Internet of Things Technology Selection for Palm Oil Mill Maintenance

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Abstract

The palm oil processing industry is the largest foreign exchange-producing industry for the Indonesian economy currently and is increasing with the presence of B-30 Mandatory in Indonesia. The focus of this paper to decide the most suitable Internet of Things technology to be implemented in palm oil mills, especially for water treatment and boiler maintenance, as well as the most significant criteria as well as sub-criteria for implementing IoT technology. The methods of this study are the Analytic Hierarchy Process (AHP) to acquire weights of the sub criteria and the Complex Proportional Assessment (COPRAS) to assess alternative technologies. The research resulted in the criteria that significantly influence the implementation of IoT, namely ease of use, competitive pressure, relative advantage, and the recommended technology which is CMMS.

Keywords
Maintenance, Palm Oil Mill, Internet of Things, COPRAS, AHP

1. Introduction
The volume of palm oil production has increased to 45 million tons in 2019. Indonesia also ranks first as a palm oil producer in the world. In 2020, the value of palm oil exports rose by 13.6% (Indonesian Palm Oil Business Association, 2017) The use of palm oil is also predicted to increase due to the mandatory B-30 policy that has been set by President Joko Widodo at the end of 2019, in which diesel fuel contain 30% fatty acid methyl ester, a processed form of palm oil. (Directorate General of New Renewable Energy and Energy Conservation, 2019)

There are several processes inside the plantations and palm oil mills, starting from palm fruit nurseries to processing fruit bunches in the factory. The processes in this plant use electricity obtained from turbines driven by steam power. The steam comes from the boiler, which gets feed water from the water treatment circuit. The water that will be used as feeder also has standards that must be met, starting from the pH level to the amount of silica and iron. If the boiler does not work then the activities of the entire plant can be stopped and cause losses. The focus of this paper will center around the water treatment and boiler network, namely the water reservoir, clarifier, sand filter, water tower, cation exchange tank, degasifier, anion exchange tank, and boiler. Currently in carrying out their maintenance procedure, the plantation that is studied have not applied any technology that enables live water condition tracking, or remote water condition tracking. The plant still relies on manual sampling and thus is prone to human error, overall boiler stagnation, and the inability for top management located in other cities to survey the daily maintenance processes.

Internet of Things also known as IoT is a type of network that could connect anything to the internet according to a defined protocol with the aim of exchanging information and communication. (Patel, 2016) A research conducted by Madushanki et al in 2019 said that in the context of agriculture, IoT is widely used in the context of water management and equipment maintenance, both in the top 10 categories. (Madushanki et al., 2019)

1.1 Objectives

The objectives of this paper is obtaining the weight of the sub criteria that significantly affects the implementation of IoT technology in palm oil mills using Analytical Hierarchy Process (AHP) method and to determine the most appropriate IoT technology to be applied in the maintenance of a water treatment series at a palm oil mill using the Complex Proportional Assessment (COPRAS) method.

2. Literature Review

The Indonesian Central Statistics Agency (BPS) has published a report in 2018 titled the Directory of Oil Palm Plantation Companies 2018 where it defines a plantation company as a company or legal entity engaged in the cultivation of plantation crops on land under control, with a commercial end goal and obtaining a business permit from the authorized agency. in the matter of granting plantation business permits. The companies that are driven by the government are called large state plantations (PBN) and companies that are driven by the private sector are called large private plantations (PBS). (Indonesian Central Statistics Agency, 2018)

The palm oil processing procedure has several steps (Asian Agri, 2018) 1) Planting and seeding process: at this stage, seedlings are planted and maintained for 8 months. 2) Afterwards it will be transferred to the plantation. For the plantation process, this stage lasts for 30 months where the seedlings are treated with sufficient water and managed with appropriate fertilizers. 3) After approximately 2 years and 6 months, the palm trees are ready to be harvested. The mature bunches are then harvested by cutting them from the tree trunk. 4) To make palm oil, the fruit is then pressed to reveal the oil, which is then filtered to clean it from contamination and meet the specified standards. Crude palm oil is then processed in processing plants to produce vegetable oil, oleochemicals, biodiesel and lauric acid. The fruit kernel is cracked to produce the kernel shell and kernel, the shell is used as biofuel, and the kernel is processed to produce palm kernel oil.

