Design of Internet of Things Alternatives Selection for Pallet Management in a Cement Company

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Abstract

Internet of Things is a set of applications that equip devices and locations to generate information and correlate it for data analysis. IoT has revolutionized how industries to act. It has a considerably new opportunity to generate compelling solutions exploring how a company can collect and analyze disparate data that might transform the business in real-time and across time. IoT has a broad implementation in the business, including in the cement industry, particularly on its pallet management system. A good pallet management system is required to ensure the good quality of pallet used in transporting products. In a cement company, pallets are transported to warehouses and retails using trucks. A standardized manual to handle pallets is required to make sure that it does not break or lost due to poor handling. This study's main objective is to assess the best alternative of IoT that used to ease pallet management system in a cement company. Using Best Worst Method (BWM), the priority of criteria was decided. The best alternative of auto-identification technology was selected using Additive Ratio Assessment (ARAS). Result of this research shows that RFID is the best alternative with utility score of 0,9854 performance rating index of 0,3452.

Keywords
Pallet Management, Internet of Things, Best Worst Method, Additive Ratio Assessment

1. Introduction
Real-time tracking of commodities in the supply chain has always been problematic due to the heterogeneity of platforms utilized in the supply chain. The Internet of Things, along with cloud computing, allows supply chain actors to collect, move, store, and exchange data with greater interoperability. (David et al., 2015).RFID and barcodes are common IoT gates used in supply chain. (Kirch et al., 2017) stated that this kind of auto-identification technology, specifically RFID, is commonly applied as identification of returnable shipping equipment such as pallets or containers. RFID is suitable for pallet identification tools because although there are many, the pallets used are usually not diverse, and it makes identification easier. In previous study, (Zhang & Dong, 2014) stated that with the rapid development of the economy, and in response to the needs of many industries, pallet monitoring and traceability, RFID technology offers considerable benefits over barcode technology. This study was held in a cement company. This company data states that the implementation of the new pallet management and monitoring system has succeeded in reducing the frequency of cement bag damage and eliminating the cost of forklifts at the plant. A potential loss of $267,000 might occurs without a better pallet management.

1.1 Objectives
This study's main objective is to assess the best alternative of IoT that used to ease pallet management system in a cement company.

2. Literature Review

2.1 Pallet Management

In previous study conducted by (Roy et al., 2016) cost-effective strategies for pallet management was proposed. (Elia & Gnoni, 2015) designed a closed loop system for managing pallet. (Zhang & Dong, 2014) demonstrated tracking system for pallet.

2.2 Internet of Things

The so called Internet of Things (IoT) is a developing network of tangible and intangible items that rely on the internet to communicate with one another (Brous et al., 2020). IoT is the concept of delivering data over the internet with little or no human-to-human and also human-to-PC interaction. The concept of IoT necessitates the association of objects with the internet. In previous studies, IoT is to be implemented in hospital for unit selection (Dachyar & Azizia, 2019), and telecommunication company (Dachyar & Risky, 2014). The Internet of Things (IoT) was previously used for improvement to be implemented in hospital in a previous study (Mahendra & Dachyar, 2019).

2.3 Best Worst Method (BWM)

The original BWM used a nonlinear model that occasionally produced several ideal weights, resulting in each criterion's weights being shown as intervals (Rezaei, 2015).
Decision makers have a strong awareness of the range of assessments that might result in more reliable pairwise comparisons by assessing factors that are considered best and worst prior to compare factors or alternative in a pairwise comparison. As a result, the paired comparison will be more consistent, as proved in Rezaei's original study (Rezaei, 2020). BWM was utilized as a tool to prioritize IoT application for educational purposes (Pour et al., 2020). BWM was integrated with ARAS for supplier selection (Liao et al., 2019).

2.4 Additive Ratio Assessment (ARAS)

The challenge of ranking a finite number of decision options, each of which is explicitly specified in terms of different decision criteria that must be taken into account simultaneously, is a common MCDM problem (Zavadskas & Turskis, 2010). The greater the value of the S_i optimality function, the more effective the option. Alternative priorities can be established using the S_i value.As a result, when this strategy is employed, it will be easier to analyze and rank choice options. The comparison of the studied variance, with ideally S_0, determines the degree of usefulness of the alternative (Zavadskas & Turskis, 2010). ARAS was integrated with BWM for supplier selection in previous study (Liao et al., 2019).

