Dimensional Analysis of Maintenance Characteristics on Maintenance Implementation in Palm Oil Company

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Abstract

The expansion of the palm oil industry has had many positive social and financial impacts. In addition to the positive impacts, there are impacts that the expansion of the palm oil industry must consider by ensuring the business activities of the palm oil industry. If business is interrupted due to system failure, financial and non-monetary burdens may occur. In terms of supporting the development of the palm oil industry, the application of maintenance is critical to achieving positive economic, environmental and health outcomes in the palm oil industry. When performing maintenance, maintenance properties are one of the factors that can greatly improve maintenance performance. Using Principal Component Analysis (PCA) to know which maintenance characteristics contribute significantly to the success of maintenance implementation can drive internal improvements related to maintenance implementation.

Keywords

Maintenance Implementation, Palm Oil, Maintenance Characteristics, Principal Component Analysis and Dimensional reduction.

1. Introduction

Palm oil is an essential and economically useful vegetable oil that is used as a raw material for food and non-food products. Most of its production takes place in Indonesia and Malaysia, producing about 83% of the total world production. The other three largest producers are Thailand, Nigeria, and Colombia (Kasim et al. 2021). Palm oil is the largest produced and consumed vegetable oil since 2005 (Kasim et al. 2021). It is a globalized agro-food product that is used in various industries such as food, cosmetics, chemical chemicals and fuels (Kasim et al. 2021).

Currently, there has been massive change in the palm oil industry, especially in Indonesia and Malaysia. Not only in the food segment, palm oil can also be developed for non-food purposes, such as biofuels and similar products(Kasim et al. 2021). The biofuel industry plays very important role in improving the economy, increasing agricultural development, increasing investment, increasing employment opportunities in rural areas(Wardhani and Rahadian 2021). Besides that, biofuels are also able to compete internationally in terms of alternative fuel innovations. In addition to the positive impact, of course there are impacts that must be considered from the expansion of the palm oil industry, that are the development of sustainable palm oil industry and healthy palm oil industry.

Another impact that must be considered is the assurance of operational activity of palm oil industry. If the operational activity is interrupted due to failure of component of machine, it will possibly cost financial and non-financial impact. In terms of supporting the development of the palm oil industry and assuring the operation of the palm oil industry, the application of maintenance industry is very important in achieving positive at palm oil industry on the pillars of economy, environment, and health. Maintenance implementation is influenced by the maintenance characteristics. There are many maintenance characteristics that need to be considered when carrying out the maintenance implementation process. The problem is that many organizations, including the palm oil industry, do not know which maintenance characteristics need to be considered more deeply to ensure maintenance implementation runs smoothly and ensure services can run optimally. In this research, dimension reduction analysis

was conducted to see which of the existing maintenance characteristics are important characteristics to ensure maintenance runs smoothly.

1.1 Objectives

The Objective of this research is to:

1. Obtained which maintenance characteristics are significantly important to palm oil 3 departments which are mechanical, electrical, and information technology.
2. Obtained recommendations from the important characteristics obtained, to optimize maintenance implementation of three departments in Palm Oil Enterprise which are mechanical, electrical, and information technology.

2. Literature Review

2.1. Maintenance

Maintenance is the set of activities, technical, administrative, and managerial, carried out during the life cycle of an item, workplace, work equipment, or means of transport, to conserve the value of an asset (Al-Turki et al. 2014).Along with a rising consciousness of maintenance produces added value to the business process, organizations are managing maintenance as an essential part of their business (Ben-Daya et al. 2009). Measuring maintenance performance helps organizations understand the value created by maintenance, reassess, and modify maintenance policies and practices, justify investments in current trends and practices, and modify resource allocations, understand the impact of maintenance on other functions and stakeholders, and understand health and safety (Fatoni and Nurcahyo 2018).

