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THE EVALUATION OF EIGHT PILLARS TOTAL PRODUCTIVE MAINTENANCE (TPM) IMPLEMENTATION AND THEIR IMPACT ON OVERALL EQUIPMENT EFFECTIVENESS (OEE) AND WASTE

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Abstract -- *In this global era where the level of competition is higher, in addition to the influence of the suitable marketing strategy is also required strategy from the side of production/productivity. PT. XYZ is a company engaged in the manufacturing of snacks especially biscuits. The problem that often occurs in this company is the number of biscuits that are not in accordance with the standard and the production does not reach the target set because the machine suddenly breaks down frequently. To overcome the problems PT. XYZ then choose to implement the Total Productive Maintenance (TPM) strategy. This study aims to evaluate the implementation of 8 TPM Pillars and measure the effects on manufacturing performance in the form of Overall Equipment Effectiveness (OEE) and Waste. This study uses questionnaire-based survey method. The number of samples distributed is 40 units. Which returned and filled 33 questionnaires and which is worth to be processed as many as 30 samples. Then tested the validity and reliability of data using SPSS program. Validity critical value R = 0.361 for n = 30 and error rate 5%. For reliability test, R value = 0.60 was selected. From the validity test, there are 7 items of questions that are not valid so it is not included in the next process. For the reliability test of the questionnaire is quite reliable with the value of Cronbach's alpha of 0.811. From the CFA analysis, only 6 of 8 TPM pillars are significant while for manufacturing performance only OEE variable is significant. Correlation between 8 Pillars of TPM and manufacturing performance is Strong enough with a value of R = 0.862, which also means 74.3% (R^2) variable manufacturing performance can be explained/influenced by variable 8 Pillar TPM and 26.7% the rest by other variables.*

Keywords: *Eight Pillars; Total Productive Maintenance; Manufacturing, Performance; OEE; Waste*

INTRODUCTION

In this global era where the level of competition is higher, the influence of the brand and appropriate marketing strategy especially word of mouth and viral marketing have a significant role to win the competition (Prabowo, 2015). In addition to the marketing side, the production/ productivity side also has a big role to ensure customer satisfaction both in terms of accuracy of quantity and delivery time, as well as product quality according to specifications. For that productivity improvement program should always be run as well as possible.

However, such productivity improvement programs are impossible to run if machinery and equipment are often disturbed, so a strategy or method that can solve them is needed. PT. XYZ, especially biscuit division is one of the biscuit manufacturers which has many customers both domestic and abroad. The most frequent problem with this company is the number of biscuits that do not conform to company standards such as the quality standard is not reached, the charred biscuits production, and the production does not reach the target set because the machine suddenly breaks down frequently. The comparison of production targets and actual is presented in Fig. 1.

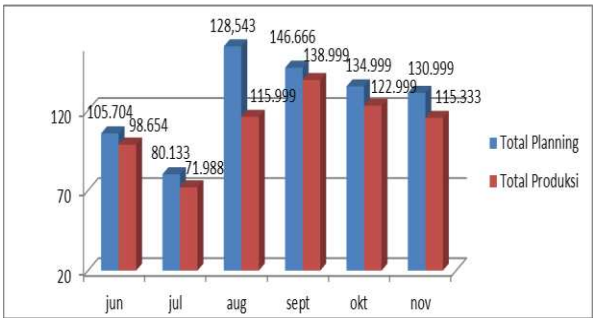


Figure 1. Comparison of Production Targets and Actual

To overcome the problems of production and breakdown PT. XYZ then chose to implement the concept/strategy of Total Productive Maintenance (TPM).

