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Study on Radio Frequency Identification (RFID) Implementation for Effective Materials Tracking at Congested Construction Site

Loh Yuan Shien[1], Narimah Kasim[1,*], Rozlin Zainal[1], Sharifah Meryam Shareh Musa[1] & Hamidun Mohd Noh[1]

[1]Department of Construction Management, Faculty of Technology Management and Business, Universiti Tun Hussein Onn, Batu Pahat, 86400, MALAYSIA

*Corresponding Author

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Abstract: Due to the population of Malaysia rise every year and the demand for property increase so the construction industry in Malaysia growth rapidly. Some of the states in Malaysia that occur urbanization lead the construction project in the current state increase and cause limited space for the construction project. Limited space of construction site directly affects to the congested construction site and bring delay issues. One of the factors of delay issues is the materials tracking problem at the congested construction site. Many types of materials tracking system implementation at the congested construction site but Radio Frequency Identification (RFID) seem more prominent. Even though RFID is established in the market but there are still challenges in the implementation of this technology. Therefore, this study seeks to identify the effectiveness of materials tracking at the congested construction site with the potential implementation of RFID. The research methodology adopted in this research is quantitative methods and the instrument that use to collect the data is questionnaires. The location of this research was conducted at Johor and the respondents of this research are G7 contractors. The results of this study show that RFID has the potential in providing convenient materials tracking to reduce the cost of materials wastage. The biggest challenge of RFID implementation is the financial support due to the cost of technology. In conclusion, the research provides substantial knowledge of effective materials management with RFID implementation in material tracking at the congested construction site.

Keywords: Congested, Construction site, Materials tracking, RFID

1. Introduction

Nowadays, Malaysia still in the stage of a developing country and has not changed to a fully developed country. It requires full possession of an economy that is competitive, dynamic, robust, and resilient. Although Malaysia just a developing country but the population still increasing every year.

**Corresponding author: narimah@uthm.edu.my*

The current population of Malaysia is now 32,217,248 as of February 2020 (Worldmeter, 2020). The population of Johor Bahru has reached 3.76 million in 2019 (Department of Statistics Malaysia, 2019). The increase of the population of Malaysia has mainly influenced the land usage of Malaysia in any function especially in the construction industry. Due to the population increases, they need more residential as their shelter and more buildings that provide the jobs to stimulate the economy. The construction sector is expected to improve in 2020 with a growth rate of 3.7%, because of acceleration and revival of megaprojects as well as the building of affordable homes (The Edge Market, 2019). The increases in the construction project will get the effect of the limited space of the construction site. The limited space of the construction site will place with plenty of materials that will be used and the site become congested. The scarcity of construction site space imposes serious challenges for contractors in planning material supply. The site layout planning faces critical performance limitations in congested construction sites, due to the contractor's poor utilize interior building spaces for long-term material storage (Said & El-Rayes, 2012). Limited space will come out with some issues like unable to find out certain materials in a short time, delivery system on-site will take a long time, limited space of walkway and others. The congested construction site full of plenty of materials and equipment. Hence, the area that can be used becomes limited and all the arrangements of materials are in disorder. This may cause issues of materials identification difficulty and missing materials. If the materials have vanished, this will lead to the purchase of the new materials. This process will extend the project time and increase the cost of the project. Due to the messy and congested construction site, the walkway of the workers will be limited and sometimes the issue of safety and health of the workers will happen. Congested construction site strongly needs the technology to help the contractor in materials management specifically materials tracking. In this technology world, most of our problems can be solved by technology. In congested construction sites, the contractor can use technology to track the materials more effectively. For example, the technology that can be implemented such as Global Positioning System (GPS), Congested Construction Logistics Planning (C2LP), Radio Frequency Identification (RFID), Barcode and others (Misron, *et al.* , 2018). All of these systems have the function of tracking and identifying the materials on-site effectively. Technology implementation for effective materials tracking at the congested construction site is essential for the project can be done easier and reduce the time been used. Therefore, this research will study the potential implementation of RFID for effective materials tracking at the congested construction site. In addition, the challenges of RFID also determine in order to improve materials tracking productivity at the congested construction site.