3. Methodology

The first step in this research methodology is factor collection. Collected factors are then validated by experts. Selected factors then will be weighted based on its importance using Best Worst Method and alternative solutions will be ranked using ARAS method. After these processes, the last step is generating analysis and conclusions.

4. Data Collection

First questionnaire aims to assess which of the collected factors are being considered when cement company is considering to use an IoT technology. The threshold value being used is 3.5. Six experts participated in filling the questionnaire and the result of the questionnaire leads to 26 subfactors being selected to be used in this study (See Table 1).

Table 1. Selected Subfactor

Factor	Subfactor
Organization	Top Management Approval (Hsu & Yeh, 2017)
	Organization Readiness (Fu & Chang, 2016)
	Business Operation Scope (El-Haddadeh et al., 2019)
	Perceived Benefit (Gangwar et al., 2014)
	Maintenance Cost (Kamble et al., 2019)

Factor	Subfactor
Environment	Vendor Support (Tripathi, 2019)
	Government Regulation Support (Krotov, 2017)
	Customer Pressure (Quetti et al., 2012)
Technology	Availability (Al-Hujran et al., 2018)
	Trialability (Alshamaila et al., 2013)
	IT Ability (Palacios-Marqués et al., 2015)
	Technology Readiness (Rosas et al., 2017)
	Relative Advantage (Al-Hujran et al., 2018)
	Technology Integration (Chana & Chong, 2013)
	Accuracy (Fosso Wamba and Ngai, 2013)
	Implementation Cost (Poon et al., 2011)
	Software Cost (Huber et al., 2007)
Tag Properties	Tag Data Storage (Fosso Wamba and Ngai, 2013)
	Tag Reading Ability
	Tag Cost (Fosso Wamba and Ngai, 2013)
	Visibility (Sarac et al., 2010)
Security	Compatibility (Ng & Wakenshaw, 2017)
	Privacy Security (Kumar et al., 2016)
	System Security (Gangwar et al., 2014)
	Data Security (Dey et al., 2016)
	Accountability (Abdel-Basset et al., 2018)

The prior questionnaire's reliability was determined using Cronbach's Alpha. The Cronbach's Alpha assessment carried out showed that with a total of 31 subfactors, the total variance was 15.67; and the total score variance is 112.556, Cronbach's Alpha is worth 0.889 so that the questionnaire is said to be at a reliable level. The result is shown in Table 2.

Table 2. Reliability Test with Cronbach's Alpha Assessment

Number of Items	31
Sum of Variance	15,67
Variance of Total Score	11,255,556
Cronbach's Alpha	0,889503

5. Results and Discussion

5.1 Factors Weight of IoT to be Implemented for Pallet Management

Five experts participated in filling the weighing questionnaire for selected factors. Assessment are based on experience and knowledge of experts. Each subfactors are weighted individually, and this weight is considered as subfactor's local weight. Subfactor's local weight is then multiplied by its factor's weight. This value is considered as subfactor's global weight (See Table 3).

Table 3. Weight of Each Subfactor

Factor	Subfactor	Weight	Global Weight	Rank
Organization	Top Management Approval	0,201	0,034	13
	Organization Readiness	0,275	0,046	9
	Business Operation Scope	0,071	0,012	25
	Perceived Benefit	0,327	0,055	6
	Maintenance Cost	0,126	0,021	21
Environment	Vendor Support	0,179	0,013	24
	Government Regulation Support	0,242	0,017	23
	Customer Pressure	0,579	0,041	11
Technology	Availability	0,105	0,038	12
	Trialability	0,080	0,029	15
	IT Ability	0,071	0,026	18
	Technology Readiness	0,118	0,043	10
	Relative Advantage	0,189	0,069	3
	Technology Integration	0,181	0,066	5
	Accuracy	0,149	0,054	7
	Implementation Cost	0,060	0,022	20
	Software Cost	0,048	0,018	22
Tag Properties	Tag Data Storage	0,207	0,022	19
	Tag Reading Ability	0,249	0,026	16
	Tag Cost	0,081	0,009	26
	Visibility	0,463	0,049	8
Security	Compatibility	0,091	0,026	17
	Privacy Security	0,233	0,067	4
	System Security	0,268	0,077	2
	Data Security	0,304	0,087	1
	Accountability	0,105	0,030	14

Consistency ratio was also calculated. The weighing of factors are only considered acceptable when its consistency ratio is no bigger than 1. Consistency ratio was performed to assess the consistency of the five factors: Technology, Organization, Environment, Tag Properties, and Security. With the result shown in figure 1., The consistency ranges between 0.1 – 0.7, which can be concluded that the weighing can be accepted.