TPM is a maintenance concept that involves all workers who aim to achieve effectiveness throughout the production system through productive, proactive and planned participation and activities (Ahuja and Khamba, 2008, Minh, 2011; Prabowo and Yunianto, 2014;

Gupta and Vardhan, 2016). TPM also aims to improve the efficiency and effectiveness of manufacturing companies as a whole. In other words, the goal of the TPM is to achieve the ideal performance of zero loss, which means zero defect, without breakdown (zero breakdowns), without accident (zero accident), without wasted in the production process or change-over (Prabowo and Yunianto, 2014; Rinawati et al., 2014, Gupta and Vardhan, 2016; Kigsirisin et al., 2016). Evaluation of TPM implementation is done by using/calculating the value of Overall Equipment Effectiveness (OEE) as an indicator of success. OEE value depends on the size of Losses, where there are at least 6 losses or so-called Six Big Losses. By doing OEE calculations, the company will know where their position is where the weak points and how to make improvements (Rimawan and Raif, 2016).

In its Implementation, the company has never conducted TPM performance evaluation process. Therefore, this study aims to evaluate the implementation of 8 TPM Pillars and measure the effects on manufacturing performance in the form of Overall Equipment Effectiveness (OEE) and Waste (Dutta and Dutta, 2016). The hypothesis of the research that will be tested: there is a significant correlation between 8 pillars of TPM implementation against OEE and Waste.

MATERIALS AND METHOD

The materials used in this research are data of production quantity, production time data, time data of machine damage, data reject and rework. The data taken is 6 months, ie June to November 2017.

8 Pillars of TPM

Borris (2006), explained that the beginning of the existence of TPM starts from the path of Preventive (Productive) Maintenance (PM) originating from America. Then the concept went to Japan and developed into a new system typical of Japan, known as Total Productive Maintenance (TPM). According to Borris (2006), and Teeravaraprug et al. (2011) in applying the TPM concept there are eight important parts with separate responsibilities known as the Eight Pillars of TPM. These pillars are the foundation for achieving TPM objectives and functioning as a space for performance and implementation of TPM. The eight pillars are Autonomous Maintenance, Continuous/Focused improvement, Planned Maintenance, Quality Maintenance, Education and Training, Safety, Healthy and Environment, Office TPM, Development Management (Prabowo and Basori, 2013; Pandey and Raut, 2016; Supriyadi et al., 2016).

Overall Equipment Effectiveness (OEE)

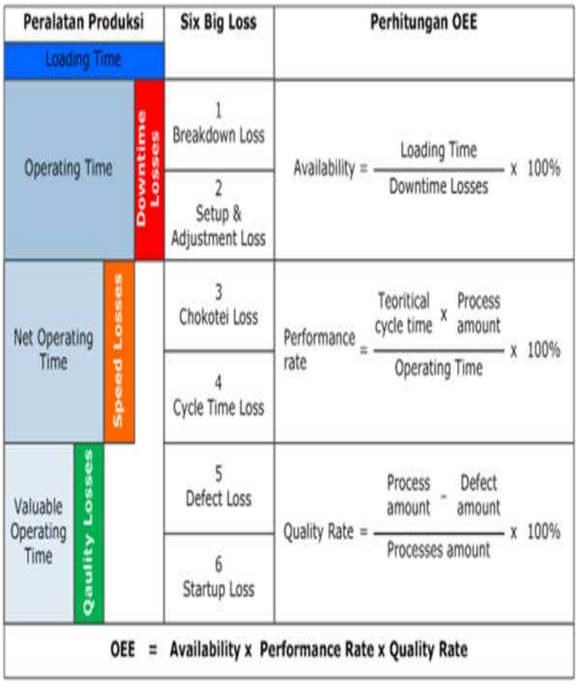
OEE is a method that measures the overall effectiveness of the machine/equipment that able to evaluate the state of the production process to the level of product quality. The company can make improvements on the part that is not appropriate because this method can calculate the value of availability rate, Performance and Quality Yield which is an important factor of OEE (Simanungkalit et al., 2016).