Missing or destructive materials become a problem to increase the cost of the project. In congested construction site only have limited space to store the materials, so it is difficult to keep materials on-site and sometimes improper management of on-site activities cause the machinery cannot be adjusted on-site (Arijeloye & Akinradewo, 2016). The materials tracking system can help to detect where the material has been a store and how is the condition of the materials. With the technology implemented, the arrangement of the materials on-site can be tidier and free up more space at the congested construction site. Delay issue is a common problem that always happens in the construction industry. Arijeloye & Akinradewo (2016) state that the preparation of material schedule has been determined can help with the problem of on-site material handling. This was prepared by the quantity surveyor and contractor during the contract phase of the building contract in order to know exactly how much material to mobilize the site. Project delay will increase the cost of the project such as cost of labour, cost of rental equipment, penalty due to the delay time, and others. Misron *et al.* (2018) state modern technologies such as mobile phones and laptops or other appropriate and affordable technologies likes Radio Frequency Identification (RFID) should be used to help better material handling and the ability to detect materials at the congested construction site. Besides, RFID is a technology system that needs skilled workers to operate it but most of the workers that work at construction sites do not have the ability to operate the system. This forces the contractor must provide additional training to their workers to efficiently use the technique but hindrances are

observed due to employee resistance and additional costs (Kereri, 2018). According to Kereri (2018) state that this technology needs institutional support, the willingness, and preparation of organizations for adopting these technologies are necessary but currently, it is minimal. Therefore, this study is to identify the potentials and challenges of RFID implementation for effective materials tracking at the congested construction site.

2. Literature Review

2.1 Materials Tracking at Congested Construction Site

An important factor that adversely affects the performance of construction projects is the improper handling of materials during site activities. Material management will occur problem due to material shortages, delay in supply, price fluctuations, damage and wastage, and lack of storage space. In addition, paper-based reports are mainly used to record and exchange information about material components in the supply chain, which are problematic, error-prone, and inefficient (Kasim, 2008). Limited space of congested construction site is strongly needed materials tracking system to avoid any issues occurs. The traditional materials tracking method still using the DO form to record the flow in and out of the materials. This will waste the manpower to record all the flow and sometimes there will be some mistakes. The improper record will cause the workers cannot to find out the materials that want to be used (Kereri, 2018). If technology likes RFID, bar-coding, GPS and others had been implemented, the usage of manpower will be reduced because all the flow of materials can be detected by the sensor. Table 1 shows the comparison between the RFID system, Bar-coding system, and GPS system.

Table 1: Comparison of technology for materials tracking (Lu, Huang, & Li, 2011)

Item	Issues	RFID	Bar-coding	GPS
1	Cost of tags	Cheap	Cheapest	Expensive
2	Storage capacity	Medium	Smallest	Largest
3	Read range	a few inches-30 feet (passive tags) 60 feet-300 feet (active tags)	0-10 inches	Unlimited
4	Size	Small	Small	Large
5	Ease of positioning for sensing	Medium	Difficult	Easy
6	Knowledge of items' exact position	Medium	Difficult	Easy

Additional costs can be happened due to the missing and destructive materials. Arijeloye & Akinradewo (2016) state that congested constructions sit only have limited space to store the materials and the congested construction site will full of machinery and materials. Improper on-site activities will cause accidents happened such as falling, injured, slips and others. Due to the scarcity of the congested construction site, the process of delivering materials to the site will be increased. The lorry that delivers materials in and out of the congested construction site is the heavy machinery and when long term the pavement of the road will be broken. The broken road requires unscheduled repair and these areas need to be kept appropriately clean, which requires additional work (Radziszewska-Zielina & Kania, 2017). Table 2 shows the factors of materials tracking implementation at the congested construction site.

Table 2: Factors of materials tracking implementation at congested construction site

Item	Factors

1	Avoid missing or destructive materials, late delivery materials on site.
2	Avoid extension time.
3	Avoid the additional cost of the project.
4	Overcome the human error that will occur in the traditional method.
5	More accurate with the technology and the big database.

2.2 Technology Implementation for Material Tracking

(a) Radio Frequency Identification (RFID)

RFID is a technology that uses radio waves of different frequencies to identify objects. A typical RFID system includes RFID tags and RFID readers. RFID tags are usually made of microchips that store data and an integrated antenna serving as transmitters (Lu *et al.*, 2011).

