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THE ANALYSIS OF WATER METER APPLICATION WITH APPROACH OF OVERALL EQUIPMENT EFFECTIVENESS IN MUNICIPAL WATERWORKS BALI

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Abstract— Companies in this globalization era face many problems. One of them is productivity, performance, and customer service. The companies must try to keep the quality. The Total Productive Maintenance (TPM) strategy is a system used to improve equipment quality based on a maintenance approach, which can be an effective solution. However, problems were occurring in the Municipal Waterworks business system due to Overall Equipment Effectiveness (OEE) which was not optimal. The solution must be to have an application system that can be used to measure and monitor the performance of water meter readers. This study used data focused on OEE, which began with TPM, which aimed to discover the problems in the maintenance of the municipal waterworks company. SPSS is software used to analyze data collection. SPSS data showed that the highest score is 87.61 and 84.21 based on descriptive statistics for the maximum and average scores. This data indicates that OEE is an application vital to the company's quality. Pearson correlation showed that the availability aspect gave more significant results than the performance and quality aspects. OEE provides benefits in developing equipment performance by analyzing equipment performance and effectively and efficiently checking six big losses. Therefore, the implementation of strategy production with TPM is a combination that provides benefits in a more flexible water meter system and customers who are satisfied with the service from company.

Keywords—Total Productive Maintenance (TPM); Overall Equipment Effectiveness (OEE); Municipal Waterworks; water meter application; aspects of availability performance

I. INTRODUCTION

Companies in this globalization era experience various problems. The problems are productivity, performance, and customer service. Companies are trying to overcome these problems to maintain quality. Total Preventive Maintenance (TPM) is the solution to this problembecause TPM is a system that can increase production costs and profits to provide maximum results [1]. So that a company will remain superior because there is a quality of thecompany. TPM focuses on developing equipment maintenance so that it can be used optimally. The maintenance of equipment benefits both the company and thecustomer because TPM can provide a reciprocal relationship between the company and the customer. This is because the company's quality development affects customer satisfaction,this can be used as positive feedback to the company itself [2].

TPM is a system that focuses on managing, maintaining, and developing essential aspects of a company.The most vital aspect of TPM is upgrading systems specific to equipment, companies and processes by utilizing the resources so that productivity can provide maximum results

[3]. This can be measured using the Overall Equipment Effectiveness (OEE) indicator, a technology-based overall measurement system [4]. OEE has a connection with TPM because OEE focuses on measuring productivity systemsusing core quantitative metrics. OEE can also cover various machine systems in manufacturing companies by analyzing, checking, and measuring their effectiveness. In addition, OEE is also used as a tool to measure equipment losses based on performance, availability, and quality.

Even though OEE provides various benefits for companies, some problems occurred in implementing OEE inthe company's business systems, especially in the performance of water meters. The solution to this problem isto use an application system capable of measuring and checking water meters in a company. One of the companies in Bali is Perumda Tirta Hita Buleleng which focuses on providing clean drinking water. There are various aspects of checking the effectiveness of a water meter reader system, such as performance, availability, and quality. Water meter readers have an essential role in firm because they can read the volume of water debit at each meter stand at the customer's house, a reference in the water bill. Therefore, thedevelopment of OEE plays an essential role in the company system in reading water meters to provide quality in the company's business performance.

This study focused on productivity data by implementing OEE as an indicator for measuring each aspectof productivity. OEE is a discrete meter measuring tool capable of showing six big losses to

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productivity. The six biglosses are problems in productivity; there are three categories, each of which significantly influences productivity [2]. Whatcan be done to overcome this problem is to check and sort outurgent problems that occur in the production process. So that these problems, which are categorized as the most critical, must be addressed as soon as possible so as not to have a fatalimpact. It focuses on sorting problems from the most urgent to problems that are not too urgent or problems that can be solved quickly and without having a significant impact.

This research combined business analytics and basic OEE measurement, which became data mining aimed toovercome business problems, especially in dashboard information systems, so that business results could provide more significant effects [5]. Implementing TPM offers various benefits for various aspects of life, especially in business aspects, because TPM can provide the effectivenessof the use of equipment that can provide maximum profit for manufacturing companies.LITERATURE REVIEW

A. Overall Equipment Effectiveness (OEE)

Overall Equipment Effectiveness (OEE) is a measure of work productivity that focuses on the production process in the form of a percentage which is the reference for measurement [6]. The OEE percentage can be used as a reporton the company's productive manufacturing processes and shows maximum performance with regulated standards [7]. This is supported by Haddad et al. [8], who state that OEE isan analytical method that focuses on equipment performanceand six big losses in a company. OEE has several essential aspects in this measurement, namely quality, performance level, and equipment availability. These aspects can be used to minimize problems that occur in the company.