OEE highlights 6 major losses (cause of production equipment not operating normally), namely:

1. Start-up Loss, categorized as quality loss due to a scrap/reject during start-up production caused by the error set-up machine, less warm-up process, and so on.
2. Setup/Adjustment Loss, categorized as downtime loss due to "stolen" time due to long setup time caused by product change-over, material shortages, an absence of operator (operator shortages), machine adjustment, etc.
3. Cycle Time Loss, categorized as speed loss due to a decrease in process speed caused by several things, eg: the machine is worn out, under the capacity written on its nameplate, below the expected capacity, operator inefficiency, and so on.
4. Speed (Chokotei) Loss, categorized as speed loss due to minor stoppage ie the engine stops quite often with a short duration usually not more than five minutes and does not require maintenance personnel eg: machine reset, cleaning/checking, obstruction of the sensor, obstruction of delivery, and so on.
5. Breakdown Loss, categorized as downtime loss due to machine failures and equipment, unscheduled maintenance, and so on.
6. Defect Loss, categorized as quality loss due to reject and rework during production runs.

Of the six losses above can be concluded that there are three types of losses associated with the production process that must be anticipated, namely: downtime loss affecting Availability rate, speed loss affecting Performance rate, and quality loss affecting the Quality Rate.

According to Prabowo et al. (2015) and Simanungkalit et al. (2016), availability rate measures the effectiveness of maintenance of production equipment, performance rate measures how effective the production equipment is used, and the quality rate measure the effectiveness of the manufacturing process to eliminate scrap, rework, and yield loss. The three elements are the OEE-forming ratios as shown in Fig. 2.



(Prabowo et al., 2015; Kumar et al., 2017)

Figure 2. OEE Calculation Procedure

The Seven (7) Waste

According to Shah and Ward (2007) and Anvari et al., 2011 in Toyota Production System (TPS) there are seven types of waste in the production process:

1. Over-production waste, which is waste caused by excessive production, means to produce products that exceed the required or produce earlier than the schedule that has been made.
2. Waiting waste, which is waste because waiting for the next process. Waiting is the time interval when the operator does not use the time to perform value-adding activity due to waiting for the product stream from the previous process (upstream).
3. Transportation waste, transportation is an important activity but does not add value to a product. Transportation is the process of moving material or work in process (WIP) from one workstation to another workstation, either by forklift or conveyor.
4. Excess processing waste occurs when the work method or work sequence (process) used is considered less good and flexible. This can also happen when the existing process is not standard so the possibility of the damaged product will be high. There are variations of methods that operators work on.
5. Inventories waste, is an unnecessary inventory. The point is that there is too much material inventory, too much work in process between processes with each other so that it takes up a lot of space to store it.
6. Motion waste is the activity/movement of the less necessary by the operator that does not add value and slow the process so that lead time becomes long.
7. Defects are products that are defective or incompatible with specifications. This will lead to less effective rework processes, high complaints from consumers, and needs very high inspections level.

Research Method

This research begins with the identification of existing problems and then formulate it. Further determined specific objectives to be achieved. The design of the questionnaire was made in accordance with the objectives of the study and distributed to corresponding respondents as well as staff and leaders related to the implementation of TPM especially in the production and maintenance (machine maintenance).

The number of samples distributed is 40 units. Which returned and filled 33 questionnaires and which is worth to be processed as many as 30 units. This amount is equal to 57.69% of the population of 52 people. The number of samples is very adequate. Then tested the validity and reliability using SPSS program. Validity limit value R = 0.361 for n = 30 and error rate 5%. For reliability test, R value = 0.60 is selected. Only valid variable items are processed for the next process of Confirmatory Factor Analysis (CFA) and Structural Equation Modeling (SEM) analysis. The results of CFA and SEM were then compared with the standard values for conclusions.

