

OVERALL EQUIPMENT EFFECTIVENESS (OEE) THROUGH TOTAL PRODUCTIVE MAINTENANCE (TPM) PRACTICES: A CASE STUDY IN CHEMICAL INDUSTRY

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ABSTRACT

In present world scenario, when manufacturing companies encounter capacity problems, they immediately look for increasing overtime, number of shifts and purchase new machine and equipment's. Instead, focus must be on the better utilization of resources and increasing performance of the existing machines, so that there is better equipment performance, reduction in bottlenecks, decrease overall downtime, improve operator performance and minimization of setup time and other major forms of losses thus enabling in decision on the investment of buying new machines.

Thus, the aim of this journal is to study the state of Overall Equipment Effectiveness (OEE) through Total Productive Maintenance (TPM) in Chemical Industry. theoretical framework is developed to determine the predominant TPM pillars that influence the OEE. Based on this theoretical framework, a survey methodology is used where questionnaires are sent to 180 respondents in PT.XYZ with the resulting response rate of 100% which is comparable with other studies. The outcome of this survey is analyzed using SPSS and the analysis show that the predominant TPM pillars indeed has a considerable impact on the OEE.

Keywords: *Total Productive Maintenance, Overall Equipment Effectiveness, Planned Maintenance, Quality Maintenance, Education and Training, Safety, Health and Environment.*

1. Introduction

In today's competitive and mature economic environment, many manufacturing plants worldwide faces many challenges to achieve world-class manufacturing standards in operations. In this highly competitive globalize scenario, the maintenance function is being looked on by organizations as a potential source of cost savings and competitive advantage. The effective integration of maintenance function with engineering and other manufacturing functions in the organization can help to save huge amounts of time, money and other useful resources in dealing with reliability, availability, maintainability and performance issues (Moubray, 2003).

The inadequacies of the maintenance practices in the past, have adversely affected the organizational competitiveness thereby reducing the throughput and reliability of production facilities, leading to fast deteriorations in production facilities, lowering equipment availability due to excessive systematic downtime, lowering production quality, increasing inventory, thereby leading to unreliable delivery performance.

This has provided the impetus to the leading organizations worldwide to adopt effective and efficient maintenance strategies such as Total Productive Maintenance (TPM), over the traditional firefighting reactive maintenance approaches (Sharma et al, 2005).

TPM employs overall equipment effectiveness (OEE) as a quantitative metric for measuring the performance of a productive system. OEE is the core metric for measuring the success of TPM implementation program (Jeong, Phillips, 2001). This metric has become widely accepted as a quantitative tool essential for measurement of productivity in manufacturing operations (Samuel et al 2002).

Implementation and reintroduction TPM in a mature company such as PT. XYZ Indonesia is still considered a major challenge due to several nonconductive environments in the adoption and implementation process. Lack of commitment and leadership from top management has always been discussed as one of the main factors that inhibit the implementation of TPM. Therefore, this research attempts to measures how close PT. XYZ Indonesia to perfect production (manufacturing only good parts, as fast as possible, with no stop time), understanding the underlying losses and analysis which significant relationship between Total Productive Maintenance (TPM) pillars and Overall Effectiveness Equipment (OEE) to improve their industrial competitiveness, which not only reduces sudden sporadic failures in production line but also reduces both operation and maintenance costs, the hidden problems would be exposed and resultant countermeasures can be executed based on TPM framework and practices.

From the above problems perspective, there are some questions need to be answered in order to solve the problem. The research questions are brought forward as follows:

- a. Is there any significant relationship between planned Maintenance (PM) and OEE?
- b. Is there any significant relationship between Quality Maintenance (QM) and OEE?
- c. Is there any significant relationship between Training and Education (T&E) and OEE?
- d. Is there any significant relationship between Safety, Health & Environment (SHE) and OEE?

2. Literature Review

In our modern world of always being conscious of productivity and efficiency,

we have become very cognizant of the importance of measurement. This section introduces some of the basic concepts in measuring and improving both productivity and efficiency.

2.1. Total Productive Maintenance

In industry, total productive maintenance (TPM) is a system of maintaining and improving the integrity of production and quality systems through the machines, equipment, processes, and employees that add business value to an organization.