In addition, Facchinetti and Citterio [9] add that OEE is a general approach that focuses on measuring the effectiveness of using equipment regulated by a framework that refers to the use of Total Productive Maintenance (TPM).TPM and OEE are related to each other in measuring equipment usage within an enterprise using core quantitative metrics. OEE is a measurement system that focuses on a combination of metrics in each manufacturing guide to provide maximum equipment performance with minimum equipment maintenance costs [10].

OEE aims to improve equipment performance by determining opportunities that can have a significant impact.According to Duarte and Scarpin [11], metrics compare the ratio of actual output and theoretical output used to measure and develop the quality of machines, products, and performance. Figure 1 shows that there are six big losses in TPM which can be categorized into breakdown losses, setup and adjustment losses, defect and rework losses, start-up losses, speed losses, and idling and minor stoppage losses. The six big losses can be measured based on the implementation of OEE, which consists of three aspects, namely processes, equipment availability, and products [12].

$$\text{OEE} = \text{Availability x Performance efficiency x Quality Rate} \quad (1)$$

Where:

$$\text{Availability} = \frac{\textit{Loading time} - \textit{Down time}}{\textit{Loading time}} \times 100 \quad (2)$$

Loading time is used in the production process per day or month. *Downtime* is the total time used in the production process that is not operating due to equipment constraints or system settings.

$$\text{Performance efficiency} = \frac{\textit{processed amount} \times \textit{cycle time}}{\textit{operating time}} \times 100 \quad (3)$$

The processed amount is the number of processed products per day or month. Operating time is the difference between loading time and downtime.

$$\text{Quality Rate} = \frac{\textit{processed amount} - \textit{defect amount}}{\textit{processed amount}} \times 100 \quad (4)$$

In addition, the Defect amount or what can be calledscrap, is the number of failed products that are not followingthe production design, so they must be repaired again. International World Class OEE has an essential role in measuring maintenance performance in manufacturing companies so that there is the development of maintenance regulations that can have a significant impact on the manufacturing system. Table 1 shows that OEE focuses on availability, performance rate, and quality rate as 85%, higherthan 90%, higher than 95%, and higher than 99%. If OEE is calculated the same as World Class OEE, this can be concluded that manufacturing companies can be categorizedas good. However, if OEE is lacking, manufacturing companies must improve maintenance policies and strategiesthat can be categorized as urgent. If these improvements are not appropriately conducted, the manufacturing company will get problems in improving the quality of the company.

B. Six big losses

There are six big losses in an enterprise breakdown losses, setup and adjustment losses, defect and rework losses, start-up losses, speed losses, and idling and minor stoppage losses. **Equipment Failure** is damage originating from machinery or equipment used in the product process within the company. This is caused by problems with production procedures, such as sudden stoppage of the production process and equipment maintenance that could be more optimal and urgent [2]. Setup and **Adjustment Losses** focus on time that is not following company procedures due to limited equipment. The adjustment of equipment owned causes this. TPM – Single Minute Exchange of Dies (SMED) aims to minimize excessive use of setup time. As stated by Wijesinghe and Illankoon [13], SMED provides an essential role for manufacturing companies because these companies can achieve their goals, namely reducing excessive production sizes, reducing setup time,

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reducing proposal budgets, reducing waste, and resources are utilized well so that products can provide high quality to customers. **Idling and Minor Stoppages** is equipment discontinued quickly [14]. This is caused by a machine that is not well maintained.**Reduced Speed**, or what can be called a slow cycle, is the difference between the design speed of the heavy equipment and the actual operating speed [15]. The factor that most influences this problem is unfavorable environmental conditions due to the lack of proper equipment maintenance.In addition, **Defects and Rework** is a problem originating from machine and equipment failures that make products inconsistent with company standards. According to Sathler etal. [16], there are several examples of defects and rework, such as problems in excessive volume and time due to defective products that must be repaired again, income problems due to low product quality, and time is wasted because the repair process takes a long time. The last is **Reduced Yield**, a problem in which production results have decreased [17]. This is because there are problems in operating equipment that is less stable and errors in installingtools in the production process.