Maintenance is critical to ensure plant assets have good availability and reliability during plant operations and it is imperative to have efficient maintenance practices that actively involve all maintenance organizations. (Suhairi et al., 2012) Maintenance itself has two main branches, the first one is unplanned maintenance, done in emergency without prior planning, normally done for unexpected events and can cause high cost. The second branch is planned maintenance, which includes proactive, preventive, predictive, and corrective maintenance. (Rani et al., 2015) Maintenance itself could also cause changes in company profits, due to having a productive maintenance affecting production efficacy and effectiveness, which in turn improves productivity and price recovery. (Alsyouf, 2007)

The water treatment and boiler network, includes the water reservoir, clarifier, sand filter, water tower, cation exchange tank, degasifier, anion exchange tank, and boiler. The current maintenance procedure carried out in the plant where research takes place is wholly manual and relies heavily on manpower. Every sampling and maintenance process are carried out with simple equipment even though the sampling activity is done every hour. This causes a series of human errors, which leads to boiler stagnation. The stagnation itself causes the mill to stop operating and thus monetary loss is experienced. See Figure 1 for monetary loss experienced by the plant throughout 2020. From the figure, it is evident that the stagnation has caused substantial loss, including reaching over $126,000 in June 2020. Aside from monetary loss, the inability to live track the water condition and for top management to directly access the maintenance process and water condition is a concern from the company being assessed.

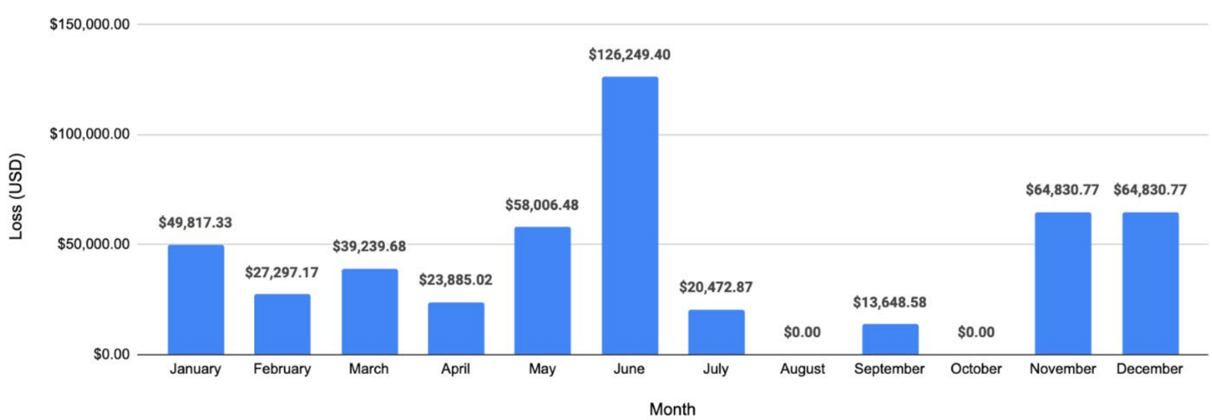

Figure 1 Monetary Loss Caused by Stagnation 2020

The Internet of Things is the foundation for maintaining person-to-object and object-to-object communication through smart technologies. (Ma et al., 2018) The architecture of IoT comprises of five key layers that define all the functions of the IoT system. They are the perception, network, middleware, application, and business layer. (Ning et al., 2013) The benefits seen after implementing IoT-based maintenance include: (O'Donoghue & Prendergast, 2004) improved uptime, increased availability time, reduction of waiting time, improved employee morale, reduced emergency maintenance, and improved work order streamlining & maintenance scheduling. The other advantages of implementing IoT for predictive maintenance: a) reduce maintenance costs to 40 percent, b) lower equipment downtime by 50 percent, c) lessen capital investment by 5 percent. (Suhairi et al., 2012) Other notable benefits include the ability for data analysis in real – time (Haight & Hyoun, 2015), decrease in product defects while at the same time increasing productivity (Davies, 2015), and improving efficiency and decreasing hazards (O'Halloran & Kvochko, 2015).

This research proposes the use of Supervisory Control and Data Acquisition also knows as SCADA, and Computerized Maintenance Management System, popularly known as CMMS. These alternatives are chosen after conducting discussion with 3 experts, specifically two industry players with considerable experience in IoT implementation and plant maintenance, and one doctoral student with an IoT research focus.

