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RFID Technology in Construction Project Management – A Review

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***Abstract:*— Increasing demands for speed and efficiency in the face of greater complexity of modern construction projects have given rise to the need for proactive and dynamic management of resources. Safety and environment are added to traditional success criteria such as cost, quality, and time. This requires project managers to make better decision to align materials, labour, and machinery based on the information available. Radio Frequency Identification (RFID) is one such system that is widely used in supply chain management. The RFID technology is a means of gathering data about a certain item without the need of touching or seeing the data carrier, through the use of inductive coupling or electromagnetic waves. RFID is used to automatically identify people, objects, and animals using short range radio technology to communicate digital information between a stationary location (reader) and a movable object (tag). Use of RFID has improved Real-time traceability and visibility capability at the upstream and increased efficiency and quality of supply chain operations, especially towards the downstream (e.g. distribution, wholesale, and retail), in manufacturing business.**

This paper deals with determining and proposing applications of RFID technology over the conventional technologies by carrying out research survey regarding that how a proposed application would be beneficial to various construction companies and their projects.

Keywords: **RFID; Construction Project; Tracking; Supply Chain; CPM**

I. INTRODUCTION

Increasing demands for speed and efficiency in the face of greater complexity of modern construction projects have given rise to the need for proactive and dynamic management of resources. Safety and environment are added to traditional success criteria such as cost, quality, and time (known as PM triangle). The success criteria, cost, quality, time, safety and environment have enhanced the standards of a successful construction project management (CPM). These success criteria in turn are directly linked with proper utilisation of resources used in a construction project. This requires project managers to make better decision to align materials, labour, and machinery based on the information available. Therefore information is one more success criteria that important for success of CPM.

Managing information in CPM is a challenge due to the unique nature of work in construction project. The nature of construction project defers from manufacturing works and makes it unique due to many factors. They are as follows; work is often seasonal work, each project is unique, often involves remote sites with various access problems, the process is not as predictable, difficulty in applying automation, there is high potential for encountering unforeseen conditions, costs can vary according to conditions, difficult to manage and supply utilities and other resources, technical innovations are adopted slower, success is dependent upon the quality of its people, very custom-oriented, product can be of mind-boggling size, cost, and complexity, the work is not performed in controlled conditions, therefore highly impacted by weather and other environmental conditions. Hence to use information system to improve real-time information visibility and traceability is a challenge though it has become most important in today's CPM. Project managers need to acquire real-time information about materials, men, and machinery so as to make prompt and informed decisions. Here the information could include inventory of materials, positions of construction workers, conditions of machinery, and so on.

Radio Frequency Identification (RFID) is one such system that is widely used in supply chain management (LSCM). The RFID technology is a means of gathering data about a certain item without the need of touching or seeing the data carrier, through the use of inductive coupling or electromagnetic waves. RFID is used to automatically identify people, objects, and animals using short range radio technology to communicate digital information between a stationary location (reader) and a movable object (tag).

Use of RFID has improved Real-time traceability and visibility capability at the upstream and increased efficiency and quality of supply chain operations, especially towards the downstream (e.g. distribution, wholesale, and retail), in manufacturing business. However, little attention

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has been paid to the investigation of RFID technology in construction which is also viewed as an information-based industry in addition to its labor, material, and capital intensive nature. In comparison with the heated debates in other sectors, a widespread adoption of the technology has not been seen in real-life construction practices.

II. GOALS & OBJECTIVES OF THE STUDY

This dissertation is to analyze and evaluate the actual benefit of RFID System which is used for facilitating the day-to-day maintenance activities, management of works at construction site, as well as decision making and control of quality. The goals and objectives of this study are :

a) To explore the benefit and potential application of RFID technology for Construction.

b) To evaluate the user satisfaction of RFID system for maintenance of A/C system comparing with traditional paper based system.

c) To identify the factors which affect the application of RFID system and evaluate the important factors in determining the satisfaction of RFID system in Construction industry.

d) To identify the obstacles of RFID application and provide recommendations.

III. APPLICATION OF RFID IN CPM – A REVIEW

The review is carried out on two broad areas. First include basic understanding of RFID technology, its architecture, infrastructure, hardware, software and system. Second area includes the review of research studies and papers on RFID in construction industry and RFID in other industries.

1. Understanding RFID Technology

Radio Frequency Identification (RFID) tags have been in existence since the 1950's and two decades ago they were introduced as the ultimate replacement for bar RFID tags, unlike bar codes offer the possibility of reading, writing, transmitting, and storing and updating information. RFID tags can hold upto 32 mega bytes (tag ID: I Q32T w/LED) of information making them more difficult to counterfeit than bar codes, and the data on existing tags can always be changed or updated.