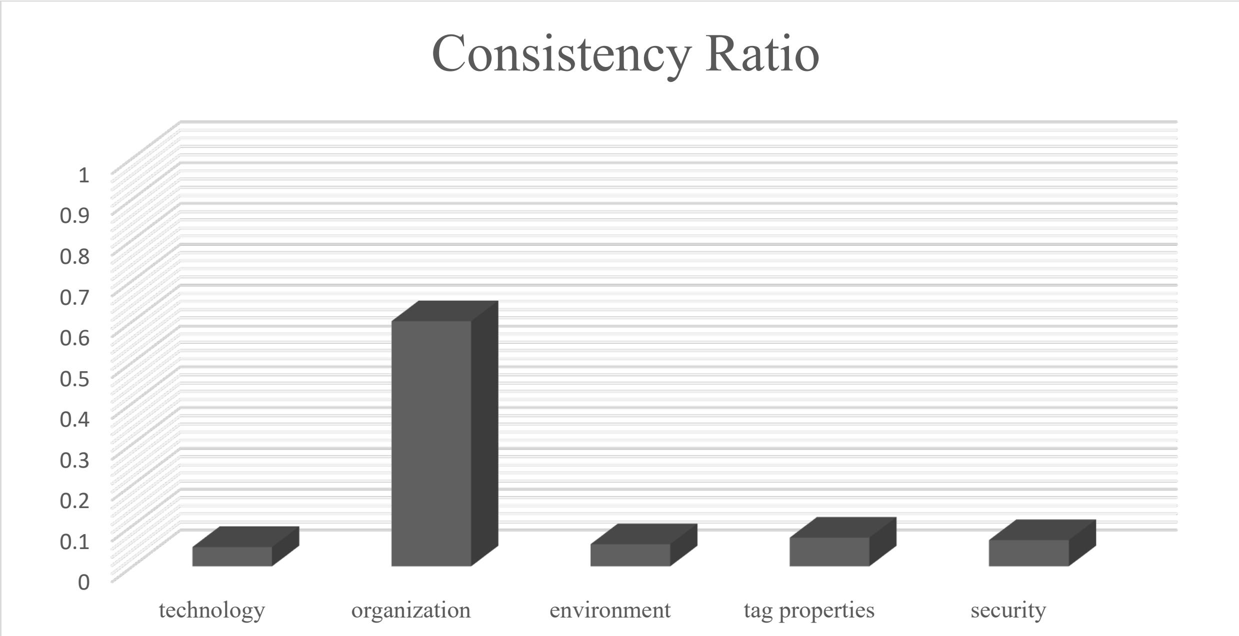

Figure 1. Consistency Ratio of Factors

5.2 IoT Alternatives Assessment

The next step following the weighing of factors and subfactors is to assess which IoT alternative should be chosen as priority to be adopted in cement company. Using the third questionnaire, five experts assessed the rating of each alternative against the factors and subfactors being used in this study. ARAS method was used to process the assessment. Subfactors are being divided into beneficial and non-beneficial subfactors and are being processed differently. There are 21 beneficial subfactors (See Table 4).

Table 4. Beneficial Subfactors

Beneficial Subfactors	
O1	Top Management Approval
O2	Organization Readiness
O3	Business Operation Scope
O4	Perceived Benefit
L1	Vendor Support
L2	Government Regulation Support
T1	Availability
T2	Trialability
T3	IT Ability
T4	Technology Readiness
T5	Relative Advantage
T6	Technology Integration
T7	Accuracy
A1	Tag Data Storage

Beneficial Subfactors	
A2	Tag Reading Ability
A4	Visibility
K1	Compatibility
K2	Privacy Security
K3	System Security
K4	Data Security
K5	Accountability

There are 5 subfactors that are classified into non-beneficial subfactors. The consideration was made because the bigger the value of these subfactors, it will make more loss for the company. The process of finding optimal value for these subfactors are different than the other 21 subfactors that are classified as beneficial factors. Subfactors associated with cost (maintenance cost, implementation cost, software cost, tag cost) and pressure (customer pressure) are classified into this category (See Table 5).

