Implementation of Maintenance Management at Manufacturing Industry: A Survey of Maintenance Characteristics

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Abstract

A survey of maintenance characteristics was needed to analyze the maintenance management implementation and was deployed to 4 organizations in the manufacturing sector. The survey used a 5-point Likert scale which consisted of 29 questions. The result from the survey obtained key maintenance characteristics for each criterion, namely breakdown time, the availability of daily, weekly and monthly schedules, the critical level of equipment, the availability of budget for essential machines or equipment, the administration record of budget utilization, and determination of maintenance management KPI (Key Performance Indicator) which is based on company's KPI. Another result of the survey is that TPM (Total Productive Maintenance) takes OEE (Overall Equipment Effectiveness), breakdown time, MTBF (Mean Time Between Failures), and MTTR (Mean Time to Repair) as its performance measurement while PM (Preventive Maintenance) only measures OEE and breakdown time. This research arguably has theoretical and practical contributions. Theoretically, this research was one of the few attempts to determine maintenance management characteristics by comparing Preventive Maintenance (PM) and Total Productive Maintenance (TPM). Practically, this study could guide the organizations to implement maintenance activity by considering the maintenance characteristics explained in this research.

Keywords
Maintenance Management, Preventive Maintenance, Survey, Total Productive Maintenance, and Manufacturing.

1. Introduction

Manufacturing is one of the leading industries and economic contributors in the world. Manufacturing played a crucial role in economic growth for a country. The manufacturing sector has been considered the main engine of economic growth and development since the industrial revolution (Szirmai 2011). Kaldor concluded that manufacturing is an engine for most developing countries' growth (Neemi 1999). McCausland and Theodossiou (2012) support Kaldor's theory that manufacturing is also an engine for developed countries' growth between 1992-2007.

Manufacturing makes products from raw materials with various processes, operations, equipment, and workforce according to a detailed plan (Scallan 2000). Another definition of manufacturing is converting stuff into things (DeGarmo et al. 1988). Examples of manufacturing processes are the production process of an automotive part, chemical products, textile, etc. The manufacturing process depends on utilizing the workforce, equipment, tools, and machines to produce the desired position. The manufacturing process relies on the availability and performance of this equipment and tools. Unfortunately, production equipment and tools are always liable to use and require maintenance (Poor et al. 2019).

Maintenance is required in the production system. Maintenance becomes the production system's center point, part of a global enterprise (Nurchayo et al. 2018). Maintenance is a combination of administrative and technical actions intended to retain an item or restore it to a state where it could perform a required function (Nurcahyo et al. 2018).

Another definition of maintenance is the set of activities performed during the life cycle of an item to preserve the value of an asset (Al-Turki et al. 2014). Maintenance is not just ensuring the equipment availability but also aiming to achieve the organization's goals and objectives (Velmurugan and Dhingra 2015).

Ensuring efficient production and equipment availability relies on how the organizations can integrate maintenance functions with other functions (Velmurugan and Dhingra 2015). The inadequacies of the maintenance practice have affected rapid deterioration in production facilities, reduced throughput, and reliability of production facilities, and lowered equipment availability (Ahuja and Khamba 2008). The equipment breakdowns could have negative impacts on production loss which affected the cost components of the firm (Dachyar et al. 2018).

The decisive factor for maximizing manufacturing asset value in terms of reliability, cost, and productivity is maintenance management, involving planning, organizing, and controlling responsibilities (Al-Turki et al. 2014). Manufacturing technology advancement is required in maintenance management for maintaining assets in terms of product reliability, availability, and safety, in addition to its financial value (Al-Turki et al. 2014). Thus, the success of manufacturing firms is emphasized in maintenance management (Al-Turki et al. 2014).

