since the number of questions was 24, the sample size was estimated to be 120 (24 * 5 = 120) and to enhance the accuracy, a total of 140 questionnaires were distributed among the participants that 132 of them were usable. The present study is an applied research and in terms of research methodology, it is descriptive with a survey approach. After collecting data about equipment and classifying them in 6 categories of large production loss, a questionnaire was designed that its validity was approved by supervisors and a group of experts of the company. To measure each of the variables the LIKERT spectrum (1 = very low, 5 = very much) was used. To assess the reliability of research tools Cronbach's alpha was used that the value of calculated coefficient for each parts of the questionnaire is given in Table 1 and the value of Cronbach's alpha for the total questionnaire was equal to 0.901 that these results showed that the survey instrument is reliable.

Table 1. Cronbach's alpha coefficients

Name of the variable	OEE	Breakdowns	Small stoppages	Waste and rework	Reduce in speed	Set up and adjustment	Startup losses
Cronbach's alpha	0.778	0.779	0.738	0.781	0.834	0.709	0.758

Kolmogorov-Smirnov test was used to verify the normality of the data and its results are shown in Table 2. Since the level of significance of all the variables is greater than 0/05, their distribution is normal.

Table 2. The significance level of Kolmogorov - Smirnov test of indicators

Indicators	Sig	Results
Overall equipment effectiveness	0.252	Confirmed
Breakdowns	0.146	Confirmed
Small stoppages	0.142	Confirmed
Waste and rework	0.067	Confirmed
Speed Reduction	0.664	Confirmed
Set up and adjustment	0.190	Confirmed
Startup losses	0.083	Confirmed

Bartlett's test was used to assess the adequacy of the sample size that the value of KMO index is equal to 0.878. Since this value is greater than 0.7 so the sample size is adequate for factor analysis. Also the value of sig in Bartlett test was equal to 0.000 that this value is smaller than 0/05 and shows that factor analysis is appropriate for identification of the structure of factor model. Data were analyzed by inferential and descriptive statistics, in order to examine the relationship between variables and the extent of this relationship and by using confirmatory factor analysis by structural equation method with the help of AMOS18 and SPSS20 statistical software that in the following part we are going to discuss it.

4. Data analysis

At this stage of the study, after the identification of factors related to the variable of the overall equipment effectiveness in the production unit of Cable Factory of Moghan, overall equipment effectiveness impact was examined on the 6 main losses of production unit. Overall equipment effectiveness factors that were identified in the mentioned factory are as follows:

- Planning for preventive maintenance
- Using DMAIC Methodology
- Troubleshooting before failure
- Necessary trainings about the proper use of the device
- Analysis of the oil of device and regular servicing
- Timely access to spare parts
- Using specialized forces
- Establishment of the 5S system
- Daily inspections of device
- Paying attention to the defined standards for devices

4.1 Model fit

In general, to assess the confirmatory factor analysis model, there are several fitness characteristics. In this study, in order to evaluate the confirmatory factor analysis model, we have used indicators of x^2 (Chi square), normed fit index (NFI), comparative fit index (CFI), incremental fit index (IFI), relative fit index (RFI), parsimony-adjusted measures (PRATIO, PNFI, PCFI) and root mean square error of approximation (RMSEA). Views about the acceptable value for the index of X^2 / DF (chi-square divided by the degrees of freedom) is different. For some people, the value between 1 and 3, between 1 and 5 is considered to be acceptable and for some others the value smaller than 3 and less than 2 is acceptable. In this study, values less than 2 are considered to be optimal. (Ghasemi, 2010, p. 161) The ratio of chi square of overall model towards the degree of freedom is obtained 0.83 and it is appropriate. Comparative fit indices (NFI = 0.93, DFI = 0.87, CFI = 1.00 and IFI = 1.00) were calculated, which are higher than 90% and are suitable. RMSEA is root mean square error of approximation and if the value of this index is equal to zero, it indicates that the chi-square is smaller than degrees of freedom and its permissible limit is 0.05. (Ghasemi, 2010) The value of this index, in this study, was obtained as 0.000, which is lower than 0.05 and is appropriate.), Parsimony-adjusted measures (PRATIO =

0.53, PNFI = 0.50 and PCFI = 0.53) are higher than 0/5 and are appropriate. So in general, it can be said that the model has a good fitness and also these values reflect the proper design of research project. Hence, in this section, the estimated parameters of the obtained model can be considered reliable and they can be used to test hypotheses. In order to verify each of the considered parameters in the model of study, the load factor and the significance level was calculated for each of them. According to Table 3, the level of significance for all of them was less than 0.05, but the load factor of timely access to spare parts (Q6) was estimated to be less than 0.3 and it was weak so it should be removed from the model. Also the structural model of the research hypotheses is observable in Figure 1, where the variable of overall equipment effectiveness is indicated by the symbol of effectiveness.

