Internet of Things Technology Selection for Monitoring Process at Palm Oil Mills

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Abstract

The palm oil industry is one of Indonesia's most important industries, contributing a significant portion of the country's non-oil and gas exports, which is growing every year. Palm oil's selling price is impacted by its quality, which is maintained by continuous monitoring of the production process in order to ensure that the oil fulfills the required quality requirements. Until now, the palm oil companies are still experiencing difficulties in monitoring the quality of palm oil in the storage process. The goal of this research is to find the best possible Internet of Things (IoT) technology that could be employed inside the palm oil mill monitoring process while considering the Internet of Things' criteria. IoT to monitoring processes could help the company monitor palm oil condition with less oversight, increase leads to an overall with actual proof of outcomes, and promptly includes recommendations discrepancies. To weight the factors for deploying monitoring technology, the Best Worst Method (BWM) was employed. Any proposed monitoring technology in palm oil mills has been rated using the Complex Proportional Assessment Method (COPRAS). The final result is that SCADA is chosen based on the criterion of Internet of Things implementation.

Keywords
Palm Oil Mill, Monitoring, Internet of Things (IoT), Multi Criteria Decision Making (MCDM)

1. Introduction
Palm oil consumption, also known as crude palm oil, is rapidly increasing over the world, as proved by statistics data from 2021, which reveals that palm oil is the most consumed type of vegetable oil by the global population. The consumption rate exceeds 75.45 million metric tons, contributing for 36.3 percent of global vegetable oil usage. Indonesia ranks first in the world in palm oil production, following by Malaysia, Thailand, Colombia, and Nigeria, according to the Mundi Index for 2020. Indonesian palm oil production is estimated to cross 51.6 million tons in 2020, while consumption climbed 3.6 percent to 17.3 million tons last year and is expected to continue to rise due to oleochemicals and biodiesel consumption.

There are various production sequences in palm oil production, including seeding, picking, planting, harvesting, and processing. The DOBI, FFA, and water content of palm oil are all essential indicators of its quality. The greater the DOBI value, the better the quality and selling price of palm oil. FFA levels in palm oil should be kept as low as possible, preferably below 2%. Meanwhile, palm oil's water content must be kept to a minimum. The temperature of Crude Palm Oil and Palm Kernel Oil must be between 50 and 55 degrees Celsius to obtain this quality. The conditions of storage in the storage tank are one of the most important variables in determining the quality of palm oil.

During the process of filling or emptying the palm oil stockpile, the storage tank system requires precise control of flow, level, volume, and temperature to ensure that the quality of the palm oil meets the specified criteria. The manual control and monitoring system, namely periodic control with human monitoring, has a number of drawbacks, including time consumption, difficulty monitoring the tank (level and temperature), erroneous results, and the lack of an integrated system for monitoring storage and storage tanks. data from the past This, of course, might result in financial losses for the company as well as a reduction in the quality of palm oil.

1.1 Objectives
This research seeks to assist palm oil mills in determining the aspects to consider when installing Internet of things technology and determining the best IoT technology priority for storage tank monitoring.

2. Literature Review
2.1 Palm Oil Mill
A plantation company is defined as a company or private corporation engaged in the crop production of plantation crops on managed territory with a commercial end goal and obtaining a business license from the authorized entity, according to a report published by the Indonesian Central Statistics Agency (BPS) in 2018. The government is in charge of huge state plantations (PBN), while the private sector is in charge of large private plantations (PBS).

The palm oil processing procedure has several steps: 1) Palm oil that has been harvested and transported to the mill, is checked for quality & maturity or is known as fruit sorting. After sorting, the oil palm fruit is then put into a temporary storage area. 2) Fresh fruit bunches are put into the palm oil boiling station (sterilizer) to soften the flesh of the palm fruit, reduce the water content, and reduce the increase in acidity. In the boiling process, steam is needed to heat the sterilizer supplied from the boiler. 3) After the oil palm fruit has been extracted from its shell, it is placed in a press machine and crushed to extract crude oil. 4) Crude oil obtained at the press station is then purified at the oil purification station to ensure that the quality and quality meet the specified standards. 5) After the palm oil has been extracted from the processing process, it is temporarily held in storage tanks before being distributed to consumers. Storage tanks must be cleaned on a regular basis, and the condition of the oil stream must be checked to ensure that the temperature is maintained and that no leaks in the stream oil pipe occur, which could result in an increase in the water content of CPO.