(b) Bar-coding

Bar-coding technology has been widely used in Malaysia for materials tracking at construction sites. Bar-coding provides the latest and up-to-date information about the number of alternatives and equipment exchanged between store managers and workgroups. The bar-coding systems can detect items involving printing and attaching labels on materials, scan labels, enter the latest information into computers, and use software to track and run the reports of the material on-site. Each barcode system has a unique identification number (ID) and attaches to every material (Misron *et al.*, 2018). The bar-coding system also has the ability to deliver all the information of the materials by scanning the barcode with the scanner. The bar-coding system is cheaper than the RFID system because it is easy to produce and no need for special tags.

(c) Global Positioning System (GPS)

GPS able to provide 24 hours all-weather positioning anywhere on or near the earth (Lu *et al.*, 2007). GPS (Global Positioning System) vehicle tracking device that includes fleet management software provides a complete automated electronic toolkit to help with equipment and personnel management. GPS helps contractors who deploy project resources to navigate complex manpower and machine distribution networks. GPS has been widely used because of the ubiquity, high accuracy, and low cost. However, GPS-based positioning systems suffer from signal shielding and multipath errors in areas such as urban canyons, streets lined with trees, tunnels, and building sites. In addition to on-site and off-site vehicle and equipment tracking and theft protection, the records generated by GPS tracking can also be used to assist with accounting and workplace compliance and reduce paperwork, shortening invoice cycles, and most importantly save time (Mauney, 2019).

2.3 Challenges of Radio Frequency Identification (RFID) Implementation at Congested Construction Site

The main reason is some of the contractors do not have the ability to implement this technology due to the high cost of the tools. The cost of tags is the most obvious expenditure even though the cost of RFID tags has been falling. In addition, attaching RFID tags may require special arrangements, which may increase costs directly related to the tags. However, before the RFID tracking system was implemented, there were many other types of expenditure. RFID tracking systems require other hardware than tags such as readers, RFID-enabled forklifts, conveyors, and sorters (Hinkka, 2012). The reader also will affect the cost of implementation. The cost depends on the type of reader, active readers are typically purchased as part of a complete system, with tags and mapping software to determine the tag's location. Companies may also have to buy each antenna separately, along with the cables and the cost of the high-frequency reader is higher compare with a low-frequency reader (Hickey, 2012). Hickey (2012) also states that the application, the size of the installation, the type of system, and many other factors will directly affect the cost of implementation. Companies will need to hire a system integrator and upgrade enterprise applications, such as a warehouse management system

and need to upgrade the network within the facilities. The cost for the installation of the reader, power source also needs to be pay and the system needs to be connected to the company network.

RFID tags and labels are very specific to the material type and size of your asset. For example, metal will deactivate the RFID antenna and the tag will not be transmitted at all. The use of RFID on metal requires a special type of tag with an RFID block to prevent interference with the antenna. Liquid products can also affect the reliability of RFID signals. RFID requires different types of tags based on the characteristics of the item itself but a barcode tag can be used for different assets (Peak-Ryzex, 2020). Lastly, an emerging issue is the low level of standardization. There is no global public body to manage the frequency used for RFID. Currently, the frequency used for RFID in one country is not compatible with other countries. In addition, although RFID-generated product information can provide unprecedented visibility in the supply chain, there is no standard information structure to facilitate sharing among supply chain partners (Lu *et al*., 2011). Table 3 shows the summary of RFID implementation challenges at the congested construction site.

Table 3: Challenges of RFID implementation at congested construction site

Item	Challenges
1	Expensive cost
2	Specific tags and labels for a certain type of materials
3	Metal and liquid materials will affect the reliability of RFID signals
4	Low level of standardization

3. Research Methodology

This part will explain and describes the method adopted in this research. The method used must ensure the objectives and scope of this research can be achieved. Methodology plays a significant role in this research and this chapter will discuss the method of data collection. This research has been used questionnaires as a data collection method. Next, it will involve data collection and data analysis, which is in numerical value. Figure 1 shows the research methodology flow chart.