Table 5. Nonbeneficial Subfactors

Nonbeneficial Subfactors	
O5	Maintenance Cost
L3	Customer Pressure
T8	Implementation Cost
T9	Software Cost
A3	Tag Cost

The last step is perform ARAS to weigh each alternatives against subfactors, simply by multiplying local alternative weights the experts gave by subfactors weight assessed using BWM in the previous step to find alternative's local weight. Each alternatives are weighted against 26 subfactors, both the beneficial factors and non beneficial factors classified in Table 4 and Table 5. The weighing of alternatives against each subfactors is shown in Table 6.

Table 6. Weight of Alternatives Against Each Subfactors

Subfactors	RFID		Barcode	
	Local Weight	Final Weight	Local Weight	Final Weight
Top Management Approval	0.355	0.012	0.290	0.010
Organization Readiness	0.321	0.015	0.340	0.016
Business Operation Scope	0.340	0.004	0.321	0.004
Perceived Benefit	0.344	0.019	0.311	0.017
Maintenance Cost	0.365	0.008	0.269	0.006
Vendor Support	0.357	0.004	0.287	0.004
Government Regulation Support	0.323	0.005	0.338	0.006
Customer Pressure	0.333	0.014	0.333	0.014
Availability	0.338	0.013	0.323	0.012
Trialability	0.354	0.010	0.292	0.009
IT Ability	0.287	0.007	0.357	0.009
Technology Readiness	0.323	0.014	0.338	0.014
Relative Advantage	0.343	0.024	0.314	0.022

Subfactors	RFID		Barcode	
	Local Weight	Final Weight	Local Weight	Final Weight
Technology Integration	0.337	0.022	0.326	0.022
Accuracy	0.364	0.020	0.272	0.015
Implementation Cost	0.346	0.008	0.308	0.007
Software Cost	0.346	0.006	0.308	0.005
Tag Data Storage	0.367	0.008	0.266	0.006
Tag Reading Ability	0.372	0.010	0.255	0.007
Tag Cost	0.360	0.003	0.280	0.002
Visibility	0.355	0.017	0.290	0.014
Compatibility	0.340	0.009	0.321	0.008
Privacy Security	0.358	0.024	0.284	0.019
System Security	0.355	0.027	0.290	0.022
Data Security	0.361	0.032	0.278	0.024
Accountability	0.344	0.010	0.311	0.009

Using ARAS, the S_i (overall performance index of a device) and Q_i (utility level value) of both IoT alternatives is calculated. The results obtained for the weighting of each alternative are as follows. RFID excels with S_i of 0.3452 and Q_i of 0.9854 compared to barcodes with Si of 0.3020 and Qi of 0.8622. So, RFID is a better alternative to be applied in pallet management of cement companies. RFID is ranked 1 against barcode due to higher both S_i and Q_i value which indicates better performance (See Table 7).

Table 7. Each Alternatives Assessment

IoT Technology	S_i	Q_i	Rank
RFID	0.3452	0.9854	1
Barcode	0.3020	0.8622	2

5.3 Scenario Analysis

Three scenarios was designed to check sensitivity of IoT technology priority selection. The first scenario is the lack of compatibility of newly adopted IoT devices with systems that are already in use results in the absence of interoperability (the ability of two or more systems to exchange information) on the IoT system. This makes it difficult to transmit data across platforms, hinders data transfer and eliminates the opportunity to use it as a decision-making tool in enterprises. This scenario causes a 50% increase in the weight of Technology and Security factors. The change in the new normalized weight of factors is shown in figure 2.