2.2 Monitoring
Monitoring is the systematic and continuous gathering and analysis of data about a situation's progress. Monitoring is carried out to ensure that all those who need to know about an intervention are appropriately informed, and that timely decisions can be made. Process monitoring is intended to give the data needed to plan and review work on a regular basis, assess the success or failure of projects and programs, and identify and address problems and obstacles (Jackson 2017).

2.3 Internet of Things
Kevin Ashton introduced the notion of the Internet of Things (IoT) in 1999 (Mohammadi et al. 2019). The Internet of Things is a word that combines two terms: the first is the internet, which is described as a network that may link people via a variety of internet protocols. The second term is object, which refers to a device or object that can be turned into a smart object (Kumar Goyal et al. 2018). IoT is a concept that entails transmitting information over the web without using any user or computer intervention. The concept necessitates common items' internet connectivity (Dachyar and Azizia 2019), such that technologies may allow connectivity with the lowest level of human intervention (Y. C. Lin et al. 2014). IoT decision makers should be able to comprehend the solution's structure of thinking and end-to-end application in order to adequately accelerate the current digital transformation path. (Saragih et al. 2019). This study proposes the use of Supervisory Control and Data Acquisition also known as SCADA, Distributed Control System known as DCS and Automatic Tank Gauging. These alternatives were selected through a literature review.

2.4 Multi Criteria Decision Making
Decision-making is a complicated process that is influenced by a variety of circumstances. Experts in various domains may have competing interests, thus they may propose different solutions. Problems may have numerous objectives or qualities, each of which has its own unit of measurement. Multi-Criteria Decision is a set of techniques for solving problems with numerous criteria and objectives (Rezaeisabzevar et al. 2020). Identifying qualities, criteria, constraints, alternatives, and goals is the first phase in MCDM. Attributes are a grouping of criteria and goals. The procedure's effective factors are the criteria. It's a set of operational parameters that decision-makers can evaluate and weigh. The attribute with the highest score is the most appropriate. Constraints are the boundaries and factors which must be considered during the procedure. Constraints can hinder decision-makers from choosing particular options or limit them to a limited number of options. A pre-existing candidate for a purpose that is ranked by the decision maker based on criteria and limits is referred to as an alternative. Goals are the system's ultimate objectives that the decision maker must reach. MCDM is a process in which data is collected according to a procedure, reviewed and translated by an algorithm, and then options are selected according to suitability utilizing information and expert opinions. This

approach has the advantage of being able to employ both qualitative and quantitative data. In addition to objective decision-making techniques, this capacity is used to construct subjective judgements (Rezaeisabzevar et al. 2020).

2.4.1 Best Worst Method

The Best Worst Method uses two pairwise comparison vectors to weigh the criterion (Rezaei 2015). The policy maker determines the optimal and worst factors, and then compares the top (most essential) and worst (least relevant) criteria to other criteria using a scale (1-9). This method, which employs a 1-9 scale to measure the disagreement, can be used to remedy the inconsistency of a pairwise comparison. BWM and AHP differ in that BWM just does preference comparisons, which means it only needs to find the best criteria's preference over all other criteria and all criteria's preference over the worst criteria using numbers 1 and 9.

2.4.2 COPRAS (Complex Proportional Assessment)

The COPRAS (Complex Proportional Assessment) approach, which was created by Zavadskas et al. in 1996, is a strategy to analyzing and picking the best option from a group of likely options. This technique compares the straight and proportionate ratios of the best solution with the proportion of the worst optimal situation to find the most suited option. This strategy is based on alternative attributes and is used to solve difficult real-world problems where attribute properties clash (Nguyen et al. 2015). COPRAS addresses problems by calculating the ratio between the ideal and worst ideal solutions (Deepa et al. 2019).

3. Methodology

To complete the four-phase IoT technology selection process, the technique integrates BWM and COPRAS. To define the IoT adoption criteria, the first step is to do a literature review. The second process entails having professionals confirm the IoT requirements. The third phase, which utilities BWM, uses expert judgment to decide the relative weight of each criterion. The COPRAS approach's fourth step determines each IoT technology option's significant value and utility that can be used to determine the rating of IoT technology. The overall steps can be seen on Figure 1.