2.2. Maintenance Characteristics

Maintenance characteristics are characteristics that will affect the maintenance implementation runs optimally and will affect the overall maintenance process(Au-Yong et al. 2014)There are several maintenance characteristics that need to be considered when doing maintenance implementation which are:

1. Maintenance Policy(Pedersen and Vatn 2022)
2. Maintenance Labor(Au-Yong et al. 2014; Chua et al. 2018)
3. Maintenance Downtime (Au-Yong et al. 2014; Basri et al. 2017; Chua et al. 2018; Van Horenbeek et al. 2013)
4. Maintenance equipment and technique (Ahmad and Kamaruddin 2012; Au-Yong et al. 2014)
5. Spare part and Material (Au-Yong et al., 2014; Chua et al., 2018)
6. Maintenance manager (Au-Yong et al., 2014; Chua et al., 2018)
7. Maintenance Reliability (Nuryanto et al. 2020)

2.2.1. Maintenance Policy

Having proper maintenance and security policies in place within your organization is essential to achieving operational excellence. These policies help optimize resource usage and ensure that devices and processes operate efficiently (Tsarouhas 2020). Improvements in remote condition monitoring technology and degradation modeling will make maintenance policies with longer maintenance windows more attractive to facilities that can reduce maintenance costs by increasing maintenance windows(Pedersen and Vatn 2022).

2.2.2. Maintenance Labor

The maintenance process involves labor in the form of human resources who oversee providing consumers with the maintenance process and who have the necessary skills and knowledge (Au-Yong et al. 2014; Chua et al. 2018). A good maintenance labor can watch and foresee wear and tear of a component as well as standby in the maintenance process, so that if a failure happens, it may be immediately seen, and further action taken. This goes beyond simply knowing what maintenance will be performed (Au-Yong et al. 2014; Chua et al. 2018).

2.2.3. Maintenance Downtime

When a system stops during the maintenance process, this is known as downtime. The production process will cease as a result of the machine or production equipment being in an idle state during the maintenance process (Au-Yong et al. 2014; Basri et al. 2017; Chua et al. 2018; Van Horenbeek et al. 2013). To avoid slower downtime that will have an impact on production costs and revenue streams, downtime during the maintenance process must be anticipated and controlled (Au-Yong et al. 2014; Basri et al. 2017; Chua et al. 2018; Van Horenbeek et al. 2013).

2.2.4. Maintenance Equipment and Technique

Maintenance equipment and technique are maintenance characteristics to consider because the maintenance process is determined by the equipment used and how the maintenance process is carried out (Ahmad and Kamaruddin 2012; Au-Yong et al. 2014). The equipment and techniques used in the maintenance process will affect the quality of maintenance as well as the required downtime; the better the equipment and techniques used, the less downtime will be required, which will affect production activities and revenue streams (Ahmad and Kamaruddin 2012; Au-Yong et al. 2014). Time Based Maintenance (TBM), which is a maintenance technique carried out when it meets a certain time span, and Condition Based Maintenance (CBM), which is a maintenance technique carried out by looking at the wear and tear conditions of the product, are two maintenance techniques that can be considered and used. When to perform maintenance on a component or system is then determined (Ahmad and Kamaruddin 2012).

2.2.5. Spare Part and Material

Spare parts and materials are maintenance characteristics that must be considered because the quality of spare parts and materials has a significant impact on the output of a maintenance program (Au-Yong et al. 2014; Chua et al. 2018). The amount of availability, the process of ordering spare parts, the budget that must be issued, and the quality of the spare parts to be ordered are all factors to consider when it comes to spare parts and materials (Au-Yong et al. 2014; Chua et al. 2018).

2.2.6. Maintenance Manager

A maintenance manager is a resource who regulates worker aspects, spare part and material allocation, when maintenance will be performed and how long downtime is required, maintenance tools and techniques, monitoring and inspection of the maintenance process, and maintenance data (Au-Yong et al. 2014; Chua et al. 2018). To ensure that the maintenance manager performs well, the maintenance manager must have the necessary qualifications and experience in managing maintenance, as well as the ability to properly plan, execute, and supervise maintenance (Au-Yong et al. 2014; Chua et al. 2018).