TPM focuses on keeping all equipment in top working condition to avoid breakdowns and delays in manufacturing processes.

TPM paves way for excellent planning, organizing, monitoring and controlling practices through its unique eight pillar methodology and the eight pillars of TPM (Sangameshwaran and Jagannathan, 2002) are:

2.1.1. Autonomous Maintenance

In autonomous maintenance, the operator is the key player. This involves daily maintenance activities carried out by the operators themselves that prevent the deterioration of the equipment. The steps for this autonomous maintenance are:

- a. Conduct initial inspection and cleaning, fix all sources of contamination, fix all areas of inaccessibility, develop and test all procedures for cleaning, inspection, and lubrication for possible standards.
- b. Based on the previous task, conduct and develop inspection procedures, Conduct inspections autonomously.
- c. Apply the standardization of the inspection procedures done previously, and apply visual management wherever possible in the proximity of the machine.

- d. Continue to conduct the autonomous maintenance for continual improvement.

2.1.2. Focused Improvement

It is aimed at eliminating waste. The basic wastes are:

- a. Unnecessary transport of materials: In moving products between factories, work operations, desks, and machines, all that is added is lead time—in other words, no value is created.
- b. Inventories beyond the absolute minimum: Caused by overproduction, inventories take up floor space—something that is always at a premium in factories and offices. There is always a tendency to use inventories to mask other problems. Remember, if you have got plenty of spares, there is no incentive to fix problems with quality!
- c. Motions of employees: When looking for parts, bending or reaching for materials, searching for tools, etc.
- d. Waiting for the next process step: While waiting, the product is just soaking up “overheads”—the last thing that the customer actually wants to pay for!
- e. Overproduction ahead of demand: This exposes the organization to risks in changing demands from customers, and is a disincentive to the firm to
- f. reduce the other wastes, because there is always plenty of extra material to use in case of problems.
- g. Over processing of parts: Running parts on machines that are too fast or too slow, or even too accurate to achieve the customer’s definition of value. What is the problem with doing too good of a job? Generally, it means it is really too expensive a job for the market’s expectations.
- h. Production of defective parts: If processes produce defects, then extra staffs are needed to inspect, and extra materials are needed to take account of potential losses. Worse than this,

Inspection does not work. Eventually, you will miss a problem, and then someone will send a defective product to a customer. And that customer will notice at which point the customer is dissatisfied. Manual inspection is only 79% effective. In some cases, however, it is the only control you have. Therefore, it is used, but with reservations.

2.1.3. Planned Maintenance

This element is aimed to minimize unplanned

- a. Planning efficient and effective PM (Preventive Maintenance), PdM (Predictive Maintenance) and TBM (Time Based Maintenance) systems over equipment life cycle
- b. Establishing PM check sheets
- c. Improving MTBF (Mean Time Before Failure), MTTR (Mean Time to Repair).

2.1.4. Quality Maintenance

This element is aimed towards the customer delight through defect free manufacturing. Focus in on eliminating non-conformance in a systematic manner, much like focused improvement. The organisation gains understanding of what parts of the equipment affect product quality and begin to eliminate current quality concern, and then move to potential quality concern. Transition is from reactive to proactive (quality control to quality assurance).

2.1.5. Education and Training

Involving and enhancing human resource for increasing productivity.

- a. Imparting technological, quality control, interpersonal skills
- b. Multi-skilling of employees
- c. Aligning employees to organizational goals
- d. Periodic skill evaluation and updating

2.1.6. Safety, Hygiene, and Environment

For achieving zero work-related accidents and for protecting the environment.

- a. Ensure safe working environment
- b. Provide appropriate work environment
- c. Eliminate incidents of injuries and accidents
- d. Provide standard operating procedures

2.1.7. Office Total Productive Maintenance

For involvement of all parties in TPM because office processes can be improved in a similar manner as well.

- a. Improve synergy between various business functions
- b. Remove procedural hassles
- c. Focus on addressing cost-related issues
- d. Apply 5S in office and working areas

2.1.8. Development Management

Continuously developing ideas and procedures.