RESULTS AND DISCUSSION

Validity and Reliability Test

Validity Test

According to (Ghozali, 2013) validity test is performed to measure whether or not a questionnaire is valid (accurately measures what it is supposed to measure). Validity test uses Bivariate Pearson correlation (Pearson Moment Product) by correlating each item score with a total score. In this research, SPSS software was used to perform validity and reliability testing. For the value of R ≥ 0.361 then the variable is considered valid (for n = 30 and alpha = 5%). The results of validity test performed listed in Table 1.

Table 1. Validity Test Result

Variabel Item	Nilar R *(kaiser-mayer)*	Keterangan
P11	504	Valid
P12	226	Not Valid
P13	377	Valid
P21	633	Valid
P22	682	Valid
P23	674	Valid
P31	241	Not Valid
P32	057	Not Valid
P33	480	Valid
P41	711	Valid
P42	430	Valid
P43	284	Not Valid
P51	303	Not Valid
P52	669	Valid
P53	475	Valid
P61	563	Valid
P62	444	Valid
P63	697	Valid
P71	653	Valid
P72	481	Valid
P73	632	Valid
P81	250	Not Valid
P82	467	Valid
P83	244	Not Valid

Based on data in Table 1, the obtained value (correlation) between the item scores with the total value score (product moment Pearson) is then compared with the R table value = 0.361 (Sugiyono, 2010). If the R value is greater than 0.361 then it is valid. The variable item is declared not valid if the correlation value (R) is below 0.361. From Table 2, there are 7 items that are not valid so they are not included in the next process.

Reliability Test

Reliability test is performed to ensure that research instruments used to obtain information can be trusted as a means of data collection and able to reveal the actual information in the field. The output of SPSS reliability analysis is none other than the item-total statistics, which yields alpha values in the Cronbach's alpha *if-item-deleted* column for each item with a simultaneous alpha value (composite). This alpha value is compared with the value of Cronbach alpha standard applicable to test Reliability that is 0.70. From Table 2 it is seen that this questionnaire is Reliable because Cronbach Alpha value (0.811) is above 0.70. So it can be continued to the next process/stage.

Table 2. Reliability Output from SPSS

Reliability Statistics

Cronbach's Alpha	N of Items
.811	24

(Source: output SPSS)

***Confirmatory Factor Analysis* (CFA) Results**

The first stage of data processing using the SmartPLS program is the confirmatory factor analysis. This analysis used to determine whether the TPM indicators really can represent the TPM construct variable. In other words, these indicators are significant in forming the TPM.

Table 3. Outer Model (Measurement Model)

	Performance	TPM Pilar
OEE	0.976	
PILAR_1		0.524
PILAR_2		0.717
PILAR_3		-0.106
PILAR_4		0.512
PILAR_5		0.507
PILAR_6		0.838
PILAR_7		0.794
PILAR_8		0.475
WASTE	-0.248	

(Source: Output Smart-PLS)

From the Table 3, the test shows that of 8 pillars of TPM, pillar 3 and pillar 8 were not significant because the loading factor was below 0.5. The indicator is said to be convergent valid if the loading factor value is higher than 0.5 (Ghozaly, 2015). This means that the Pillar 3 ie. Planned Maintenance and Pillar 8 ie. Development Management has not run very well and could not represent TPM implementation in this company. While the other 6 pillars can represent the application of TPM very well namely: 1st Pillar: Autonomous Maintenance, 2nd Pillar: Continuous / Focused improvement, 4th Pillar: Quality Maintenance, 5th Pillar: Education and Training, 6th Pillar: Safety-Health and Environment, and 7th Pillar: Office TPM. Although only 6 pillars are significant this condition is quite good compared to other companies in others countries. For example, in India, only 35.7% of manufacturing companies are capable of running 8 TPM Pillars well / success.

While in Malaysia the research conducted by Meng and Yusof (2012) said that only 5 pillars of TPM are significant and have an effect to performance namely: Top management leadership, Planned maintenance management, Focused improvement, Autonomous maintenance, dan Training approach.