2.2.7. Maintenance Reliability

Reliability Centered Maintenance (RCM) is a process that ensures maintenance tasks are performed in an efficient, cost-effective, reliable, and safe manner. Maintenance tasks may be preventive, predictive, or involve nondestructive inspections to identify or monitor flaws. A reliability engineering program offers a sound alternative for improving the maintenance function. Reliability centered maintenance (RCM) can be utilized to enhance maintenance policies and improve equipment reliability. In RCM, the maintenance program is developedbased on the concept of restoring equipment function rather than bringing the equipment to an ideal condition.In recent years, managing reliability and maintainability has emerged as a new concern in the corporate world. Efforts to remain competitive and provide accurate service are primarily influenced by reliability and maintainability(Nuryanto et al. 2020).

2.3. Principal Component Analysis

Principal Component Analysis (PCA) is a statistical method to reduce the dimension of a large datasets by reducing the data but keeps the important data that describe a data (Jaadi 2022). In PCA, the dataset will be standardized by subtracting the value with the mean and divided it with the standard deviation. Covariance matrix computation then held to ensure the related component or variable did not have close correlation, otherwise can be treated as the same data and can be dimensionally reduce (Jaadi 2022). The eigenvalue of each component is computed and analyzed to see whether any component has less than 1 eigenvalue. The component which has larger eigenvalue then can be treated as principal component which later can be describe as a new dimension that can describe a larger data set with fewer values (Jaadi 2022).

3. Methods

The method that is used in this research consists of three main methods which are:

3.1. Data Collection

Data Collected by questionnaire related to component of maintenance characteristics. A Likert scale question is conducted with a six-point scale. The choices range from Strongly Agree to Strongly Disagree distributed to 42 respondents, consist of 27 questions which represent each labor of electrical, mechanical, information technology, and the user. The questions asked on the questionnaire as follows:

1. Maintenance Policy: Did maintenance policy on your organization run stable? (Q1), Is top management involved in making the maintenance policy of your unit? (Q2), Does top management encourage maintenance policies to be implemented properly? (Q3), Do you or your unit fill out a maintenance report after each regular maintenance process? (Q4).
2. Maintenance Labor: Is the maintenance labor qualified? (Q5), Is the number of maintenance labor fulfilled? (Q6), Is maintenance labor involved in teamwork? (Q7)
3. Spare-part and Material: In the maintenance process, does your unit have sufficient components or spare parts? (Q8), Are the components or parts owned by your unit of good quality? (Q9), Is the procurement planning process for components or spare parts in your unit good? (Q10)
4. Maintenance downtime: When performing the maintenance process, does downtime during the maintenance process significantly affect production activities? (Q11), Does the availability of components and spare parts affect the length of downtime? (Q12), Can the quality of parts and components affect the likelihood of downtime? (Q13)
5. Maintenance Equipment and Technique: Is Facilities in good condition? (Q14), Is Maintenance guide has been set? (Q15), Is the Maintenance guide easy to understand? (Q16)
6. Maintenance Manager: Is the Manager qualified? (Q17), Is Manager Properly Planned Maintenance? (Q18), Is Manager Properly Evaluated Maintenance? (Q19)
7. Maintenance Reliability: Are Reliability analysis conducted on all assets? (Q20), Are all departments on track focused on reliability maintenance? (Q21), Are there any constraints to implement reliability maintenance? (Q22)

And the questions related to user experience as follows:

1. Does the work complete as per user request? (Q23)
2. Does the work complete in a timely manner? (Q24)
3. Is the maintenance labor polite and respectful to the user? (Q25)
4. Is there any work left unfinished by the maintenance labor? (Q26)
5. Is the overall quality of the maintenance services satisfying the user? (Q27)

3.2. Principal Component Analysis

The data thatis collectedfrom the previous phase will be analyzed using the PrincipalComponent Analysis (PCA). PCA is used to reduce the dimension of collected data so it can be identified which dimension significantly affect the maintenance implementation and which maintenance characteristics strongly impact the maintenance implementation. The new dimension of maintenance characteristics can be referred to as principal component of maintenance characteristics that strongly affect maintenance implementation.