- a. Minimal problems and running in time on new equipment
- b. Utilize learning from existing systems to new systems
- c. Maintenance improvement initiatives (Ahuja, et al., 2008)

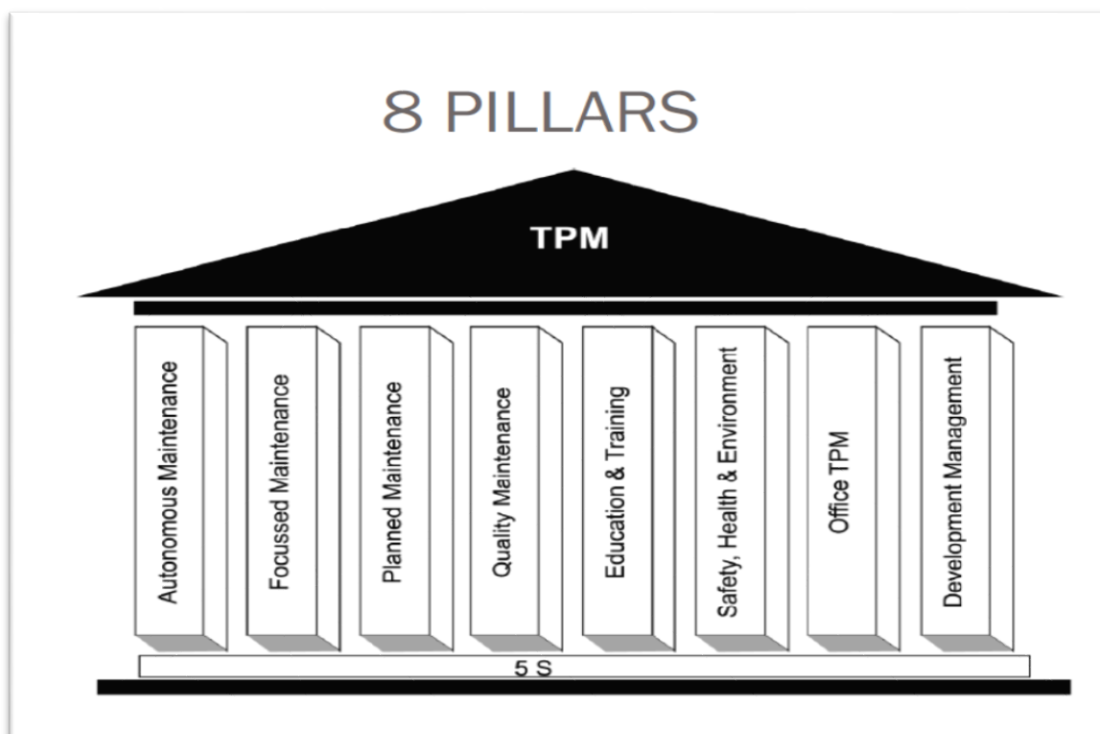


Figure 1. Eight pillars of TPM (Shingo, 2007)

2.2. Overall Equipment Effectiveness.

Overall equipment effectiveness (OEE) was initially used by Seiichi Nakajima in the 1980s. It aimed as a quantitative metric for measuring productivity of individual production equipment in a factory. This metric has significantly gained popularity in recent years as it turns to reveal and measure hidden or irrelevant costs related to a piece of equipment (Nakajima, 1988). Overall Equipment Effectiveness is part of total productive performance (TPM) concept launched by Seiichi Nakajima in the 1980s'. It is regarded as a measurement tool under TPM and at aimed identifying production losses related to equipment (Williamson, 2006), achieving a zero breakdown, zero defect of equipment, a high control on quality, productivity, cost, inventory, safety and health, and production output. This led to an improvement in production rate, reductions in costs, reductions in inventory, and an eventual increase in labor productivity.

Losses from the manufacturing disturbances apply the bottom-up approach where an incorporated workforce strives to accomplish overall equipment effectiveness by eliminating big losses:

2.2.1 Unplanned Downtime Losses as a Function of Availability.

There are made up of the first two big losses presented below and are used to help calculate the true value for the availability of a machine in an industry.

a. Equipment failure:

Breakdown losses are categorised as time and quantity losses caused by failure, breakdown or by defective products. In a brewery plant as analysed by Pintelon et al. (2000), a breakdown of palletizing plant motor led to downtime and thus, production loss.

b. Set-up and Adjustment:

These are losses that occur when production when production is changing over from requirement of one item to another. Still in the brewery plant, the type

of losses encountered during the set-ups, were set-ups between different products, testing during start-ups and fine tuning of machines and instruments.