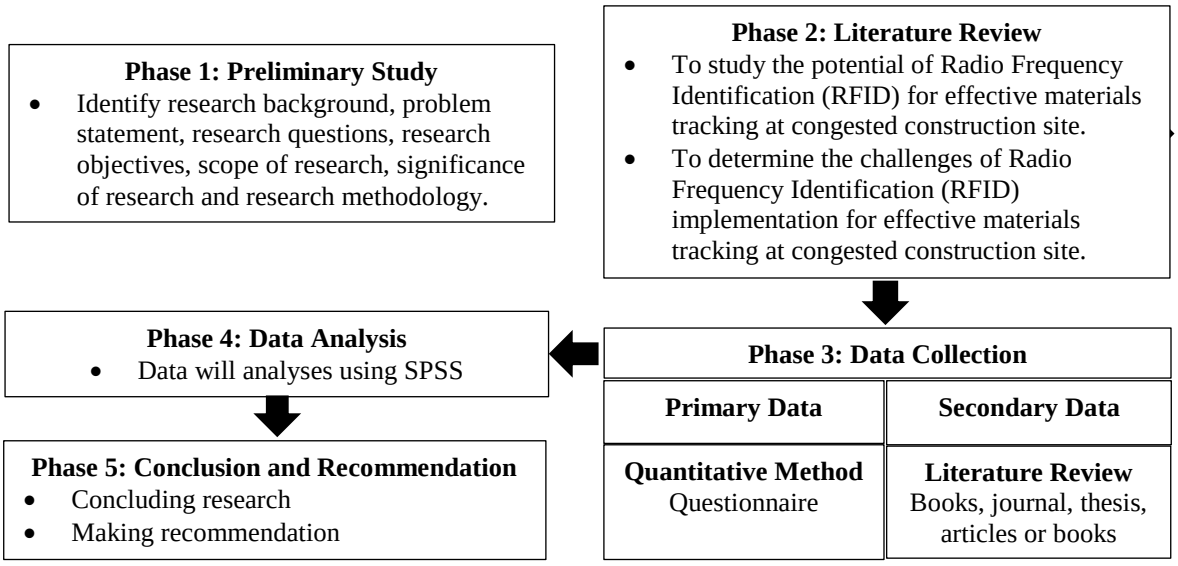

Figure 1: Research methodology flow chart

3.1 Research Design

This research used the quantitative method. Quantitative data is information about quantities and therefore numbers. Quantitative methods are concerned with discovering facts about social

phenomena and assume a fixed and measurable reality. The data are collected by measuring things and analyze through numerical comparison. Lastly, data will be reported through statistical analysis (McLeod, 2019). In this research, a survey questionnaire will be constructed using Google forms. The collected information and results that are obtained from the respondents, together with the literature review that is analyzed and studied to achieve the objectives of this research. Table 4 shows the study design method.

Table 4: Research design method

No	Research Objectives	Method
1	To study the potential of Radio Frequency Identification (RFID) for effective materials tracking at the congested construction site.	• Literature Review • Quantitative (Questionnaires)
2	To determine the challenges of Radio Frequency Identification (RFID) implementation for effective materials tracking at the congested construction site.	• Literature Review • Quantitative (Questionnaires)

3.2 Data Collection

This research contains two types of data, which are primary data and secondary data. All the information was collected from primary data and secondary data. Hence, the data collection methods are discussed in detail. The primary data from this research is using a quantitative method to collect data via giving the questionnaire to the target respondents. The questionnaire focuses on the objective of this research to ensure the objective is achieved. The questionnaire was created by using Google Form and distributed by e-mail. The respondent of this questionnaire is consists of 731 G7 contractors at Johor. Hence, the number of 256 is taken as the sample size according to Krejcie and Morgan Sampling Method (Krejcie and Morgan, 1970). The secondary data is the existing data collected earlier by the investigator agencies and organizations. Secondary data is data related to the past and the process is rapid and easy. The secondary data collection sources are websites, books, journal articles, internet articles, and others (Ajayi, 2017).

3.3 Data Analysis

Data analysis is the science of analyzing raw data to draw conclusions about that information. Many techniques and processes of data analysis have been automated into mechanical processes and algorithms, which process raw data for human use (Frankenfield, 2019). Data analysis is one of the ways to collect all the data from questionnaires and form a conclusion or results. All the data collected will present in a simple, easy, and understandable form. The results of data analysis will come out in graph, chart or table form to show the information more clearly. The data collected will be analyzed by using Statistical Package for Social Science (SPSS).