These tags have proven to be very useful in the delivery of construction materials where a shakedown of a large quantity and variety of items can be read simultaneously without having to be separated and scanned individually. Information is communicated electronically via radio waves and does not require contact or line-of-sight to transmit stored data, therefore, using RFID technology for the collection and transfer of information provides one with an inexpensive and non-labor intensive means of identifying and tracking products.

The smart chips (RFID tags) come in a large range of packaging options, they are reusable, and can withstand harsh environments. In fact, RFID tags can operate effectively in temperatures ranging from –400 to 2000 C. The chips are also capable of performing under rugged conditions or when they are dirty, and not until recently were they capable of overcoming the interference of metal objects. Today's active tags are now able to use metal objects that they are identifying as a device that amplifies its operating ability. Over the past five years the information technology industry has seen a surge towards the development of an affordable RFID tag. Such developments have lead to larger reading 4 ranges, greater memory capacity, and faster processing of radio frequency operating systems.

Unlike any other material management and material identification tag, RFID has a read – write capacity. A rewritable tag's ability to keep information up-to-date gives it the potential to strengthen national security and better inform people of maintenance and service records. It also enhances the user's ability to locate objects when used in combination with GPS for real-time tracking.

2. Components

An RFID system is composed of tags, which carry the data in suitable transponders, and an RFID reader, which retrieves the data from the tags. Products that contain RFID tags embedded in them or fastened to them enable stored information to be transferred from an RFID tag to a remote reader through radio frequency waves of a specific wavelength. There currently is not a definite industry standard for wavelength, but the most common applications around the world use wavelengths of 125 kHz and 13.56 MHz. Initially, data is written to the RFID tag enabling it to identify and characterize a product as a particular manufactured good with a determined application. At some later point, a RFID remote reader will scan and acknowledge the information once the tag is within range of an electromagnetic field activating the tag to perform a user defined function. Also, many passive RFID transponders have antennas sealed with the tags to give them greater read-write abilities (see Figure 1).

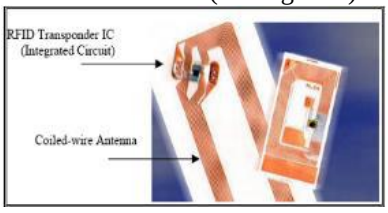

Figure 1 Antenna sealed with RFID tag

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Vol 2, Issue 3, March 2017

2.1 RFID Tags

There are two classifications of RFID tags: Passive and Active. The means in which they receive power for transmission determines their classification. Passive tags depend on a power source provided by the RFID reader's energy field and may have read-write or read-only capabilities, whereas, the active tags have an internal power source and are rewritable. Passive tags generally have shorter read ranges but have a life that usually outlasts the object that it is identifying. Active tags have longer reading ranges, high memory, and better noise protection. However, these tags are larger and heavier, more expensive, and have a shorter life (3 – 10 years) than passive tags. Read-only tags are used forsimple identification purposes because they can only store a limited amount of information that cannot be altered.

Presently, these tags are being produced with the design weight of 50 grams, a life cycle of being written to 100,000 times, data retention greater than 10 years without power, and the durability to withstand being dropped to concrete from a height of 1 meter a multiple number of times (see Figure 2.2).

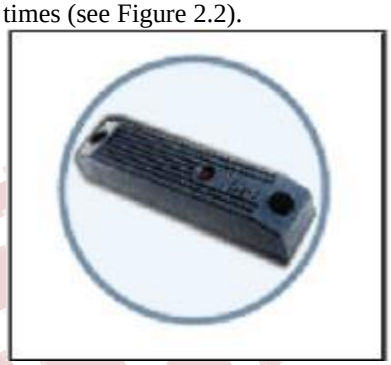

Fig 2 RFID Tag

2.2 Antenna

The function of the antenna attached to a reader is to transmit an electromagnetic field that activates a passive tag when it is within reading range. Once a passive tag is activated it can transmit information from its antenna to that of the reader where it is processed. During rewriting applications the antenna of the reader acts as a relay device in the reverse direction, the reader communicates a message through its antenna, which transfers and stores the new data to the activated transducer via its antenna. The RFID tag's antenna is practically maintenance free and can be configured in a variety of shapes and sizes ranging in size from a grain of rice to the size of a brick. However, it is very common to see transponders and tag antennas packaged as smart labels (sealed RFID tags) consisting of an integrated circuit (IC) attached to an antenna in the shape of a coil of wires as in Figure 3.