2.2.2. Speed Losses as a Function of Performance

Speed losses are required for calculating the true value for performance of a machine. It cannot be calculated during downtime of machines.

a. Idling and minor stoppage:

These losses occur when production is interrupted by temporary malfunction or when a machine is idling. For example, dirty photocells on palletizing machines cause minor stoppages even though they are quickly fixed, due to their frequency, much capacity is lost.

b. Reduced speed:

These losses refer to the difference between equipment design speed and actual operating speed. The use of unadapt pallets in a palletizing plant has presented

by Muchiri and Pintelon (2008) led to longer processing times for the same number of bottles leading to speed losses.

2.2.3. Quality Losses as a Function of Quality

Quality losses affect the quality of the final product. This causes serious economical setbacks in a factory due to waste of resources or cost for recycling. They are based on;

a. Defect in process / rework:

These are losses caused by malfunctioning of production equipment. In the case of pallets, some got stuck in between depalletize and unpacker and are damaged.

b. Reduced yield:

They are yield losses during start-up that occur from machine start-up to stabilization. Poor preparation for morning shift by night shift in the brewery led to problems with the filling taps and thus led to reduced yields.

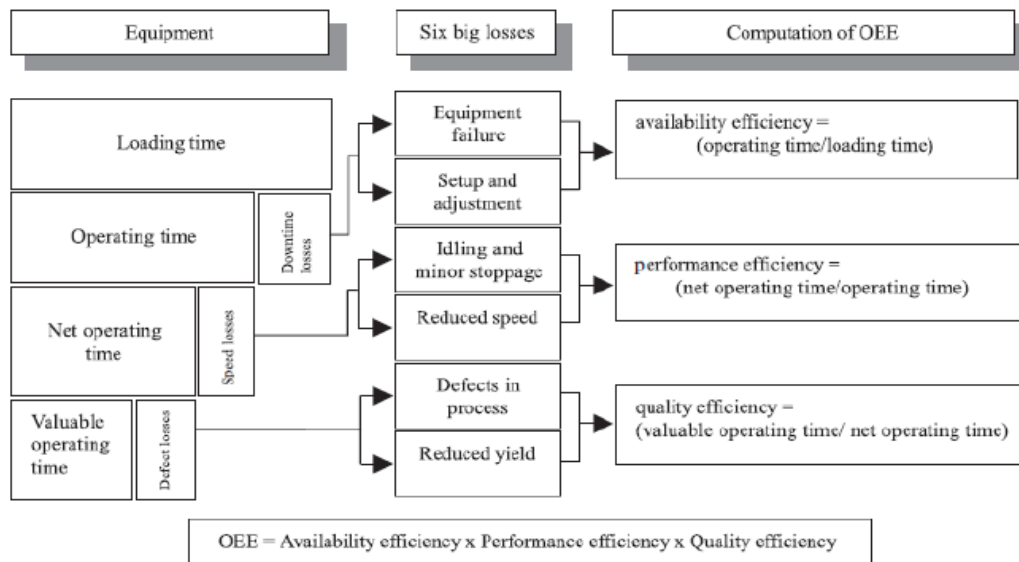


Figure 2. Overall Equipment Effectiveness and computation procedure

3. Research Framework

Based on review on the previous and literature discussed, researcher has constructed the conceptual research framework. Conceptual research framework presented in figure 3 describes the relationship between variables that will be observed in this research.

The framework is using Overall Equipment Effectiveness (OEE) as a dependent variable (DV) that is predominantly influenced by Total Productive Maintenance (TPM) four main pillars, i.e. Planned Maintenance (PM), Quality Maintenance (QM), Training & Education (T&E), and Safety, Health & Environment (SHE).