Remarkably research has been carried out in terms of maintenance management. Marquez et al. (2009) summarize that the process is needed to manage maintenance management. Wienker et al. (2016) stated in their research that working maintenance management without a computer-based system is almost impossible. Sinha (2015) developed particular actions, namely Actionable Program for Maintenance, which can be used for effective and efficient maintenance management. Fraser et al. (2015), in their research, found that Total Productive Maintenance (TPM), Condition Based Maintenance (CBM), and Reliability Centered Maintenance (RCM) are the popular management models. Research on conveyor networks in underground copper ore mines has been completed by Stefaniak et al. (2016), in which maintenance management requires a dedicated computerized system.

Even though several types of research have been conducted to observe and understand the practice of maintenance management in many sectors, there is still a limited amount of research that elaborates the maintenance characteristics in the manufacturing industry. Besides that, the lack of research observation regarding the differences in maintenance characteristics by comparing the organizations which have implemented fully Total Productive Maintenance with the other organization which has applied Preventive Maintenance only without Total Productive Maintenance practice. This paper aims to understand and identify the most critical maintenance characteristics of the manufacturing sector.

1.1 Objectives

The following objectives are defined as:
1. To understand the maintenance characteristics in the manufacturing sector
2. To understand the maintenance characteristics difference between Total Productive Maintenance and Preventive Maintenance

2. Literature Review

2.1 Manufacturing

Manufacturing produces goods by converting raw materials using machines, tools, labor, and chemical processing. Manufacturing could give an added value to the raw material being processed. The goal of any organization in the manufacturing sector is to obtain the value-added. Examples of manufacturing processes are the production of chemical, automotive parts, pharmacy, and many more. Manufacturing is generally conducted on a large scale using skilled labor and technology.

Organizations need to manage their resources to produce the part item to remain competitive. The resources need to be governed by the organization based on machine or equipment availability. Maintenance is required to keep the machine functioning properly during the manufacturing process. Care is one of the significant activities influencing production quality and quantity, affecting production cost and customer satisfaction (Al-Turki 2014). Hence, maintenance practice played a vital role in the manufacturing process.

2.2 Maintenance Management

Management is the process of leading and managing all or part of an organization, usually a business, through the deployment and manipulation of resources (Marquez 2006). Meanwhile, maintenance is described as a combination of technical, administrative, and management actions carried out throughout the life cycle of an item, workplace, work equipment, or mode of transportation to protect the asset's worth (Al-Turki 2014). Maintenance is also defined as a combination of all administrative, technical, and managerial actions during the life cycle of an item intended to retain it or restore it to a condition in which the thing could perform the required action (BSI Standards Limited 2017).

Another term having the same meaning to maintenance is Maintenance, Repair, and Overhaul (MRO). MRO means a comprehensive term including steps that need to be taken to ensure continuity of operation equipment (Kamili 2020). MRO activities are related to modification, inspection, overhaul, repair, and service (Anham 2019). The goals of maintenance are keeping availability, reliability, and productivity of its assets. Another maintenance goal is to improve the manufacturing system of company productivity and profitability in cost efficiency and product quality improvement (Alsyouf 2003).

Moreover, maintenance management is defined as all activities of the management determining the maintenance requirements, strategies and responsibilities, objectives, and implementation of them by involving maintenance planning, maintenance control, and the improvement of maintenance activities and economics (BSI Standards Limited 2017). Maintenance management also means an act of planning, controlling, and organizing maintenance operations to maintain the ability of industrial facilities to function correctly in a ready-to-use condition (Setiawan et al. 2019).

Maintenance planning contributes positively to effective maintenance activity (Nurcahyo et al. 2018). Maintenance planning is done at three levels: strategic, medium, and short-term (Al-Turki 2014). A Maintenance strategy is created based on organizational objectives and is based on understanding the role of maintenance in corporate strategy (Al-Turki 2014).