Analytic Hierarchy Process (AHP) is a method designed by Saaty. It uses pairwise comparison and results of expert assessments to obtain weights and priorities. (Saaty, 2008) Several studies that use this method include supplier selection, assessment of new technology implementation factors, selection of mobile phone modes, and selection of computerized maintenance management systems. (Abdel-Basset et al., 2018; Goswami & Mitra, 2020; Meira et al., 2020; Stevic, 2016)

Complex Proportional Assessment (COPRAS) is developed by Zavadskas et.al., typically used to assess, maximize, and minimize the index value, and the effects of maximizing and minimizing the attribute index of assessment results are judged separately. Similar research that used COPRAS method include supplier selection, civil engineering project ranking, mobile model selection, investment prioritization, and maintenance strategy selection (Ajalli et al., 2017; Fouladgar et al., 2012; Goswami & Mitra, 2020; Hashemkhani Zolfani & Bahrami, 2014; Imrona et al., 2019; Stevic, 2016)

3. Methods

The methodology of this paper begins with criteria and sub criteria collection using literature review. The collected items are then selected by the respondents, which are the individuals that works in the maintenance and water treatment network of the plantation being assessed. The selected criteria and sub criteria are then used for second questionnaire to obtain their respective weights using the AHP method. Weights obtained are then used to assess the proposed technology using COPRAS method. The final step is to analyze possible scenarios and form the conclusion.

4. Data Collection

This research is carried out by handing out three questionnaires to the respondents. The first questionnaire is sub – criteria validation, where in the beginning sub criteria are collected through an extended literature review. The respondents then validate the criteria by giving them a score between 1 – 5, with 5 being the most important in the palm oil mill setting. The scores are then evaluated with their respected geomean score. (Arovah & Dachyar, 2020) The results are shown in Table 1.

Table 1 Selected Criteria

Criteria	Sub criteria	References
Technology	Compatibility	(Dey et al., 2016; J. H. Park & Kim, 2019)
	Complexity	(Alshamaila et al., 2013; Chana & Chong, 2013; Dey et al., 2016)
	Reliability	(Al-Hujran et al., 2018; Alkhater et al., 2015; Tripathi, 2019)
	Ease of use	(Isa et al., 2019; J. H. Park & Kim, 2019)
	Technology Infrastructure	(Gerritsen, 2018; Lambok Siregar & Asvial, 2020; Tripathi, 2019)
	IT expertise	(Bhattacharya, 2015; Kim et al., 2017; Lambok Siregar & Asvial, 2020)
	Technology integration	(Hsu & Yeh, 2017; Lambok Siregar & Asvial, 2020; Palacios-Marqués et al., 2015)

Criteria	Sub criteria	References
	Availability	(Abdel-Basset et al., 2018; Alkhater et al., 2015; Gerritsen, 2018)
	Relative advantage	(Alkhater et al., 2015; Alshamaila et al., 2013; Shahzad et al., 2020)
Organization	Expected benefits	(Chana & Chong, 2013; Gangwar et al., 2014; Lambok Siregar & Asvial, 2020)
	Top management support	(Gerritsen, 2018; Isa et al., 2019; J. H. Park & Kim, 2019)
	Cost reducing	(Shahzad et al., 2020; Susanto & Aljoza, 2015; Thiesse et al., 2011)
	Monetary source	(Chana & Chong, 2013; Isa et al., 2019; J. H. Park & Kim, 2019)
	Acquisition cost	(Chang et al., 2019; Gerritsen, 2018; Kamble et al., 2019)
	Maintenance cost	(Hogaboam & Daim, 2018; Kamble et al., 2019; Pumplun et al., 2020)
Environment	Competitive pressure	(Kim et al., 2017; Lambok Siregar & Asvial, 2020; J. H. Park & Kim, 2019)
	Government regulation	(Gerritsen, 2018; Lambok Siregar & Asvial, 2020; J. H. Park & Kim, 2019)
	Vendor availability	(Dey et al., 2016; Kim et al., 2017; Tripathi, 2019)
Security	Authentication	(Cirani et al., 2013; Ning et al., 2013; K. C. Park & Shin, 2017)
	Institution security	(Al-Hujran et al., 2018; Gerritsen, 2018; Hsu & Yeh, 2017)
	System security	(Hsu & Yeh, 2017; Lambok Siregar & Asvial, 2020; Tripathi, 2019)
	Privacy	(Gerritsen, 2018; Isa et al., 2019; K. C. Park & Shin, 2017; Tripathi, 2019)
	Accountability	(Abdel-Basset et al., 2018; Ma et al., 2018; K. C. Park & Shin, 2017)

The selected criteria and sub – criteria above will be used to obtain their respective weights using AHP method and will use to determine the final selected technology, using COPRAS method.