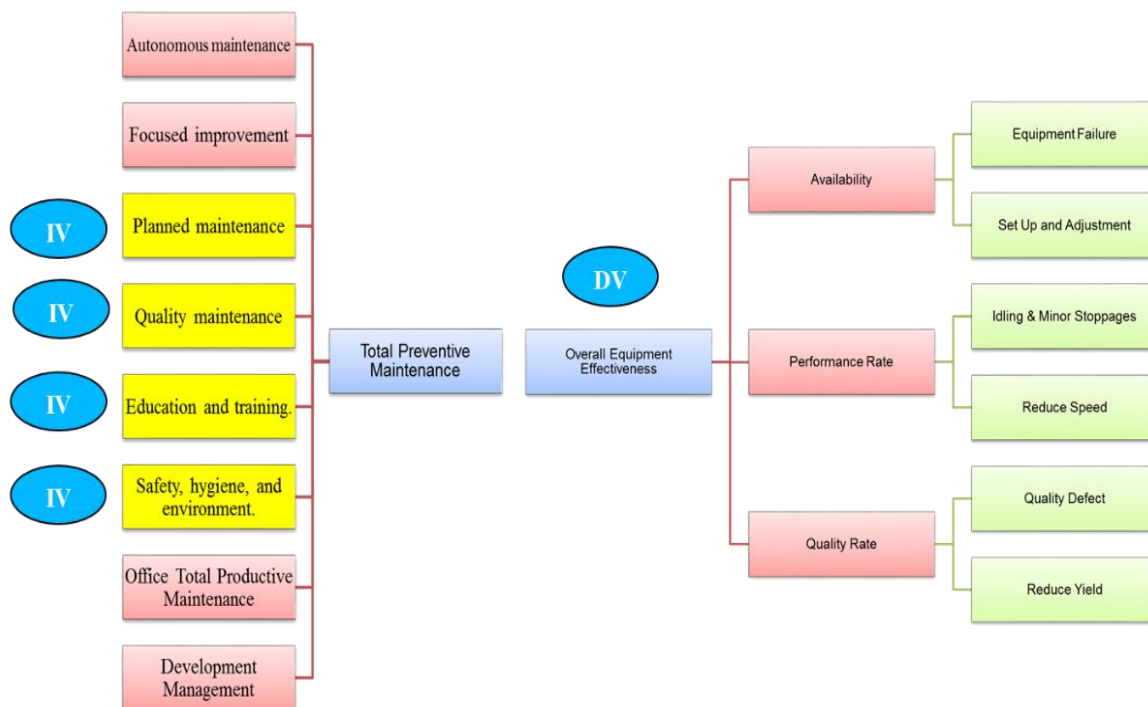


Figure 3. Research Conceptual Framework

The main propose of this research is focused on the TPM's four predominant pillars and their effects on the OEE and their inter relationship, here, four hypothesis are proposed as follow:

Hypothesis #1

There exists a significant relationship between Planned Maintenance (PM) and OEE

Hypothesis #2

There exists a significant relationship between Quality Maintenance (QM) and OEE.

Hypothesis #3

There exists a significant relationship between Training and Education (T&E) and OEE.

Hypothesis #4: There exists a significant relationship between Training and Education (T&E) and OEE.

Hypothesis#1, Hypothesis#2, Hypothesis#3 and Hypothesis#4 will be validated using Pearson Correlation Coefficient and used as correlation coefficient value (r). The questions are considered as valid if the correlation coefficient value $(r) \geq 0.361$ with significant level 5%. If the correlation between one question and another question has a total score less than 0.361, then the questions are considered as invalid.

Finally, a regression model will be developed in order to find out which independent and moderating variable has the most influence on the OEE.

4. Research Methodology

As mentioned before the aim of the study is to promote competitiveness of PT. XYZ Indonesia through the management method of OEE and identified predominantly influenced of Total Productive Maintenance (TPM) four main pillars such as Planned Maintenance, Quality Maintenance, Training & Education, and Safety, Health & Environment and then search for effective and scientific approaches to improve it.

A structured survey approach used as the research strategy in this case study, a four-point Likert type scale is designed for 29 items question in two section i.e. Planned Maintenance (PM), Quality Maintenance (QM), Training & Education (T&E), Safety, Health and Environment (SHE), PT.XYZ Indonesia west plant and were chosen for this study because they had the most relevant information with this research and present workplace of the author

Target population is combination of all elements which share some common set of characteristics and possess the information seeks by researcher. Based on Roescoe (1975) in Sekaran & Bougie (2013), sample sizes larger than 30 and less than 500 are appropriate for most research. The target population for this study is total employee PT.XYZ and sample is same amount with 180 number of respondents which are all employees in PT.XYZ.