4. Results and Discussion

The data were collected from G7 contractors at Johor. The data collected will be analyzed using Statistical Package for Social Science (SPSS). The analysis will be carried into 3 parts including Part A, Part B, and Part C. Part A would consist of respondent background. Part B is discussing the potential of Radio Frequency Identification (RFID) implementation for effective materials tracking at congested construction sites and Part C deliberating the challenges of Radio Frequency Identification (RFID) implementation for effective materials tracking at congested construction sites. The results obtained from the analysis will be described in a table and graph which allows readers to understand

more effectively. The respondent of this questionnaire is a contractor where total consists of 731 G7 contractors at Johor. Hence, the number of 256 is taken as the sample size according to Krejcie and Morgan Sampling Method, 1970. The questionnaire started distributed on 1st November 2020 and it took around one month to receive back the 66% of the questionnaire distributed. Table 5 shows obviously the rate of the questionnaire distributed, received with its percentage respectively.

Table 5: Respond rate of questionnaire survey

Questionnaire	N	Response Rate
Questionnaire Distributed	256	100%
Questionnaire Received	168	66%
Questionnaire Not Received	88	34%

4.1 Respondent Background

The entire data of the respondent's background have consisted of gender, age, working position, working experience, and experience in RFID usage as shown below Table 6. The data are included frequency and the percentage of respondents who involved. According to the table below, most of the gender is male (58.9%) because the area of research is majority male. Thus, the male is highly participating. Next, the respondents involved are mostly between 31-40 years old (33.3%). This is because most of them are Project Manager, which is 40 respondents (23.8%), and this position required more working experience. The table shows 56 respondents (33.3%) have 6-10 years of working experience. However, most of them only have 1-5 years of experience in RFID usages, which represent 78 respondents (46.4%).

Table 6: Summary of respondent's background

	Item	Frequency	Percentage (%)
Gender	Male	99	58.9
	Female	69	41.1
Age	20-30 years old	38	22.6
	31-40 years old	56	33.3
	41-50 years old	54	32.1
	51 years old and above	20	11.9
Working Position	Project Manager	40	23.8
	Contractor	37	22.0
	Site Supervisor	24	14.3
	Project Engineer	31	18.5
	Engineer	32	19.0
	Other	4	2.4
	(i) 3 Quantity Surveyor		
	(ii) 1 Contract Manager		
Working Experience	1-5 years	49	29.2
	6-10 years	56	33.3
	11-15 years	40	23.8
	16 years and above	23	13.7
Experience in RFID usage	1-5 years	78	46.4
	6-10 years	57	33.9
	11-15 years	23	13.7
	16 years and above	10	6.0

4.2 Potential for RFID Implementation

Table 7 below, consists of the potential of RFID in terms of technology and economics. For the potential of technology, the highest mean is 4.524, which is "Provide convenient materials tracking", within the 168 respondents, at the same time it also the lowest standard deviation (0.619). RFID can be used to improve tracking, delivery, and receipt, and location of materials and components such as pipes, structural steel members, and interior decorating materials in lay-down yards and under shipping in construction. RFID can improve the quality of management practice (Sardroud, 2012). The lowest mean of potential RFID in terms of technology is "Provide clean construction site" which is 4.298 with a ranking of 8.

In summary, "Reduce the cost of materials wastage with materials information can be recorded at the congested construction site" reached the highest mean 4.423 and first ranking for the potential of RFID in terms of economics. This is because according to Kasim *et al.* (2012), RFID can provide accurate information about the receiving, shipping, and inventory of the materials. This process can avoid missing, misplace, or not received the item on time. RFID can help in tracking to overcome human error in materials identification and reduce congestion time due to constraints of site storage. Meanwhile, the lowest mean is "Reduce management cost due to lack of materials damages" which is 4.161. Thus, the total average mean is higher which is 4.360. According to Table 7, the mean of potential RFID implementation in terms of technology is higher than economics, which is 4.524 and 4.423. This result shows that the potential of RFID is more reliable in terms of technology.