5. Results and Discussion

The selected criteria are then assessed to obtain their weight by respondents using AHP method, the second questionnaire. This questionnaire is answered based on each of their relative experience and insight of the palm oil mill maintenance processes. The author then calculated the overall weights for each sub criteria using an excel model. For the results of the AHP calculation and weights of each sub criteria, see Table 2.

Table 2 Weights of Criteria

Criteria	Sub criteria	Global weight	Global weight rank
Technology	Compatibility	0,031	15
	Complexity	0,035	14
	Reliability	0,030	16
	Ease of use	0,114	1
	Technology Infrastructure	0,043	7
	IT expertise	0,040	10
	Technology integration	0,043	8
	Availability	0,043	6
	Relative advantage	0,087	3
Organization	Expected benefits	0,010	23
	Top management support	0,018	19
	Cost reducing	0,018	21
	Monetary source	0,018	20
	Acquisition cost	0,016	22
	Maintenance cost	0,024	18

Criteria	Sub criteria	Global weight	Global weight rank
Environment	Competitive pressure	0,082	5
	Government regulation	0,091	2
	Vendor availability	0,086	4
Security	Authentication	0,027	17
	Institution security	0,037	12
	System security	0,037	11
	Privacy	0,042	9
	Accountability	0,036	13

A consistency ratio calculation is then carried out to determine the consistency of the assessment. AHP calculation is deemed consistent if its consistency ratio is below 0.1, and is acquired by dividing the consistency index with the random consistency index (Saaty & Vargas, 2001) For the consistency ratios of each criteria as well as sub criteria from the table above, see Table 3 below. The table below shows that each group has a consistent ratio.

Table 3 Consistency Ratio

Description	Consistency Index	Random Consistency Index	Consistency Ratio)
Criteria	0,084	0,900	0,094
Technology sub criteria	0,089	1,450	0,061
Organization sub criteria	0,117	1,240	0,094
Environment sub criteria	0,001	0,580	0,002
Security sub criteria	0,053	1,120	0,047

IoT technology assessment for this research uses the Complex Proportional Assessment (COPRAS) method, the third questionnaire. It is used to assess utility functions from each alternatives. In this stage, each respondent will be asked to assess the IoT technology that has been identified. There are seven respondents involved, ranging from plant operators, mill manager, head of process, assistant head of process. The significance level (Qi) and utility level (Ni) of each alternative are shown in table 4 (See Table 4). It shows that CMMS technology has the highest Qi and Ni number, ranked first, and is therefore the selected technology for this research.

Table 4 Significance and Utility Level of IoT Technology Alternatives using COPRAS

Function	Alternatives	
	SCADA	CMMS
Qi	0,042	0,045
Ni	93%	100%
Rank	2	1

After obtaining sub criteria weights and selected technology, this research continues by using two potential scenarios to assess whether there are any differences to the technology ranks. The first scenario is when the government and IoT-related associations encourage technological development by simplifying IoT implementation and therefore driving the market towards higher IoT use. With this scenario, it will cause an increase in weight of the environment sub criteria by 45%. The second scenario is when the system is overloaded because of the large number of devices connected to the port and large amounts of data is passing through. This will cause a 50% increase in weight in the technological and organizational sub criteria to better prevent this from happening. (See Table 5).

Table 5 Scenario Calculation using COPRAS

Function	Before		Scenario 1		Scenario 2	
	SCADA	CMMS	SCADA	CMMS	SCADA	CMMS
Qi	0,042	0,045	0,047	0,050	0,054	0,058
Ni	93%	100%	94%	100%	92%	100%
Rank	2	1	2	1	2	1

Table 5 shows there are no differences in technology rank in both scenario 1 and 2. However there are slight changes in in the Qi and Ni value between scenario 1 and 2, despite not large enough to change the selected technology, and thus in both scenario, CMMS is selected.

6. Conclusion

The results showed that there were several conclusions from this study, which are: validation testing on sub-criteria collected through literature study resulted in 23 selected sub-criteria from a total of 30 sub-criteria, the criterion for Technology has the highest importance weight out of 4 criteria and the Ease-of-Use sub-criteria has the highest importance weight out of 28 sub-criteria, the IoT technology ranking results using COPRAS show CMMS Technology as the technology with the highest utility level. Based scenario calculation, there are no change in selected technology although there is a change in the utility level of SCADA technology.

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Biography

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