Questionnaire survey will be distributed to 180 respondents which has three parts of questions. Total item number of question is 33 which consist of division, age, service period, gender and main questions which measure independent and dependent variables. As shown in below figure 4 about summary of items which included in the questionnaire method.

Out of 180 questionnaires sent, 180 were answered by the respondents, all respondents received were usable with complete information. The valid response rate is 100 percent. Which is meet with our expectation.

Table 1. Summary questionnaire

No	Section	Point	Detail	Scale	Type	No. of question
1	A	General information	Department	Range	General	1
			Age	Range	General	1
			Gender	Range	General	1
			Service period	Range	General	1
2	B	Various TPM Pillars / elements	Planned Maintenance	Likert	Main	5
			Education & Training	Likert	Main	5
			Safety, Health & Environment	Likert	Main	5
			Quality Maintenance	Likert	Main	5
3	C	Contribution of TPM towards OEE performance	Availability	Likert	Main	3
			Performance	Likert	Main	3
			Quality	Likert	Main	3

5. Analysis and Result

This study carried out at PT. XYZ plant in Jakarta, Indonesia. A structured survey used for identified predominantly influenced of Total Productive Maintenance (TPM) four main pillars and four point Likert type scale is designed for 29 items question in two sections i.e. TPM pillars and Overall Equipment Efficiency (OEE).

5.1. Data Reduction

In this research, there are four dimensions Planned Maintenance (PM), Quality Maintenance (QM), Training & Education (T&E), and Safety, Health & Environment (SHE). Each dimension is measured through a few questions. It is a must to know whether all the questions are valid on the given dimensions. Hence, factor analysis has been used for each dimension. There are 35 questions in the questionnaire, which were reduced to 29 questions using the factor analysis.

5.2. Validity and Reliability Test Analysis

To conduct validity and reliability test of the variable's questions in the questionnaire, the

researcher did the test that distributed the questionnaire to 180 respondents (PT.XYZ employees). After all the questionnaire was collected, validity and reliability test can be conducted using SPSS IBM version 22.

Reliability test was used to measure internal consistency reliability of variable in the questionnaires. Cronbach's Alpha was used to measure the reliability of the variable in the questionnaire. As a rule of thumb, Cronbach's Alpha value of 0.7 is commonly used benchmark. Cronbach alpha value that greater than 0.7 suggests a strong evidence of internal consistency exist in the survey instrument and according to Sekaran & Bougie, (2013), it stated that if the alpha is greater than 0.60, then the variable is considered as reliable, and if the alpha is lower than 0.60, then the variable is considered as not reliable.

Table below is summary for Cronbach's alpha values for all the 29 questions has worked out to be significantly greater than 0.7, this indicates high reliability of data collected.

Table 2. Summary Cronbach alpha

Variable	Cronbach's Alpha	No. of Items
Planned Maintenance (PM)	0.768	5
Quality Maintenance (QM)	0.818	5
Training and Education (T&E)	0.731	5
Safety, Helath and Enviroment (SHE)	0.788	5
Overall Equipment Effectiveness (OEE)	0.847	9
Total question		29

Composite reliability considered as good if the value is above 0.70. Based on the above table we can see that Composite reliability for Planned Maintenance (PM) 0.768, Quality Maintenance (QM) 0.818, Training and Education (T&E) 0.731, Safety, Health & Environment (SHE) 0.788 and Overall Equipment Effectiveness (OEE) 0.847, where the value of composite reliability in

the model are all larger than 0.70 from all of the constructs.

5.3. Correlation Between Variables

In order to establish relationships between OEE (dependent variables) and TPM's four pillars (independent variables),

Pearson correlation test techniques are used.

Table 2 depicts Pearson correlations between various independent variables (Planned Maintenance, Quality Maintenance, Training & Education and Safety, Health & Environment) and dependent variable (OEE). The Pearson correlations

have been worked out to ascertain the significant factors contributing to success of the OEE program in the organizations. Only those pairs with Pearson correlation greater or equal to 40 percent and statistically significant at 1 percent level of significance are considered as having a strong association.

Table 3. Correlation test.