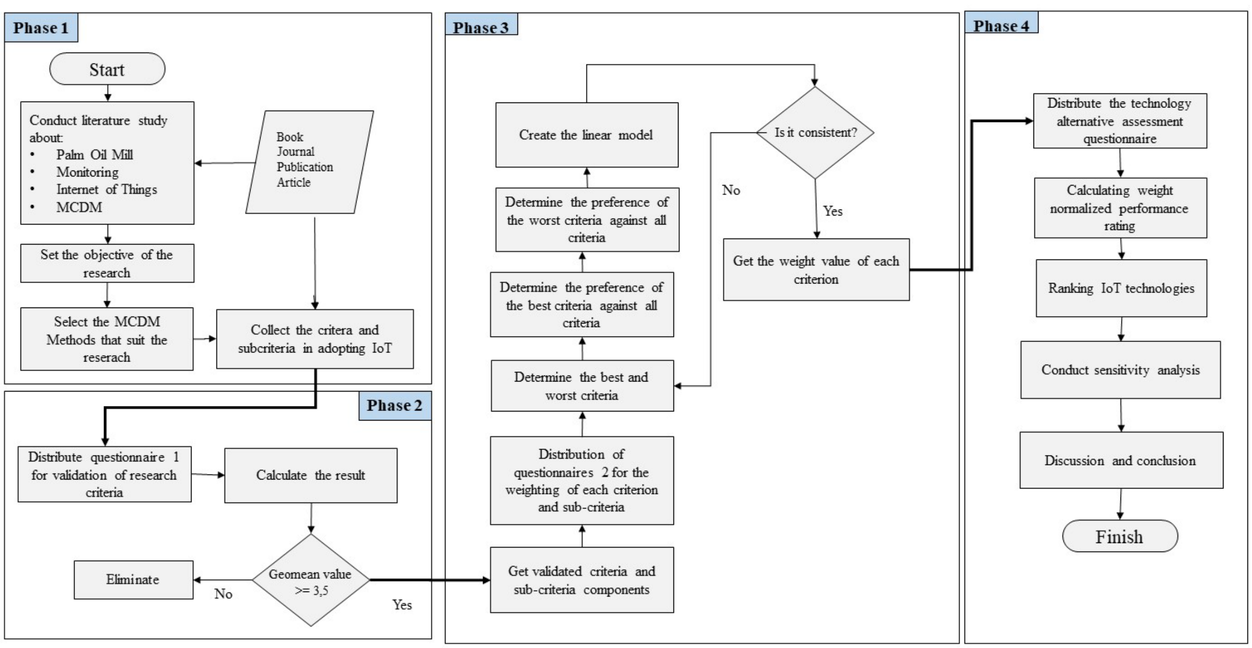

Figure 1 Methodology of the research

4. Data Collection

This research is carried out by handing out three questionnaires to the respondents. The first questionnaire is for sub-criteria validation, in which sub-criteria are initially gathered by a comprehensive literature research. The criteria are then validated by the respondents, who assign a score from 1 to 5, with 5 being the most important in the palm oil mill environment. After that, the scores are compared to the geomean score (Arovah and Dachyar 2020). Seven experts assessed the questionnaire, and factors below the minimum threshold or under a score of 3.5 were removed. The results are shown in Table 1.