For manufacturing performance construct variables only OEE indicator which significant represent it because of the loading factor = 0.976 far above the limit of 0.5 while the waste indicator is not significant (loading factor = -0.248) <0.5. This is because waste (seven waste) is more appropriate to measure the performance of Lean Manufacturing initiative (Anvari et al., 2011; Bakri et al., 2012; and Nitin et al., 2016).

Structural Equation Modelling (SEM)

The next step is to see the relationship between TPM construct variable with Performance construct variable in a structural equation model (inner model). For more details, the SEM model of the relationship between TPM construct variable with construct performance variable can be seen in Fig. 3. Before discussing the structural model, the figure shows the value of Cronbach's Alpha and Composite Reliability of TPM construct variables of 0.729 and 0.780 respectively, these values according to Ghozali (2015) shows a good reliability of TPM construct because the value is above 0.70. But for the Performance (*Kinerja*) construct variable were not reliable because all values were below 0.70 (0.061 and 0.349 respectively).

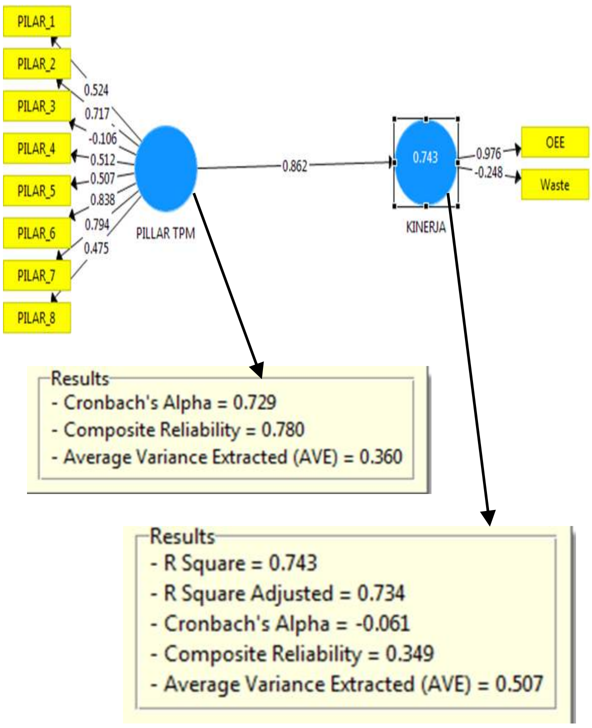


Figure 3. SEM for 8 Pilar TPM against OEE and Waste

From Fig. 3, it can be seen that the value of R coefficient as a measure of the influence of TPM Pillar construct (6 Pillars only) on the Performance construct (OEE only) value is 0.862. This value means there is a Positive and very Strong relationship (correlation) between TPM pillars and Performance. The tested hypothesis is answered. From these results can be concluded also that the better implementation of TPM pillars the higher the Performance results (OEE).

While the value of R2 = 0.734 explains that the Performance construct variable that can be explained/influenced by 8 TPM pillars construct variables is 73.4% while the remaining 26.4% is explained/influenced by other factors

CONCLUSION

Based of experiment been discussed, it can be concluded that from the Smart-PLS model there are only 6 pillars that significantly from the TPM Pillar namely, Autonomous maintenance, Continous/dedicated improvement, Quality maintenance, Education and training, Safety-Health and Environment and Office TPM. While the 2 pillars not significant are Planned Maintenance and Initial/Development Management pillars.

In addition, correlation/relationship value between TPM pillars to Performance is 0.862, meaning that there is a very strong and positive correlation between TPM Pillar with Performance variable (OEE). The tested hypothesis is answered. While the value of R^2 = 0.734 means that 73.4% Performance characteristic can be explained and influenced by TPM Pillars (6 pillars).

Furthermore, the waste indicator is not significant to measure TPM performance because it is more suitable/appropriate to measure the implementation of Lean manufacturing strategy**.**

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