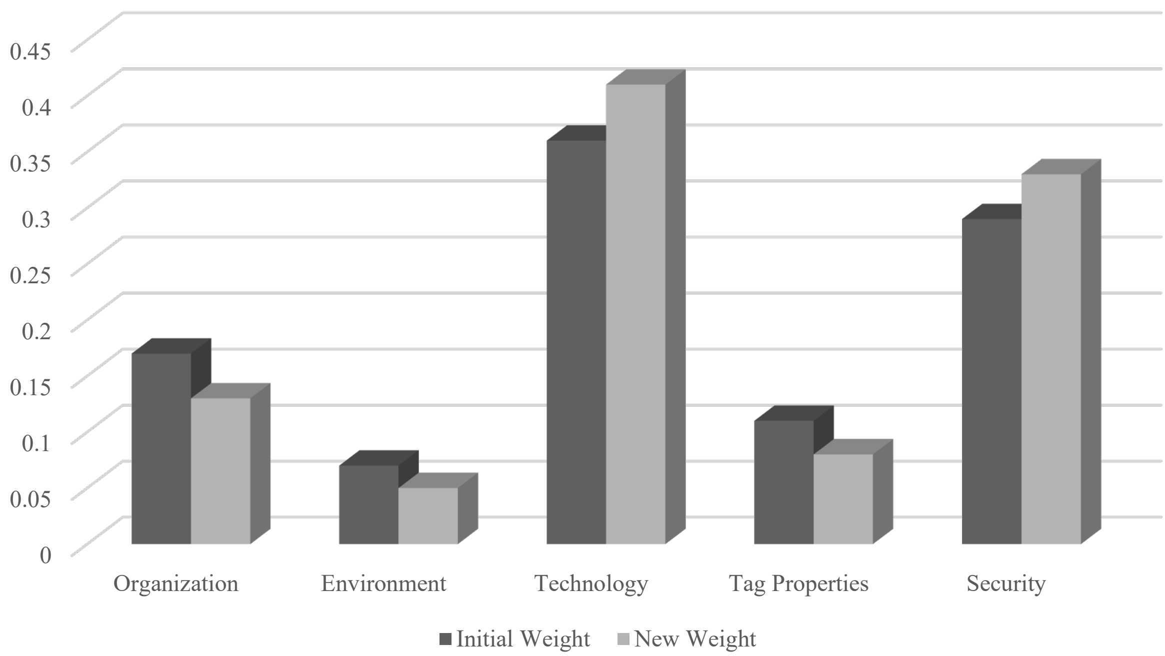

Figure 2. Factor Weight Change in Scenario 1

The second scenario is the occurrence of problems related to security attacks toward the data, which have far-reaching consequences for individuals, organizations and supply networks. Related examples of attacks include services, eavesdropping, forgery, unauthorized access, and data theft. Related examples of attacks include services, eavesdropping, forgery, unauthorized access, and data theft. For smart logistics, information is a major concern due to loss of personal and organizational information. This scenario causes a 50% increase in the weight of Security factor. The change in the new normalized weight of factors is shown in figure 3.