Table 1 The Selected Criteria and Sub criteria of IoT Adoption

Criteria	Sub criteria	References
Technology	Technology Infrastructure	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Hawash et al. 2021)
	IT Expertise	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Al Hadwer et al. 2021)
	Technology Integration	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Abdel-basset et al. 2018)
	Compatibility	(Al Hadwer et al. 2021) (Shi and Yan 2016) (Sivathanu 2019) (D. Lin et al. 2016) (Abdul et al. 2019)
	Relative Advantage	(Al Hadwer et al. 2021) (Asiaei and Nor 2019) (Sivathanu 2019) (Abdul et al. 2019)
	Ease of Use	(Shi and Yan 2016) (Abdul et al. 2019) (Park and Kim 2019)
	Trialability	(Sivathanu 2019) (Abdul et al. 2019) (Alkhater et al. 2015)
Technology	Availability	(Al-hujran and Sumaya 2018) (Alkhater et al. 2015) (Abdel-basset et al. 2018)
	Reliability	(Alkhater et al. 2015) (Tripathi 2019) (Al-hujran and Sumaya 2018)
Organization	Top Management Support	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Al Hadwer et al. 2021) (Asiaei and Nor 2019) (Shi and Yan 2016)
	Organizational Readiness	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Ahmed 2020) (Sivathanu 2019)
	Expected Benefit	(Hsu and Yeh 2017) (Ladasi et al. 2019) (Kamble et al. 2019)
	Cost Reduction	(Al Hadwer et al. 2021) (Abdul et al. 2019) (Park and Kim 2019)
	Technical Knowledge	(Shi and Yan 2016) (D. Lin et al. 2016) (Tripathi 2019)
	Acquisition cost	(Ladasi et al. 2019) (Sivathanu 2019) (Kamble et al. 2019)
	Employee Readiness	(D. Lin et al. 2016) (Staake et al. 2011) (Ahmed 2020)
	Maintenance Cost	(Kamble et al. 2019) (Pumplun et al. 2020) (Sookoo et al. 2016)
Environment	Competitive Pressure	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Al Hadwer et al. 2021)
	Government Regulation	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Al Hadwer et al. 2021)
	Support Industry	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Alkhater et al. 2015)
	Environmental Uncertainty	(Shi and Yan 2016) (D. Lin et al. 2016) (Staake et al. 2011)

	Vendor Availability	(Ladasi et al. 2019) (Sivathanu 2019) (Tripathi 2019)
Criteria	Sub criteria	References
Security	Institution Security	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Hawash et al. 2021) (Sivathanu 2019)
	Data Security	(Hsu and Yeh 2017) (Lambok Siregar and Asvial 2020) (Asiaei and Nor 2019)
	Authentication	(Abdel-basset et al. 2018) (Ning et al. 2013) (Cirani et al. 2013)
	Accountability	(Abdel-basset et al. 2018) (Chul and Shin, 2016)
	Privacy	(Abdul et al. 2019) (Park and Kim 2019) (Alkhater et al. 2015)
	Fault Tolerance	(Abdel-basset et al. 2018) (Chul and Shin 2016) (Sookoo et al. 2016)

All IoT adoption criteria and sub-criteria were weighted using the Best Worst Method. Following the many stages of the BWM technique, each expert was asked to determine the criteria and sub-criteria that had the most influence on technology adoption in oil palm mills with each level of criteria, as well as the criteria and sub-criteria that had the least effect on the decision in IoT adoption. The outcomes of utilizing BWM to process data locally with in form of values for each of criteria and sub-criteria. The overall weight for each sub criteria is calculated by multiplying the value of the value of the criteria locally with the values of the weight of the criteria, namely technology, environment, organization, and security. Alternative Internet of Things technology will be evaluated using the determined priority weight. Table 2 shows the outcomes of the weighting and ranking.

Table 2 Final Weight of IoT Adoption for Palm Oil's Storage Tank Monitoring Process

Criteria	Weight	Sub Criteria	Local Weight	Overall Weight	Ranking
Technology	0.350	Technology Infrastructure	0.126	0.0441	7
		IT Expertise	0.082	0.0287	18
		Technology Integration	0.112	0.0393	12
		Compatibility	0.130	0.0455	6
		Relative Advantage	0.096	0.0336	16
		Ease of Use	0.245	0.0860	1
		Trialability	0.065	0.0229	22
		Availability	0.045	0.0158	25
		Reliability	0.098	0.0343	15
Organization	0.369	Support from Top Management	0.111	0.0409	10
		Organizational Readiness	0.111	0.0408	11
		Expected Benefit	0.178	0.0657	2
		Cost Reduction	0.140	0.0517	4
		Technical Knowledge	0.113	0.0417	9
		Acquisition cost	0.130	0.0478	5
		Employee Readiness	0.143	0.0527	3
		Maintenance Cost	0.074	0.0274	20
Environment	0.154	Competitive Pressure	0.106	0.0164	24
		Government Regulation	0.286	0.0440	8
		Support Industry	0.170	0.0261	21
		Environmental Uncertainty	0.185	0.0285	19
		Vendor Availability	0.252	0.0388	13