Plans need to be combined with a mechanism for monitoring the effectiveness of the programs allowing for corrective actions and contingency planning (Al-Turki 2014). Hence, the performance measurement system helps measure the maintenance achievement based on organization targets (Al-Turki 2014). Many performance levels could be used, such as Overall Equipment Effectiveness (OEE) and breakdown time. To evaluate the effects of a machine breakdown, parameters such as Mean Time Between Failures (MTBF) and Mean Time To Repair (MTTR) can be used as the measurement (Ahmadi et al. 2016).

Singh et al. (2020) explained that OEE (Overall Equipment Effectiveness) implementation prolongs the life of machines by improving and monitoring the maintenance process. Implementing TPM was beneficial to limit breakdown time and emergence failures (Shagluf et al.2014). Mean Time Between Failures (MTBF) is an index providing information regarding equipment reliability. At the same time, Mean Time To Repair (MTTR) is the average time needed to repair a malfunction (Ribeiro et al. 2019). The formula calculation can be found between MTBF, MTTR, and Ai-related breakdown in the beer filling production line (Zeng 2021).

2.3 Maintenance Management Characteristics

Au-Yong et al. (2013) divided characteristics of preventive maintenance into two parts such as scheduled maintenance and condition-based maintenance:

- Scheduled maintenance is labor, spare parts, material, interval, cost budgeting.
- Condition-based maintenance is proficient manager, data integration, monitoring, and inspection recurrence.

Cholasuke et al. (2004) stated that the maintenance characteristics consist of policy deployment and organization, maintenance approach, task planning and scheduling, information management and CMMs, spare part management, human resource management, contracting out maintenance, financial aspect, and continuous improvement.

2.4 Likert Scale

A Likert scale is a psychometric scale with numerous categories in which respondents can express their ideas, attitudes, or feelings about a topic (Nemoto and Beglar 2014). According to Diamantopoulos (2012), the Likert Scale needs at least four items to get consistent evaluation results (Willits et al. 2016).

3. Methodology

The concept of maintenance characteristics has attracted authors to explore its implementation in the manufacturing industry. The manufacturing industry was chosen due to the rapid change of the technology used, which requires maintenance to keep manufacturing assets available and reliable. The methodology of this research comprises the following steps:

1. Literature review
   This step is done to understand the research theme, the definition of maintenance characteristics, and application in industries.
2. Survey questionnaire development
   This research divides the maintenance characteristics into five criteria: performance measurement, maintenance management, equipment & spare part management, maintenance cost, and maintenance strategy. The questionnaire consists of 29 questions. The survey collects information to compare, describe, and explain: knowledge, practice, and behavior (Fink 1995). This research uses surveys to gain information related to maintenance practices in the manufacturing industry. The survey uses a Likert scale to give a rating for each criterion. Holgado et al. (2016) use the Likert scale in their research of e-maintenance in service provision. Hence, the authors use a 5-point Likert scale to measure the maintenance characteristics. The definition of each scale is explained in table 1.

Table 1. 5-point Likert Scale

Scale	Information
1	Never
2	Rare
3	Sometimes
4	Often
5	Always

3. Questionnaire deployment & data gathering
   The survey questionnaire is then deployed to 4 companies representatives engaged in the manufacturing industry. Those four companies implement maintenance management either using Total Productive Maintenance or Preventive Maintenance. The company's full name is not stated due to confidentiality, but a brief profile is reviewed below in table 2.

Table 2. Company Profile

Company Initial	Main Business	Location	Type of Maintenance
FI	Chemical products	Indonesia	Preventive Maintenance
DF	Pharmacy	Indonesia	Total Productive Maintenance
IK	Tire component	Indonesia	Total Productive Maintenance
PS	Fishing gear	Indonesia	Preventive Maintenance

4. Data analysis
   Data from the questionnaire is then analyzed further to compare each maintenance characteristic. The analysis includes measuring the total score of each criterion from all respondents to obtain the highest score sub-criteria for each criterion in the maintenance management indicator. The maximum score for sub-criteria is 20. The data which was collected is listed out as per respondent in the Table 3