3.3. Cross-Analysis

From the identified maintenance characteristics component cross-analysis can be done between departments related to maintenance implementation, so if there is some maintenance characteristics that is not implemented correctly in one department, the solution that is applied from the other department could be applied to solve related problems.

4. Data Collection

Based on the questionnaires that have been distributed to 42 respondents which represent eachmanpowerofelectrical, mechanical, information technology, and the user.The answer questionnaires shown inFigure1.

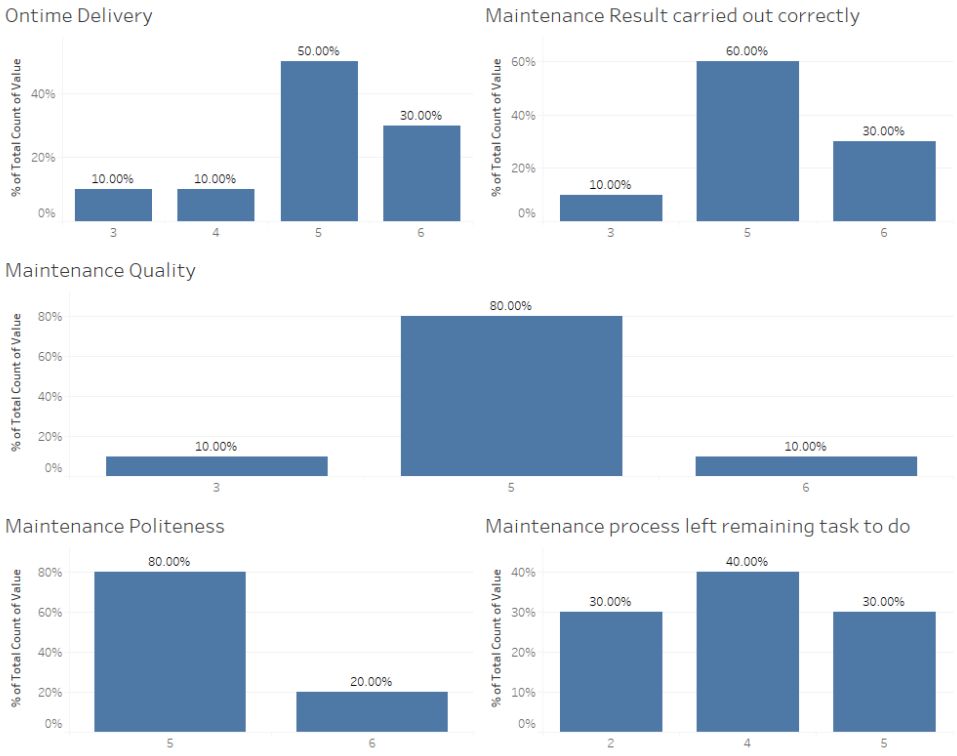

Figure 1. Answer to user questionnaire related to user experience about maintenance process and maintenance quality

Figure 2 shown that 70% of users respond more agree and strongly agree on the user experience on service of maintenance, it means user overall satisfied with existing on time delivery, result, quality, politeness, and processes of maintenance services.

5. Results and Discussion

5.1. PCA Analysis

From the data, the respondent variesin experience from 1 year experience to more than 6 years' experience. The data distribution spread across 3 main areas which are mechanical, electrical, IT and the users.The non-maintenance user is conducted with user experience questionnaire that is plotted in Figure 1. From the data, then the PCA analysis is performed, the first step of this analysis is finding the eigenvalues of each question/component that is shown inTable 1, Table 2, Table3.