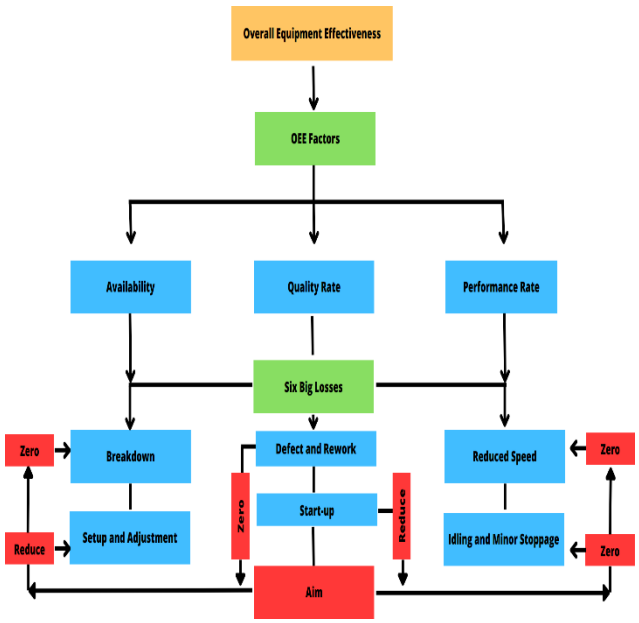

Fig. 1. Example of OEE Model

II. METHOD

A. Company case study

This research was conducted in the municipal waterworksof Buleleng, located in Buleleng Regency, Bali Province. Based on Government Regulation number 54 of 2017 concerning Regional Owned Enterprises (BUMD), PDAM Buleleng Regency, or Local water company of BulelengRegency, has now become a Regional Public Company (Perumda) whose name has changed to Perumda Tirta Hita Buleleng. Perumda Tirta Hita Buleleng is a city water company under regional management or BUMD. The local government built this water company, including procurement, management, and development of clean water.There are around 63.000 customers in the Buleleng area, which consists of 9 districts that consume public service water.

Fig. 2. Graph of OEE Trend

B. Data Collection and Analysis

The researchers analyzed data from a compression machine operating history for 2 years and 8 months. From this data, the researchers obtained the essential score of OEE; after that, the researchers implemented TPM as the next stage.The compression machine was chosen based on the criteria formulated by the researchers, namely problems in productivity which were still in the less-than-optimalcategory. In this research, OEE becomes a reference in analyzing the effectiveness of compression machine tools. After that, the researcher would conduct a basic study of the 6 months' data.

TPM aims to provide information, knowledge, and experience focused on implementation and significant impact on company staff. This research is in the form of a manufacturing strategy that can be a new introduction for thestaff. The next stage was the researchers checked the level of improvement with readings.

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Previously, researchers implemented a 5-why approach as an initial observation regarding the causes of engine failure. Then, the operators performed routine maintenance tasks before the production process every day. These maintenance activities had a significant influence in minimizing the causes of damage. Asshown in Table 2, OEE shows maximum results. Productiondata is measured based on aspects in OEE, namely availability, performance, and quality.

Fig. 3. Dashboard Information System for Checking Water Consumer

III. RESULT ANALYSIS

The researchers analyzed the data collected to get an interpretation of the results from the OEE indicator using equations. Based on Table 1 shows the results of the OEE values after TPM implementation at points (1), (2), (3), and (4). These results provide evidence of an increase in the OEE factor in companies. However, companies must also continue to develop effectiveness in the spaces that are still available to maintain this quality.

Based on Table 2, which refers to descriptive statistics, aims to evaluate the system parameter statistics. These results refer to the data's average, maximum, minimumand standard deviation scores, the quality of which has the highest score. Based on Table 3, which focuses on Pearson's correlation, shows significant results for each parameter. These results also show that performance and quality significantly influence measuring OEE. This differs from the Availability results, which do not show an insignificant effect.

Table II. Descriptive Statistic Analysis

	N	Minimum	Maximum	Mean	Std. Deviation
Availability	18	90,10	94,20	92,69	1,15
Performance	18	89,40	94,80	93,61	1,25

Table I. The OEE Factors After Implementing OEE

Months	Availability (%)	Performance (%)	Quality (%)	OEE (%)
Jan. 2022	90,1	89,4	95,4	76,85
Feb. 2022	91,5	92,3	96,1	81,17
Mar. 2022	91,7	92,6	96,3	81,78
April 2022	91,8	93,1	96,6	82,56
May 2022	90,9	93,2	96,2	81,49
June 2022	92,2	93,6	96,5	83,28
July 2022	92,4	93,8	97,1	84,16
Aug. 2022	92,5	94,1	97,2	84,61
Sep. 2022	92,7	94,2	97,4	85,06
Oct. 202	93,1	93,9	97,8	85,49
Nov. 2022	93,2	94,1	97,7	85,68
Dec. 2022	93,4	94,3	97,9	86,22
Jan. 2023	93,4	94,2	97,5	85,78
Feb. 2023	93,6	93,8	97,1	85,25
Mar. 2023	93,8	94,5	97,2	86,16
April 2023	93,9	94,4	97,1	86,07
May 2023	94,1	94,7	97,3	86,71
June 2023	94,2	94,8	98,1	87,61