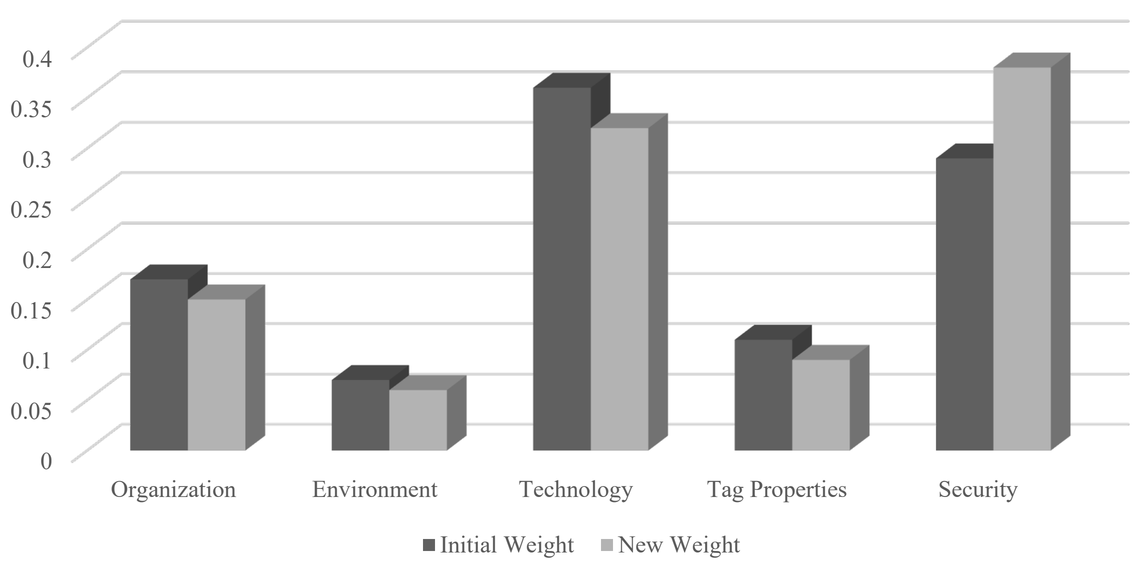

Figure 3. Factor Weight Change in Scenario 2

The third scenario implies a situation where the government encourages the people to get into the use of Internet of Things in various regions, and focuses attention on the spread of its use. The goal is to increase work productivity. The government is also preparing the best scenario to ward off security attacks in the implementation of IoT. This scenario causes a 50% increase in the weight of Environment factor. The change in the new normalized weight of factors is shown in figure 4.

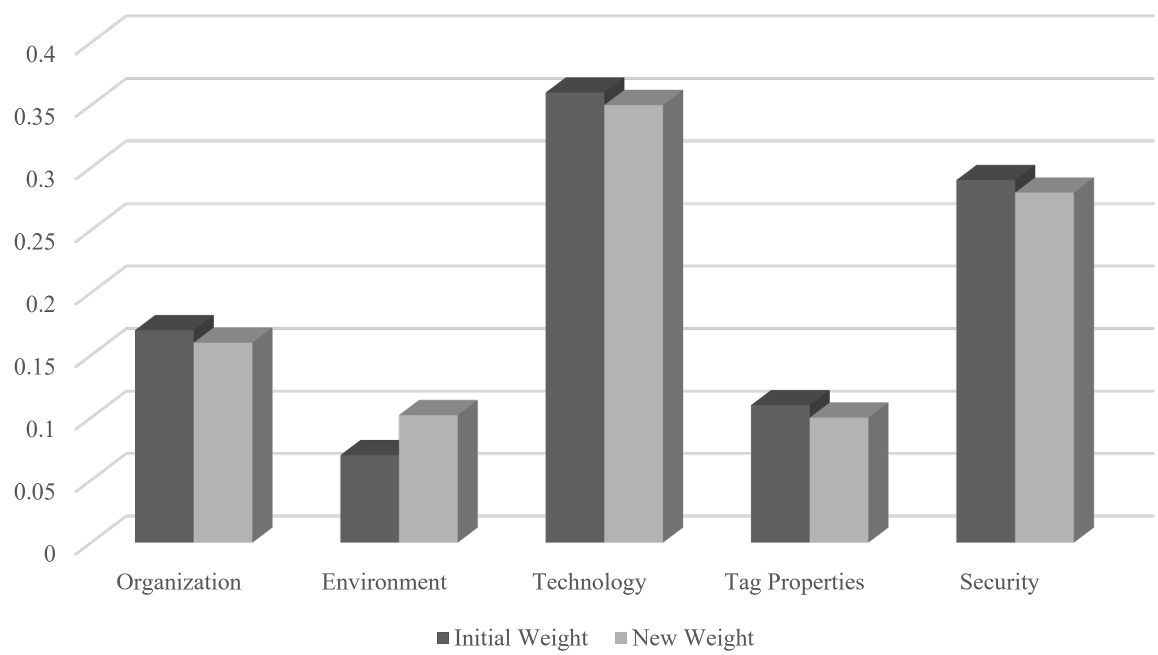

Figure 4. Factor Weight Change in Scenario 3

The Qi value of the three scenarios are then compared to the initial condition. RFID, which is considered to have a superior security compared to barcode, increases its utility value in the three scenarios. The rank of priority does not change. In the three scenarios, RFID remains as the top priority despite the changes in the weighs of factors (See Table 8).

Table 8. Change in Utility Value in Each Scenario

Alternative	Initial Condition		First Scenario		Second Scenario		Third Scenario	
	Utility Value	Priority Rank	Utility Value	Priority Rank	Utility Value	Priority Rank	Utility Value	Priority Rank
RFID	0.9854	1	0.9892	1	0.9924	1	0.9883	1
Barcode	0.8622	2	0.8659	2	0.8610	2	0.8679	2

6. Conclusion

In this research 26 subfactors were used to assess the best alternatives to be adopted for pallet management in a cement company. The calculation using BWM shows that Data Security is the most important subfactors to be considered in IoT adoption. ARAS is used to decide technology ratings by calculating optimal value and utility level of each alternative. Result and scenario analysis shows that RFID is the top priority to be adopted with utility value of 0.9894.

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