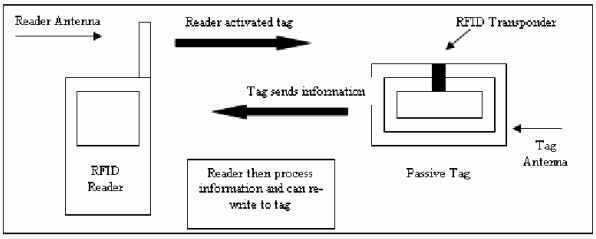

Figure 3 – Signal Transmission through Antenna

2.3 Readers

Readers may be integrated into handheld computers or they may be stationary and positioned at strategic points, such as a facility entrance or on an assembly line (see Figure 4). The handheld readers offer portability, however, the stationary devices offer a larger reading range. The reader receives instructions and information from the antenna through the scanner, which is a part of the reader that examines analog output from the antenna. The scanner's information is then converted into a digital format by the reader, which the computer or processor can then use for data analysis, recording, and reporting (CII, 2001).

Figure 4 - Handheld and Stationary Readers

2.4 Read Ranges And Tag Frequency

Reading range may be determined by the power available or the frequency of the tag. Generally, active tags that have power supplies embedded in them have a larger reading range than those of passive tags, however, they do come at a cost. Some companies on today's market claim that their active tags can be written to and read up to 100 meters in free air. Passive tags on the other hand have a read range of up to 2 meters. Other factors affecting reading distances include the frequency at which the tags communicate.

The most commonly used tags are classified as low frequency because they more easily readable through materials and are not as orientation sensitive as higher frequency tags. Generally speaking, higher frequencies have greater reading ranges and are less sensitive to noise than the lower frequency tags. Conversely, RFID tags with microwave frequency do have greater read ranges and higher reading speeds than lower frequency tags, but they tend to be line of sight dependent, orientation sensitive, and require more power.

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Vol 2, Issue 3, March 2017

IV. RFID IN CONSTRUCTION

The construction industry has characteristics that separately are shared by other industries but in combination appear in construction alone. The areas seeing the applications of RFID in other industries can also be seen in construction while with heterogeneity. To the construction industry, RFID technology is not completely new. Early in 1995, Jaselskis et al. (1995) envisaged its potential applications in construction, including concrete processing and handling, cost coding for labour and equipment, and materials control. Since that, a few more studies have been conducted to explore potential applications of RFID in this industry.

Jang and Skibniewski (2009) developed an embedded system for tracking construction assets (e.g. materials and equipment) by combining radio and ultrasound signals. Likewise, Goodrum (2006) implemented the technology for tool tracking on construction job sites. Dziadak et al. (2009) developed a model for the 3D location of buried assets based on RFID technology. Domdouzis et al. (2007) explored the applications of RFID in the construction industry including automated tracking of pipe spools and other valued items, and an on-site inspection support system. Tzeng et al. (2008) explored the influence of combination manners of RFID and interior decorating materials on RFID system recognition. Yin et al. (2009) developed a precast production management system using RFID technology in the face that prefabrication is increasingly adopted in construction. Wang (2008) explores how the RFID technology can be used to enhance construction quality inspection and management.

However, not many applications of RFID have been seen in real-life construction practices in spite of the desire for this technology. The possible reasons are many. Project managers may not have been fully aware of the potential uses of RFID in construction. Various technical, financial, or ethical hurdles may also prevent it from being widely adopted in this heterogeneous industry. These encourage the authors to investigate a comprehensive list of potential applications of RFID in CPM by envisaging its advantages and hurdles.

Application & Benefits of RFID in Construction :

RFID is a versatile, widely used and proven technology for monitoring materials, tools, capital assets and people. It can be used to report on their whereabouts, track the history of their use, and help control where they can be used. It can provide information on the usage of consumable materials and provide the means to keep track of items through the supply chain and on into their eventual installation and subsequent use.

Examples of application areas for RFID in the construction sector include:

- Control of the location of valuable assets.
- Maintenance control and management.
- Access control to sites or areas within sites and monitoring of security staff activities on site.
- Material identification and tracking; plant equipment tracking and control.
- Plant hire.
- Health, safety & environmental compliance.

These applications offer potential benefits to the business which can, in turn, be translated into a valuable return on investment for RFID projects.