		Total PM	Total ET	Total EHS	Total QM	Total OEE
Total PM	Pearson Correlation	1	.274**	.423**	.633**	.571**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	180	180	180	180	180
Total T&E	Pearson Correlation	.274**	1	.189*	.296**	.207**
	Sig. (2-tailed)	.000		.011	.000	.005
	N	180	180	180	180	180
Total SHE	Pearson Correlation	.423**	.189*	1	.536**	.369**
	Sig. (2-tailed)	.000	.011		.000	.000
	N	180	180	180	180	180
Total QM	Pearson Correlation	.633**	.296**	.536**	1	.778**
	Sig. (2-tailed)	.000	.000	.000		.000
	N	180	180	180	180	180
Total OEE	Pearson Correlation	.571**	.207**	.369**	.778**	1
	Sig. (2-tailed)	.000	.005	.000	.000	
	N	180	180	180	180	180

** . Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The next step is to investigate critical success factors for the OEE implementation. The significant correlations thus obtained as a result of Pearson's Correlation is validated through "Multiple Regression Analysis" as depicted in Table 4. The notations depicted in the table include: β = Regression coefficient (beta coefficient), R = Multiple correlation coefficient. The significant factors with (β) significance level, multiple correlation coefficient (R) and F values are indicated in the table.

The results imply that there is a significant contribution of TPM implementation dimension (Planned Maintenance (PM) and Quality Maintenance(QM)) with respective Overall Equipment Effectiveness reported beside that result we also have another result for Education & Training (T&E) and safety, Health & Environment (SHE) which showing the contribution is not quite significant impact with respective OEE. Independent variables all together explain 62.1 percent of the variance (R Square) in OEE implementations or awareness, which is highly significant, as indicated by the F-value of 71.784

5.4. Multiple Regression

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.788 ^a	.621	.613	.276584562768207

a. Predictors: (Constant), Total QM, Total ET, Total EHS, Total PM

b. Dependent Variable: Total OEE

Table 4. Anova multi-regression

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	21.965	4	5.491	71.784	.000 ^b
Residual	13.387	175	.076		
Total	35.353	179			

a. Dependent Variable: Total OEE

b. Predictors: (Constant), Total QM, Total T&E, Total SHE, Total PM

Table 5. Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients		Sig.
	B	Std. Error	Beta	t	
1 (Constant)	.902	.192		4.704	.000
Total PM	.116	.048	.148	2.435	.016
Total T&E	-.033	.044	-.036	-.740	.460
Total SHE	-.087	.058	-.084	-1.506	.134
Total QM	.607	.054	.739	11.251	.000

a. Dependent Variable: Total OEE

An examination of the t-values indicates that Planned Maintenance (PM) & Quality Maintenance (QM) contributes the implementation or awareness of the OEE.

From the coefficients, Table 4.15 the relationship between the dependent and independent variable can be written as follow:

$$Y = b_0 + b_1x_1 + b_2x_2 - b_3x_3 - b_4x_4 + \varepsilon$$

$$Y = 0.902 + 0.148x_1 + 0.739x_2 - 0.036x_3 - 0.084x_4 + \varepsilon$$

Where,

Y = Overall Equipment Effectiveness (OEE)

X₁ = Planned Maintenance (PM)

X₂ = Quality Maintenance (QM)

X₃ = Training and Education (T&E)

X₄ = Safety, Health and Environment (SHE)

ε = Error rate

5.5. Hypothesis Test

Hypothesis testing and relationships between variables can be seen from the results of path coefficient on the model. Following is the result of path coefficient from inner model.

t-analysis:

$$\begin{aligned}
 t\text{-table} &= N - K - 1 \\
 &= 180 - 4 - 1 \\
 &= 175 \\
 t\text{-table} &= (175, 0.05) = 1.962
 \end{aligned}$$

Table 6. Coefficient & hypothesis

Indicator variabel	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Hypothesis
	B	Std. Error	Beta			
(Constant)	.902	.192		4.704	.000	
Total PM	.116	.048	.148	2.435	.016	significant
Total T&E	-.033	.044	-.036	-.740	.460	no significant
Total SHE	-.087	.058	-.084	-1.506	.134	no significant
Total QM	.607	.054	.739	11.251	.000	significant

From the above multiple regressions equation, the biggest contributor for the OEE is Quality Maintenance (QM) where the coefficient is 0.739.