4. Data Collection

Table 3. Survey Result

	Measurement Indicator of Maintenance Management	**Respondent**				**Total**
		FI	**DF**	**IK**	**PS**	
A	**Performance Measurement System Criteria**					
1	**Maintenance Management Measurement**					
	Overall Equipment Effectiveness (OEE)	4	5	4	3	16
	Breakdown Time	5	5	5	4	19
	Mean Time Between Failures (MTBF)	2	4	4	4	14
	Mean Time To Repair (MTTR)	2	4	4	1	11
2	**Steps to Achieve Maintenance Management Indicators**					
	Coordination between production and maintenance department	5	4	4	5	18
	Perform maintenance management based on the Plan–Do–Check–Act (PDCA) cycle	4	5	5	3	17
	Release Corrective Action Report (CAR)	4	3	4	2	13
B	**Maintenance Management Criteria**					
1	**Planning and Scheduling**					
	Documentation of planning and scheduling administration is available	5	4	5	5	19

	Daily, the weekly, monthly schedule is available	5	5	5	5	20
	Tools Utilization in Condition Monitoring	4	3	4	2	13
2	**The benefit of Condition Monitoring Implementation in Maintenance Management**					
	Minimize breakdown time	5	4	4	3	16
	Minimize product failure caused by the machine	5	5	5	3	18
	Improve the quality of maintenance management	4	5	5	3	17
C	**Equipment & Spare Part Management Criteria**					
1	**Factors to consider in designing equipment & spare part management**					
	Suitability of production time with maintenance management schedule	4	4	4	4	15
	Critical level of equipment	4	4	5	5	18
	Organization budget	4	5	3	5	17
	Supplier availability in providing equipment / spare part	4	3	5	2	14
2	**Inventory Control Strategy**					
	Utilize min-max order	4	5	4	2	15
	A lead time of spare part availability	4	3	5	4	16
	Administration record of the item	4	4	4	5	16
D	**Maintenance Cost Criteria**					
1	**Budget Utilization**					
	Maximum utilization of maintenance budget	4	3	1	3	11
	Budget is available for critical machine/equipment	5	5	4	4	18
	Budget is available for spare part	4	4	4	4	15

	Consideration and measurement of machine depreciation	3	4	4	5	16
	Maintenance cost allocation for routine and non-routine maintenance	4	4	4	4	16
	Administration record of budget utilization	4	5	4	5	18
E	**Maintenance Strategy Criteria**					
1	**Alignment of maintenance strategy with company policy**					
	Determination of maintenance management Key Performance Indicator (KPI) based on company's KPI	5	5	5	3	18
2	**Determination of outsourcing**					
	Supplier's knowledge of equipment	4	4	5	2	15
	Availability of resources	4	4	5	2	15
Total		119	122	124	102	464