Table 1. Eigenvalues of Electrical Unit questionnaire Response

Initial Eigenvalues			
	Total	% of Variance	Cumulative %
1	***9.34***	39.30%	39.30%
2	***4.72***	19.90%	59.20%
3	***2.74***	11.60%	70.80%
4	***2.47***	10.40%	81.20%
5	***2.31***	9.70%	90.90%
6	0.99	4.20%	95.10%
..	..	..	..

..	..	..	..
22	-5.13E-33	0.00%	100.00%

Table 2. Eigenvalues of IT Unit questionnaire responses

Initial Eigenvalues			
	Total	% of Variance	Cumulative %
1	***5.54***	32.40%	32.40%
2	***3.76***	22.00%	54.30%
3	***2.69***	15.70%	70.00%
4	***2.5***	14.60%	84.70%
5	0.95	4.90%	96.80%
6	0.68	4.00%	94.80%
..	..	..	..
..	..	..	..
22	-1.07E-32	0.00%	100.00%

Table 3. Eigenvalues of Mechanical Unit questionnaire responses

Initial Eigenvalues			
	Total	% of Variance	Cumulative %
1	***10.31***	41.20%	41.20%
2	***5.09***	20.30%	61.50%
3	***3.8***	15.20%	76.60%
4	***2.02***	8.10%	84.70%
5	***1.41***	5.60%	90.30%
6	0.8	3.20%	93.50%
..	..	..	..
..	..	..	..
22	0.33	1.30%	98.60%

From Tables 1, 2 and 3 it can be concluded that there are five dimensions in each mechanical and electrical unit and four dimensions in IT unit that contributes to maintenance implementation. These dimensions could be the existing maintenance characteristics or some other characteristics that consist of several questions related to existing maintenance characteristics. The dimensions with higher eigenvalues will have more contribution to maintenance implementation in palm oil company.

Each dimension will consist of the question number and the correlation value of each question. If the correlation value is greater than 0.5 means the question is identified as a principal component, and if the correlation value is below 0.5, it is identified as non-principal component.Table 4, Table 5, Table 6show the principal component of each unit related to the dimensions.

Table 4. Principal component of Electrical Unit to be considered while implementing maintenance

Dimension 1 Component	Value	Dimension 2 Component	Value	Dimension 3 Component	Value	Dimension 4 Component	Value	Dimension 5 Component	Value
Maintenance policy stability	0.78	Top management role in maintenance policy	0.74	Availability of component during downtime period	0.97	Reliability analysis	0.82	Reliability Constraint	0.74
Maintenance labor qualification	1.26	Maintenance labor qualification	1.11	Quality of component that affects downtime period	0.62				
Number of maintenance labor	1.04	number of maintenance labor	1.03	Reliability Constraint	0.77				
Maintenance labor teamwork	1.36								
Downtime effect on production	1.01								
Availability of component during downtime period	0.77								
Facilities Condition	0.7								
Reliability minded	1.21								

Table 5. Principal component of IT Unit to be considered while implementing maintenance

Dimension 1 Component	Value	Dimension 2 Component	Value	Dimension 3 Component	Value	Dimension 4 Component	Value
Top management role in maintenance policy	0.72	number of maintenance labor	0.79	Top management role in maintenance policy	0.55	number of maintenance labor	0.79
Availability of component during downtime period	0.95	Reliability Constraint	0.98	number of maintenance labor	0.7		
Reliability analysis	0.75						

Table 6. Principal component of Mechanical Unit to be considered while implementing maintenance

Dimension 1 Component	Value	Dimension 2 Component	Value	Dimension 3 Component	Value	Dimension 4 Component	Value	Dimension 5 Component	Value
Top management involvement in maintenance policy	0.7	Top management involvement in maintenance policy	0.57	Maintenance labor qualification	0.71	Downtime periods affect production	0.6	Reliability minded	0.52
Top management encourage in maintenance policy	0.54	Top management encourage in maintenance policy	0.55	number of maintenance labor	0.74	Evaluation from maintenance manager	0.71		