Security	0.127	Institution Security	0.262	0.0334	17
		Data Security	0.283	0.0360	14
Criteria	Weight	Sub Criteria	Local Weight	Overall Weight	Ranking
Security	0.127	Authentication	0.147	0.0187	23
		Accountability	0.113	0.0144	26
		Privacy	0.085	0.0109	28
		Fault Tolerance	0.110	0.0140	27

The final questionnaires is based on the personal opinions of alternative technology by the experts. The data collected will be analysed with the COPRAS methodology to figure out the best technological priority for the palm oil mill's storage tank monitoring operation. Classifying the criteria for benefits and expenses is one of the stages in the COPRAS technique. The benefit criteria are those that have a higher value, while the cost criteria are those that have a lower value. The utility level (Ni) will be calculated once the complete sum of the criteria for benefits and costs has been processed to generate a relative significance value (Qi). The alternate priority order will be determined by these two values. When implementing IoT technology for palm oil mill storage tank monitoring, COPRAS calculations suggest that SCADA is the most significant technology to consider (see Table 3).

Table 3 Computation of Total Benefit and Cost Criteria, as well as the relative significance and utility of every alternative

Alternative	Benefit	Cost	Relative Significance Value (Qi)	Utility Level (Ni)	Rank
SCADA (Supervisory Control and Data Acquisition)	0.31463	0.0260	0.338209	100%	1
DCS (Distributed Control System)	0.30482	0.0290	0.325970	96.38%	3
ATG (Automatic Tank Gauging)	0.30541	0.0202	0.335821	99.29%	2

5. Results and Discussion

The results of the weighing of the criteria suggest that for the application of IoT technology in palm oil mills, the factor with the highest weight is organization, followed by technology, environment, and security. Organizations are ranked first because they are more likely to use new technology to increase performance because they have the necessary human resources and financial resources. This finding is consistent with (Bandura 2001), who discovered that enterprises will not adopt an invention even if they enjoy it if they lack the necessary skills, resources, and money to do so. This emphasizes the relevance of the company's financial readiness and ability to implement new technologies. Security is the lowest-weighted criterion since, according to experts, it can be enhanced by designing a security strategy, estimating the danger and probability of security attacks, as well as the effects of security threats based on previous experience. The sub-criterion with the highest weight in the sub-criterion weighing is ease of usage. The reason for this is that the majority of users are palm oil supply chain employees with low experience, so ease of use is critical. Privacy is one of the problems in deploying IoT, however it receives the lowest sub-criteria weight in this study. Employees are willing to give up their privacy in exchange for more productivity and profits.

According to the findings of the technology assessment, SCADA is the most appropriate system for monitoring storage tanks in palm oil mills. The first Pi value or advantage is SCADA technology, followed by ATG and DCS. Compatibility (T4), Relative Advantage (T5), Expected Benefits (O3), Cost Reduction (O4), and Fault Tolerance (T5) are all sub-criteria that the SCADA assessment shines in (S6). The value of Ri or Cost indicates that DCS technology is placed first, indicating that it has the highest implementation cost. The amount of gaps between ranks one and two is rather small, at 3.62 percent. Experts believe that the superiority of SCADA is due to the system's ability to collect data from one or more sources.

SCADA was chosen as the IoT implementation for palm oil's storage tank monitoring process measures based on the prior data processing. This research looks at three scenarios to see if the ranking of technology shifts. The first scenario is one in which the government encourages the use of IoT in the industrial sector and increases the quality of human resources in palm oil mills. The weights of environmental and organizational factors will be raised by 50% in this scenario. Changes in weight in the first scenario can be seen in Figure 2.

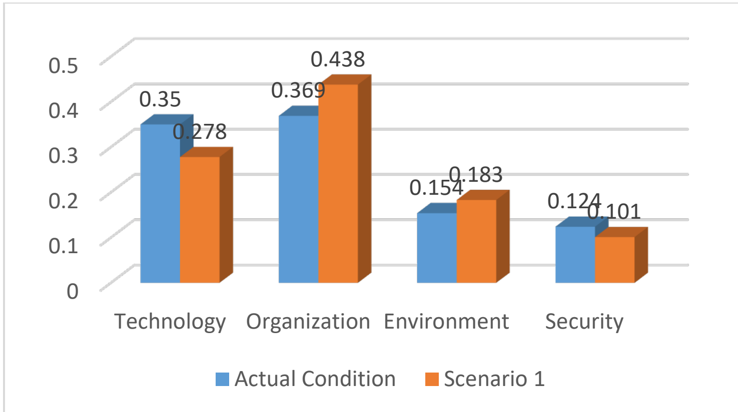

Figure 2 Graph of Change in Weight After Organization and Environment Criteria Increases 50%

The second scenario in which interoperability issues arise is when the device being utilized is unable to exchange data on a reliable network. As a result, the weight given to technological factors will be increased by up to 50%. Changes in weight in the first scenario can be seen in Figure 3.