Table 3. Critical ratio and significance level

Latent feature	**Symbol in the model**			**Standard error**	**The critical ratio (T-statistics)**	**Significance level**	**Standardized coefficients**
	Production waste	◄·–	OEE	0.079	-2.308	0.021	-0.306
Planning for preventive maintenance	q1	◄·–	OEE	-	-	-	0.308
Using DMAIC Methodology	q2	◄·–	OEE	0.526	4.237	***	0.681
Troubleshooting before failure	q3	◄·–	OEE	0.356	4.765	***	0.601
Necessary trainings about the proper use of the device	q4	◄·–	OEE	0.409	4.015	***	0.596
Analysis of the oil of device and regular servicing	q5	◄·–	OEE	0.399	3.834	***	0.505
Timely access to spare parts	q6	◄·–	OEE	0.290	2.287	0.022	0.225
Using specialized forces	q7	◄·–	OEE	0.398	3.752	***	0.500
Establishment of the 5S system	q8	◄·–	OEE	0.356	3.812	***	0.553
Daily inspections of device	q9	◄·–	OEE	0.370	3.828	***	0.429
Paying attention to the defined standards for devices	q11	◄·–	OEE	0.413	4.898	***	0.670
Breakdowns	ET11	◄·–	Production losses	-	-	-	0.301
Small stoppages	ET22	◄·–	Production losses	0.493	2.847	0.004	0.417
Waste and rework	ET33	◄·–	Production losses	1.014	3,352	***	0.834
Reduce in speed	ET44	◄·–	Production losses	0.452	2.736	0.006	0.369
Set up and adjustment	ET55	◄·–	Production losses	0.559	3.306	***	0.581

Latent feature	Symbol in the model			Standard error	The critical ratio (T-statistics)	Significance level	Standardized coefficients
Startup losses	ET66	◄- –	Production losses	0.743	3.424	***	0.632

Thus, considering the Table No 3 the ultimate model of the research is presented as follows:

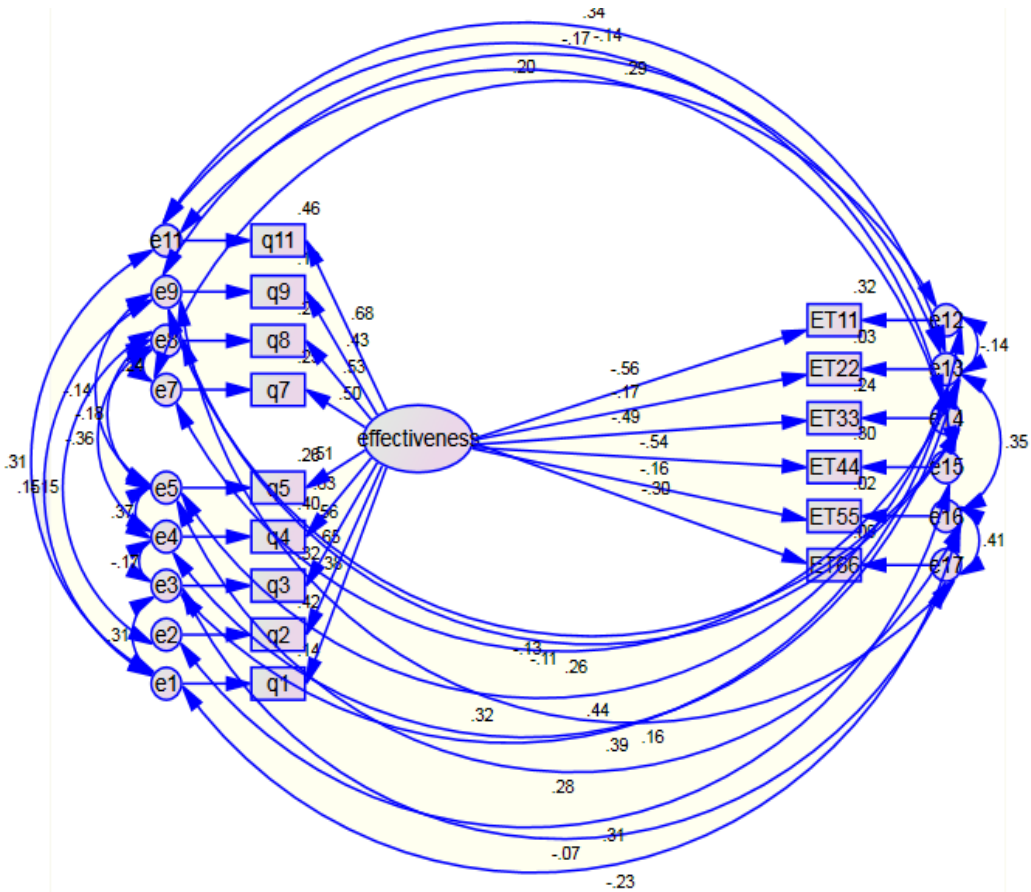

Figure 1. Research model

Finally, to evaluate the impact of the overall equipment effectiveness on each of the losses of production unit, T-statistics was used that the results are given in Table 4.

Table 4. Estimates of the research model

Independent variable→dependent variable			Standard error	The critical ratio (T-statistics)	Significance level	Standardized coefficients	Coefficients of determination
Production losses	←	Overall effectiveness	0.079	-2.228	0.022	-0.299	0.09
Breakdowns	←	Overall effectiveness	0.315	-3.705	***	-0.562	0.31
Small stoppages	←	Overall effectiveness	0.214	-1.634	0.102	-0.172	0.03
Waste and rework	←	Overall effectiveness	0.348	-3.502	***	-0.488	0.24
Reduce in speed	←	Overall effectiveness	0.309	-3.653	***	-0.543	0.29
Set up and adjustment	←	Overall effectiveness	0.170	-1.737	0.082	-0.157	0.02
Startup losses	←	Overall effectiveness	0.269	-2.722	0.006	-0.304	0.09

According to the output of the Amos software in Table 3, about the impact of overall equipment effectiveness on the reduction of production losses, significance level was 0/02 and less than 0/05 that accordingly verifies the significant impact of overall equipment effectiveness on production losses. And also the relationship of overall equipment effectiveness, separately, with each of the production losses was investigated that considering the above table, only the relationship of overall equipment effectiveness with small stoppage losses and set up and adjustment losses was rejected because the level of significance was higher than 0/05. In order to assess the importance of each of the production losses in the mentioned factory, Friedman test was used that the related results are shown in Table 5.

Table 5. Ranking of the research variables

Aspects of Production losses	Average	Rank
Breakdowns	3.06	1
Waste and rework	2.33	3
Reduce in speed	2.69	2
Startup losses	1.92	4

5. Conclusion

According to the model presented in this study, initially the factors that related to overall equipment effectiveness and production losses were identified on the basis of the research literature and documentation of Moghan Cable & Wire Manufacturing Company. Then the results of processing the related data, was presented in the form of a hypothesis as "overall equipment effectiveness has a significant influence on production losses." Then, in order to evaluate and approve or reject the hypothesis of the study and the level of influence of the identified factors T-test was used, that according to its results the impact of application of overall equipment effectiveness system on improvement of production and reduction of losses is evident. To use this tool and to reduce production losses at the mentioned factory the following items are recommended:

1) Using DMAIC, use of Six Sigma methodology, statistical analysis, and investigations in the site and

use of brainstorming methods. According to the DMAIC methodology, it has been demonstrated that stoppages, delay in receiving materials, inadequate maintenance programs, worn and damaged devices, conventional alarms during production and the sudden stops during the production are the main reason for reduction in the availability rate of equipment and consequently, the reduce in the overall equipment effectiveness. In order to increase the rate of availability of equipment, the following items are essential and necessary: periodical check of inventory and detection of the reordering time, training and familiarization of operators with conventional alarms of equipment and the ways to resolve them and also elimination of erosions and factors causing them on the machine, through preparing and developing daily inspection standards and replacement of worn parts.

2) Overview in the period of maintenance of device according to the results of the research.
3) The use of restrictions management during stoppages: Each stop includes components of detection, exploit, compliance, promotion and return.
4) Centralized improvement of equipment and process: centralized improvement of equipment and process is one of the one of the principles of total productive maintenance that directly focuses on improving losses of equipment.
5) Promotion of the rapid replacement system: Since the set up and adjustment time of machines reduce the available time of production, it is considered as an objective of improvement in the overall equipment effectiveness factor.
6) The use of computer systems in order to enter information, creating a database and to record detailed information about the machines and devices.
7) Training of production operators for familiarizing them with the control items (such as dimensional and external characteristics of the product) and involving them in the product quality control during production, if possible.

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