Maintenance labor qualification	1.37	maintenance labor teamwork	0.51	Reliability analysis	0.81	Reliability minded	0.7		
number of maintenance labor	1.32	Downtime periods affect production	0.69						
maintenance labor teamwork	0.79	Quality of component that affects downtime period	0.98						
Availability of component during downtime period	1	Presence of maintenance guideline	0.69						
Facilities Condition	0.53	Maintenance Manager qualification	0.54						
Maintenance Manager qualification	0.93	Reliability analysis	0.66						
Maintenance manager properly planned maintenance	1.2								
Evaluation from maintenance manager	0.97								

Based on Table 4, electrical unit have five dimensions that are considered as five principal dimensions with principal component. The first and second dimension of electrical unit are dominated by maintenance labor. This shows that, for electrical maintenance conducted successfully the organizations need to make sure the maintenance labor who will do the maintenance activity is available, qualified, and coordinate with each other to ensure the success of maintenance activity. The third dimension is dominated by maintenance downtime component, so if the organization wants to ensure the maintenance implementation, the availability of component and quality of component that is used to replace the older one is in excellent quality. The fourth and fifth dimension is consisting of maintenance reliability component, that needs to be concerned by the organization to have reliability analysis and constraint mitigation related to reliability to ensure the maintenance implementation of electrical in palm oil company.

Based on Table 5, IT unit have four dimensions that considered as principal dimension. The first dimension consists of three maintenance characteristics which are maintenance policy, maintenance downtime, and maintenance reliability. Different from the mechanical unit that have a dominated dimension, IT unit from palm oil company have evenly spread maintenance characteristics in each dimension. But the overall dimensions consist of maintenance labor, maintenance reliability, and maintenance policy. This shows that, to ensure success of maintenance implementation in the IT unit, it is needed to consider the number of existing workers, reliability analysis, and the role of top management in encouraging the implementation of the maintenance policy.

Based on Table 6, mechanical units have five dimensions that consist of several maintenance characteristics. The first dimension that significantly affected the maintenance implementation is dominated by maintenance labor and maintenance manager component. It shows that in mechanical unit the role of maintenance manager significantly affects the maintenance implementation and the maintenance labor who do the maintenance activities. In second dimension, is dominated by maintenance policy and maintenance downtime. This shows after considering the maintenance manager and maintenance labor, it is needed to have top management who support and align the maintenance policy along the maintenance activities and the downtime period related to the quality of the component. The third dimension is dominated by maintenance labor characteristics, which tells that if maintenance implementation wants to be successful, it needs to consider the maintenance labor qualifications and the number of maintenance labor. The fourth and fifth dimension is distributed evenly between maintenance downtime, maintenance manager, and maintenance reliability.

5.1. Cross analysis PCA result and descriptive data

From the Figure 3 the on-time delivery, maintenance result, maintenance quality, and maintenance labor politeness show satisfactory results, which all parameters are scored more agree from the users in palm oil company. But there is still room for improvement in maintenance completion done by the maintenance unit in mechanical, electrical and IT. The palm oil company should focus on maintenance labor who conduct the maintenance activities related to electrical unit, increasing the awareness of maintenance labor, maintenance reliability and maintenance policy when conducting IT maintenance, and ensuring the maintenance manager in mechanical unit could plan and evaluate the maintenance result, and hopefully the maintenance will be completed as planned.

6. Conclusion

Maintenance in palm oil company has become important to ensure maximum efficiency of the manufacturing process, utilities, and related facilities. Several characteristics of maintenance become concern of this study to analyze and identified characteristics which are significantly important in 3 departments consist of Electrical, IT, Mechanical. Using PCA have found that Electrical has five dimensions with the most important characteristic is maintenance labor. IT has four dimensions with the most important characteristic are policy, downtime, and reliability. Mechanicals have five dimensions with the most important characteristic are maintenance manager and maintenance labor. By increasing awareness in the principal dimension, hopefully could improve the maintenance implementation in palm oil company.

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