5. Results and Discussion

5.1 Maintenance Characteristics Criteria at Manufacturing Sector

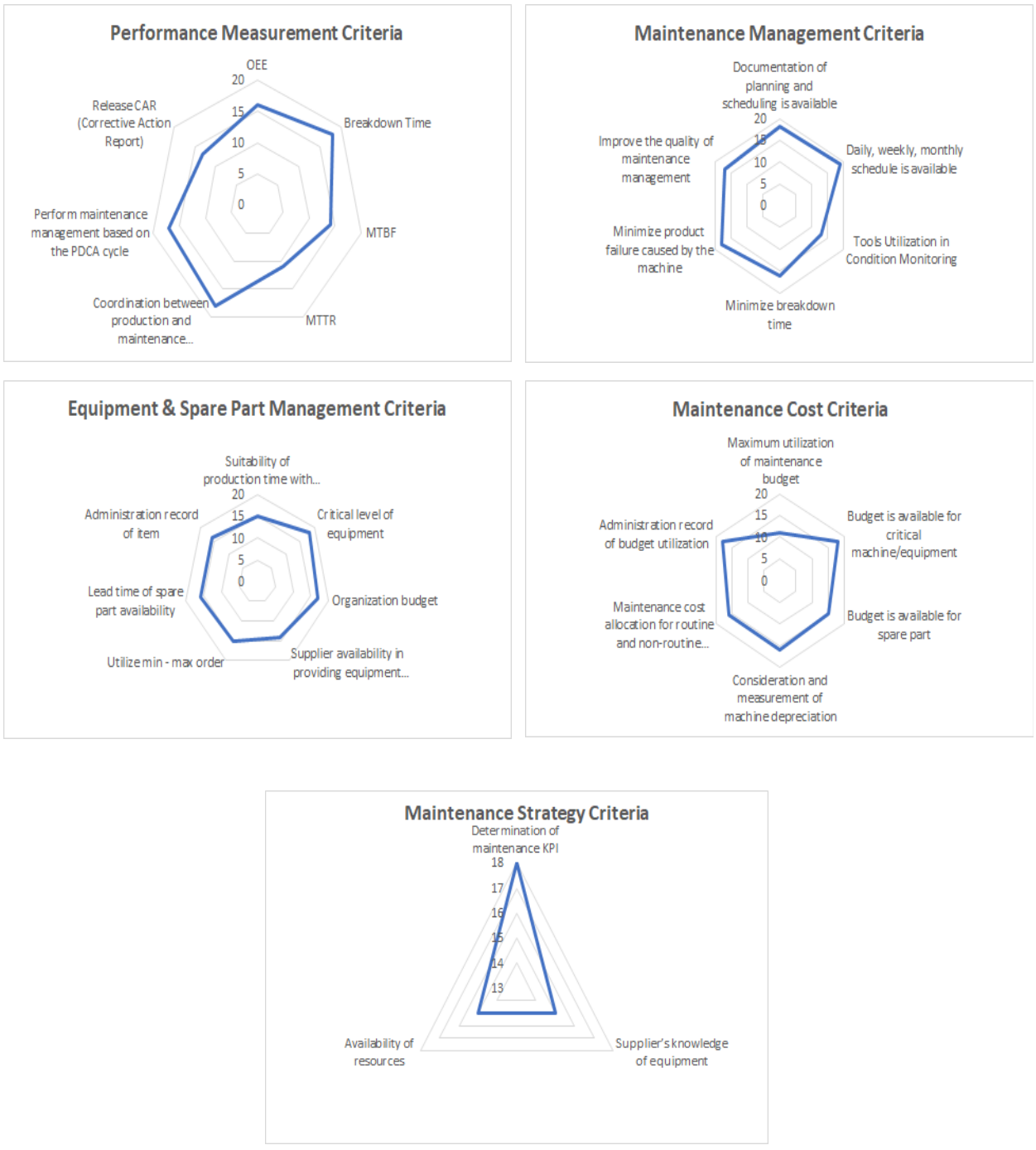

Figure 1. Result of Maintenance Characteristics for Each criterion at Manufacturing Sector

Based on the data collected from survey results, the data is then visualized in graphs using radar charts. Figure 1 shows the effect of maintenance characteristics for each criterion in the manufacturing sector. The result was done by using a survey in which each respondent was asked to identify maintenance characteristics that were applied frequently on each criterion. Using a 5-point Likert scale, their judgment was calculated as a number and represented in radar charts. The radar charts depict each maintenance criteria. The maximum bar score in the chart was estimated by calculating the total score of all four respondents, with 20 as the top score.

The first criteria from figure 1 are performance measurement criteria. From figure 1, we can conclude that breakdown time comes as the priority applied in the manufacturing process. This maintenance characteristic obtains a score of 19 from 4 respondents. This could be reasonable as breakdown time is the most critical maintenance characteristic in many organizations. High breakdown time could affect the production process leading to revenue loss. Hence, organizations need to implement good maintenance to prevent high breakdown time.