The scatter plot of residuals against the

predicted values (Figure 4), it can be observed that there is no clear relationship between the residuals and the predicted values, consistent with the assumptions of linearity.

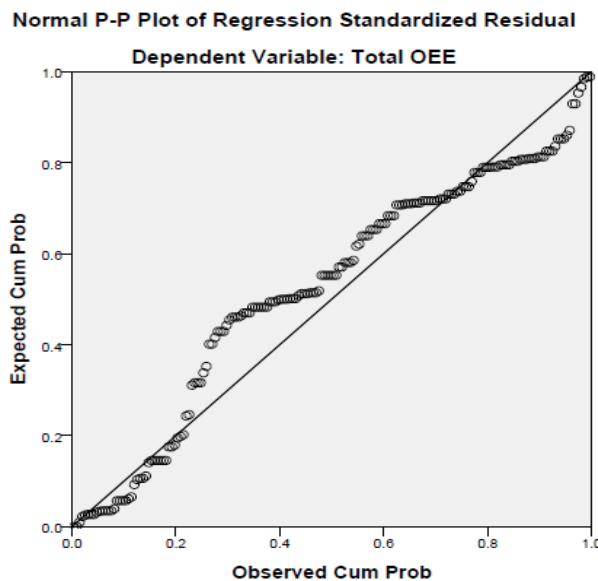


Figure 4. Normal P-P Plot Regression Standardized Residual

6. Discussion and Conclusion

From above paper, it is evident that the biggest contributing when combining all the four TPM pillars is Quality Maintenance (QM). And the questions of

the research as stated before have been answered, as follow:

- a. The Planned Maintenance (PM) have significant influence to Overall Equipment Effectiveness (OEE) at PT.XYZ. The result from data shows that

t-value from PM \rightarrow OEE = 2.435 (more than significant t-value target = 1.962) and it is emphasized by coefficient correlation result that shows 0.571 (within the coefficient correlation range between 0-1).

The fact above is linear with author's opinion that as a regional support plant PT.XYZ has broader portfolio product and change the planning quite often for fulfil market demand. That is why Planned Maintenance can cause significant result in OEE result.

b. The Quality Maintenance (QM) have significant influence to OEE at PT.XYZ. The result from data shows that t-value from QM \rightarrow OEE = 11.251 (more than significant t-value target = 1.962) and it is emphasized by coefficient correlation result that shows 0.739 (within the coefficient correlation range between 0-1).

Result above reflected the real situation at PT.XYZ where a lot of stock can't deliver due to quality issue and process failure. That is why Quality Maintenance can cause significant result in Overall Equipment Effectiveness result

c. The Training & education (T&E) have no significant influence to Overall Equipment Effectiveness (OEE) at PT.XYZ. The result from data shows that t-value from T&E \rightarrow OEE = - 0.740 (more than significant t-value target = 1.962) and it is emphasized by coefficient correlation result that shows 0.207 (within the coefficient correlation range between 0-1).

This is match with researcher's interpretation that's Multi-skilling of employee and periodic skill valuation at PT.XYZ contribute to increasing productivity. That is why in this research T&E can't cause significant result in Overall Equipment Effectiveness.

d. The Safety, Health and Environment (SHE) have no significant influence to Overall Equipment Effectiveness (OEE) at PT.XYZ. The result from data shows that t-value from SHE \rightarrow OEE = - 1.506

(more than significant t-value target = 1.962) and it is emphasized by coefficient correlation result that shows 0.369 (within the coefficient correlation range between 0-1).

This is in line with author believes that PT.XYZ has a strong SHE awareness and set a safety as priority number one in all aspect and that might be of that reason SHE can't cause significant result in Overall Equipment Effectiveness.

e. The result shows Planned Maintenance (PM) & Quality Maintenance (QM) positively influenced to Overall Equipment Effectiveness.

f. TPM implementation dimensions i.e. PM, QM, T&E and SHE are the essential components in OEE improvements. So, the companies should continue implementing the TPM practices.

g. Management should focus to design a continuous improvement system to achieve zero defects, achieve world class OEE and customer satisfaction in terms of quality.

h. Future works could focus on the relationship between all TPM pillars and other continuous improvement programs like lean manufacturing or 5S

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