Table 7: Summary of potential of RFID implementation

No.	Item	N	Mean	Standard Deviation	Ranking
	Technology				
1	Provide convenient materials tracking.	168	4.524	0.619	1
2	Provide better job tracking.	168	4.500	0.726	2
3	Provide better stock control.	168	4.470	0.683	3
4	Provide better quality control.	168	4.399	0.805	4
5	Provide tidy construction site.	168	4.381	0.832	5
6	Provide more accurate job tracking.	168	4.351	0.630	6
7	Provide safety at congested construction site.	168	4.304	0.716	7
8	Provide clean construction site.	168	4.298	0.671	8
	Economics				
1	Reduce the cost of materials wastage with materials information can be recorded at congested construction site.	168	4.423	0.713	1
2	Reduce management cost due to lack of materials stolen.	168	4.381	0.673	2
3	Reduce the cost of paperwork.	168	4.381	0.741	2
4	Reduce cost of extension time with delivery process can be tracked at congested construction site by the real time information.	168	4.304	0.672	4
5	Reduce the cost of labours for materials tracking.	168	4.292	0.613	5
6	Reduce project cost.	168	4.232	0.742	6
7	Reduce management cost due to lack of materials damages.	168	4.161	0.650	7
	Total Average Mean		4.360		

4.3 Challenges for RFID Implementation

Based on Table 8 below, the highest mean of the challenge for RFID implementation is "Financial support to implement the technology due to high cost" with 4.268. This is because according to Hickey (2012), the cost of an RFID system depends on the type of reader and companies may also

have to buy each antenna separately, along with the cables and the cost of the high-frequency reader is higher compare with a low-frequency reader. However, the lowest mean (4.125) are "Special handling due to plenty of materials at the congested site" and "Skilled worker to operate the technology". Thus, the average mean among this section is higher which is 4.165.

Table 8: Summary of challenges of RFID implementation

No.	Item	N	Mean	Standard Deviation	Ranking
1	Financial support to implement the technology due to high cost.	168	4.268	0.705	1
2	High cost for technology investment.	168	4.214	0.751	2
3	Specific tags for specific type of the materials.	168	4.167	0.787	3
4	Specific tags for specific size of the materials	168	4.161	0.753	4
5	Attaching RFID tags for special arrangement that occur cost increment.	168	4.161	0.761	4
6	Strengthen privacy issues in order to avoid leakage of consumer information.	168	4.137	0.725	6
7	High cost of the equipment (tags and reader) which cause the increment of project cost.	168	4.131	0.722	7
8	Skilled worker to operate the technology.	168	4.125	0719	8
9	Special handling due to plenty of materials at congested site.	168	4.125	0.835	9
	Total Average Mean		4.165		

5. Conclusion

Radio Frequency Identification (RFID) not a new system in Malaysia but this system needs to evolve for a better user experience. The main objective of this research is to study the potential of RFID for effective materials tracking at congested construction sites in terms of technology and economics. The results of this study prove that RFID provides convenient materials tracking at the congested construction site. On the other hand, RFID also has the potential of reducing the cost of materials wastage with materials information can be recorded at congested construction sites. The second objective of this research is to determine the challenges of RFID implementation for effective materials tracking at the congested construction site. Most of the respondents agreed that RFID implementation needs financial support due to the high cost of the system. It is intended to explore the other potential of an RFID system in a country. In conclusion, the research objectives have been achieved.

During this study have been done, there were a few problems and limitations faced by the researcher. Due to the unpredictable situation as the world suffers from the Covid-19 pandemic and our country is no exception. This situation forced the researcher must create the questionnaire by using the Google Form and distributes it by Email, WhatsApp, and Messenger. Based on the result of the study, some suggestions and recommendations can be given to the organization. RFID not only a system that uses for materials tracking but also can implement for other functions. Hence, the recommendation for the construction industry to implement this system is to track the worker's attendance and ensure illegal workers are only allowed at the site. Recommendation for future research is provided to support this study. In the future, any researcher who intended to conduct the research in this area of study may combine both research methods, which is quantitative and qualitative method due to the quantitative method not enable the respondent to provide in-depth info and opinion. Since the consolidation of these two ways would be able to give a comprehensive and thorough understanding of the potential of RFID. This would give a clear insight into the findings

report. Finally, the data that had been collected could help industry players in understanding the potential and the challenges of RFID implementation for effective materials tracking at congested construction sites.

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