Quality	18	95,40	98,10	97,03	0,71
OEE	18	76,85	87,61	84,21	2,63

Table III. Pearsons Correlations

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		Availability	Performance	Quality	OEE
Availability	Pearson Correlation	1	.863**	.861**	.961**
	Sig. (2-tailed)		.000	.000	.000
	N	18	18	18	18
Performance	Pearson Correlation	.863**	1	.849**	.957**
	Sig. (2-tailed)	.000		.000	.000
	N	18	18	18	18
Quality	Pearson Correlation	.861**	.849**	1	.932**
	Sig. (2-tailed)	.000	.000		.000
	N	18	18	18	18
OEE	Pearson Correlation	.961**	.957**	.932**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	18	18	18	18

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

Additionally, Table 1, which focuses on the availability score, also shows a trend that can be categorizedas positive due to an increase in the equipment used as a watermeter reading system. This is due to a decrease in downtime which has a significant effect. This is evidenced by the total number of days used for customer stand meter readings which increase more on holidays than weekdays, as Jain et al. [18] stated that the availability results from 2022 to June 2023 arehigher than world-class standards, namely 90%. This result isevidenced by an average rate of 92.69% in the last 18 months.This shows that the staff of the drinking water company has used the meter reading system effectively and efficiently. In addition, Table 3, which focuses on Pearson correlation results, shows significant results on aspects of performance, quality, and OEE, as evidenced by a very high correlation score based on the total sample population from the last 18 months.

Table 1 shows the performance score that gets the results of a development trend which can be categorized as positive because there has been an increase in the system toolof water meter reading. This happens because the water meterreading system can show maximum performance, especially for vendors who update their application systems regularly. For example, 2022 officers could process 50 customers basedon a water meter stand. Whereas in the first 6 months of 2023,it increased to 60 customers. This proves that the performanceof water meter readers has shown more significant results than in the previous period.

Quality score can be seen in Table 1, which refers tothe quality of the development trend. This can be categorizedas positive based on the water meter reading system increase.The results of the meter stand photos are of high quality usingthe system application of water meter reading. For example, a water meter reading officer got 100 data per day from a customer's house; after processing it using the system on the dashboard, there were 95 data per day in 2022. The data results refer to water usage bills by customers. In addition, there was a more significant increase in the quality of water meter readers compared to the previous period.

Finally, the OEE score shows significant results due to an increase in the 2022 period. The September 2022 period showed an OEE score of 85.06%, higher than August 2022. These results are related to a study by Jain et al. (2013) which shows that the OEE value is greater than the limit score of 85%. Table 2 shows that the average OEE was 84.21% for 18 months. This becomes a reference for the company to maintain the quality of the company's management in order to be able to exceed the standard of 85%. This is proof that the quality of the water meter system has an essential role in OEE which must be developed continuously so that six big losses can be optimally minimized and other problems, especially in customer service for drinking water services.

IV. CONCLUSION

From the research results, researchers can concludethat Total Productive Maintenance (TPM) significantly influences the company. TPM is a tool used to measure equipment performance in a company. The problems faced by the company can be overcome by implementing TPM. This is because TPM aims to improve competitive business performance, which does not only focus on city water companies but also other industries.

The research results are additional information to theresearch results by Basak et al. [19] and Bengtsson et al. [20]that OEE is an effective method that can be used to analyze equipment performance and predict six big losses. Municipal water companies implementing water meters aim to minimizethe six big losses: breakdown losses, setup and adjustment losses, defect and rework losses, start-up losses, speed losses, and idling and minor stoppage losses.

This research has limitations that become obstacles during the initial observation of this study. This obstacle was the difference in the specifications of the RAM of the cellphone, processor, and cellphone battery that are used by staff in the process of reading the water meter stand. However, the company made maximum efforts to minimize these problems by installing new hardware.

The introduction of TPM to companies has made progress. Although there were problems of excessiveovertime, defects, and hardware failures that the company hasnot been able to address but the company must be able to getsolutions to solve these problems. Therefore, researchers expect that further

research must combine production strategies with TPM so that water meter staff can provide thebest service to customers.

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