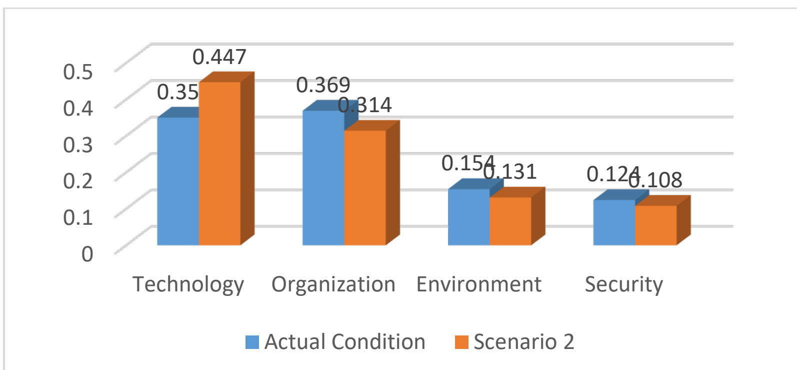

Figure 3 Graph of Change in Weight After Technology Criteria Increases 50%

The third scenario is the emergence of the cybercrime problem. As a result of this scenario, the weight of the security requirement is enhanced by 50%. Changes in weight in the first scenario can be seen in Figure 4.

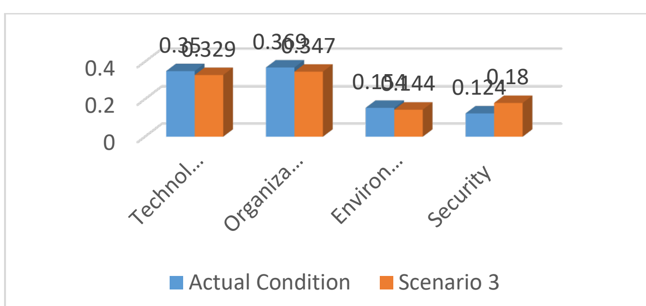

Figure 4 Graph of Change in Weight After Security Criteria Increases 50%

Two of the options in scenarios 2 and 3 have the same priority, as shown in Table 4. However, after the analysis of scenario 1, there is a shift in technological ranking (see Table 4).

Table 4 After a scenario analysis, the priority of alternative technologies shifts.

Technology Selection	Actual Condition		Scenario 1		Scenario 2		Scenario 3	
	Utility Level (%)	Rank	Utility Level (%)	Rank	Utility Level (%)	Rank	Utility Level (%)	Rank
SCADA	100%	1	99.85%	2	100%	1	100%	1
DCS	96.38%	3	96.42%	3	95.93%	3	96.66%	3
ATG	99.29%	2	100%	1	99.18%	2	98.41%	2

However, of the three assumed scenarios, SCADA technology is often an alternative technology with implementation priorities. The capabilities of this technology are also in line with the company's requirements, as it is widely utilized in process control and commercially offered systems. As a result, palm oil mill management tends to prioritize the adoption of this technology because it aligns with the organization's aim to simplify the process of monitoring storage tanks in the storage process in order to maintain quality and increase reading accuracy.

6. Conclusion

This study shows that the objective of using a combination of BWM and COPRAS methodologies to determine the optimal IoT technology application was achieved. This research resulted in the selection of 28 sub-criteria from four existing criteria. The Ease of Use sub criteria has the highest weight in the BWM computation findings, indicating that this factor plays a huge role in adopting the IoT. According to COPRAS, SCADA technology should be prioritized when considering IoT technology deployment for storage tank monitoring process measures at palm oil mills because it has a 100% utility rate. Based on the fact that these technologies have high priorities in the majority of cases, the final results suggest that SCADA is the top priority for technologies that can be implemented.

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