The second criterion is maintenance management. The availability of daily, weekly, and monthly schedules becomes the priority in this criterion. This maintenance characteristic obtains a total score of 20 from 4 respondents. The availability of maintenance schedules becomes critical as it guides the maintenance technicians and production operators to perform maintenance as required. This maintenance schedule also helps prevent unnecessary maintenance activities that could consume budget organizations.

The third criteria are equipment and spare part management. The critical level of equipment is the top priority in this criterion. This maintenance characteristic obtains a score of 18 from 4 respondents. Compared to other elements in the equipment and spare part management criteria, the critical level of equipment is the most vital factor that should be identified to achieve performance. The maintenance department needs to prepare the equipment leveling to prevent any shortage of equipment if a failure occurs during the production process. This should be done to avoid breakdown time leading to production loss and high maintenance costs.

The fourth criterion is maintenance cost. Budget availability for critical machines or equipment and the administration record of budget utilization become the requirements' priority. The organization needs to allocate a high portion of the maintenance budget on the critical machine or equipment that frequently needs to be maintained. This is to ensure the continuity of the production process. On the other hand, the record of budget utilization is required to monitor the maintenance cost to prevent over budget.

The last criterion is maintenance strategy. Determination of maintenance management Key Performance Indicator (KPI), based on the company's KPI, becomes the top priority in the maintenance strategy criteria. The key performance indicator of maintenance management is significant as it determines the organization's strategy to achieve maintenance management objectives. If there is no alignment between the maintenance department and the organization's Key Performance Indicator, the organization could fail to accomplish the maintenance management target.

5.2 Maintenance Types: Preventive Maintenance VS Total Productive Maintenance

This research was conducted on four manufacturing organizations, two of which each applied Preventive Maintenance (PM) and Total Productive Maintenance (TPM). Preventive Maintenance (PM) was used on FI and PS organizations, while Total Productive Maintenance (TPM) was applied on DF and IK organizations.

The survey implied that the score of performance measurement criteria between organizations implementing Total Productive Maintenance (TPM) and Preventive Maintenance (PM) differs. Total Productive Maintenance (TPM) takes OEE, breakdown time, MTBF, and MTTR as its performance measurement, while preventive maintenance (PM) only measures OEE and breakdown time. Simply said, Total Productive Maintenance (TPM) considers more variables as its measurements. Another difference between those maintenance types is the approach to achieving measurement targets. PM treats coordination production and maintenance departments more than performing maintenance using the PDCA (plan–do–check–act) cycle, while Total Productive Maintenance (TPM) does the opposite.

6. Conclusion

This research aims to observe maintenance management implementation and the difference in maintenance type in manufacturing. The result from the survey obtained key maintenance characteristics for each criterion, namely breakdown time, the availability of daily, weekly and monthly schedules, the critical level of equipment, the

availability of budget for essential machines or equipment, the administration record of budget utilization, and determination of maintenance management Key Performance Indicator (KPI) which is based on company Key Performance Indicator (KPI). Another survey result is that Total Productive Maintenance (TPM) takes OEE, breakdown time, MTBF, and MTTR as its performance measurement while PM only measures OEE and breakdown time.

This research provides theoretical and practical contributions. Theoretically, this research was one of the few attempts to determine maintenance management characteristics by comparing Preventive Maintenance (PM) and Total Productive Maintenance (TPM). Practically, this study could guide the organizations to implement maintenance activity by considering the maintenance characteristics explained in this research.

The limitation of this research lies in the lack of data surveys on organizations implementing maintenance management. Besides, this research only observes manufacturing organizations in Indonesia. So, future research should be done by having more data surveys comparing Total Productive Maintenance (TPM) and Preventive Maintenance (PM) practices in manufacturing organizations. Moreover, future research should cover and compare manufacturing organizations outside Indonesia to acquire comprehensive insights.

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