The areas where RFID can be useful to construction businesses include :-

- Improving the traceability of materials from manufacturer to site and into the final construction, so supporting the integration of the construction phase and the maintenance phase.
- Enhancing security and reducing loss of materials, tools and other capital items.
- Speeding information flows on the location of equipment, tools and materials.
- Improving the control of inventories of materials and tools, reducing wastage and avoiding loss of time in projects as a result of non-availability of materials and tools.
- Improving control of maintenance and health and safety processes.
- Reducing paperwork and making efficient information capture possible in demanding environments.
- Gaining real time information on the progress of projects as an aid to better decision making and improved customer information.

These advantages translate into financial benefits that provide the basis for a return on

Investment in the use of RFID technology.

Areas where RFID projects contribute to ROI within construction projects are:

- Reduced inventory costs through “just in time” delivery to site.
- Lower asset costs for tools and equipment through better utilisation.
- Less “shrinkage” in inventory and asset base.
- Less time lost to industrial injuries, lower compensation payments.
- Lower sub-contractor costs through better control.

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Vol 2, Issue 3, March 2017

To date, however, the construction industry has been slower than others to take advantage of these technologies. In other sectors the presence of very large enterprises that can impose an approach for their industry has enabled the creation of industry standards that make it possible for many other enterprises to exploit the technology.

About 30 research papers were studied to understand the implementation of RFID technology over various sectors and conclusion was drawn to find out the gap between implementation of RFID technology on Construction sector versus its implementation on other different sectors.

V. SUMMARY TABLE

Sr. No.	TITLE	AUTHOR	FINDINGS	SECTOR
1.	A Simulation Tool for Radio Frequency Identification Construction Supply Chains	Frans van Gassel et. al.	When using an RFID system for the supply chain, (i) fewer errors may be made, leading to fewer irregular and incidental processes, (ii) the information becomes available faster and (iii) work is more efficient	Supply Chain Management
2.	RFID Applications In Construction And Facilities Management	Robert Wing	The paper indicated that RFID and its associated sensing and networking technologies are likely to have a major role in facilities management	Construction And Facilities Management
3.	Effects Of RFID Technology On Efficiency And Profitability In Retail Supply Chains	Seungjae Shin et. al.	The author in this paper found that RFID companies have better cost efficiency than non-RFID companies and RFID companies have improved sales efficiency, RFID technology adoption severely affects inventory management efficiency but the author was not able to find if RFID technology adoption also contributes to profitability and per employee efficiency in U.S. retail industry.	Supply Chain and inventory Management
4.	A Framework for the Implementation of RFID Systems	S. L. Ting et. al.	The paper found that with proper adaptations to different types of industry, the framework can achieve a better appreciation and execution of any project. The findings provide decision makers with a balanced view of the change initiative and asked organization to consider both the pros and cons of implementation to develop better implementation strategies.	RFID Implementation
5.	A systematic review of RFID applications and diffusion: key areas and public policy issues	Kwangho Jung et. al.	RFID is effectively used by military and airports/ports management, prison management, child protection programs etc. governments introduced RFID tools such as e-passport and e-ID. Problem related to RFID could be in securing cryptography techniques, international standards of frequency, and storage capacity etc. Governments' trust is important for technological innovation and policy issues arising from a rapid RFID diffusion.	RFID Application
6.	Scenarios for applying RFID technology in construction project management (CPM)	Weisheng Lu et. al.	It is found that RFID shows great potential in improving CPM goals such as time, quality, cost, safety, and environment by applying it in the management of materials, labours, and machinery. And recommended to integrate itself with the developments of RFID in other industries, with Building Information Model, and with people, projects in construction	Construction project management
7.	Critical Success Factors and Challenges of Implementing RFID in Supply Chain Management	Mohsen Attaran	The paper developed a research model for RFID success to facilitate research integration and variable selection in future research. The model is general and allows new factors or success variables to be added easily. The results are useful to identify the exact factors that need attention in providing a basis for prioritizing those factors. The results could also suggest several promising directions for continued research on RFID success.	Supply Chain Management
8.	The Adoption and Implementation of RFID: A Literature Survey	Mohd Kamir Yusof et. al.	Tracking of library materials, improves accuracy of data collection, and reduces the amount of time required for check-in, check-out, inventory control and shelf -management	Library material and inventory management
9.	Implementation of RFID Technology for Real-Time Materials Tracking Process in Construction Projects	Narimah Kasim et. al.	Material tracking process with RFID employment to improve materials management in the construction site.	Materials Management in Construction Industry
10.	Resource Management in Civil Construction Using RFID Technologies	Changyoon Kim et. al.	This research evaluated the applicability of the RFID technology in managing resources. Coupled with the LAN connection to track material information in construction site office and head office, RFID tags for metallic objects were attached to structural components used in a cable-stayed bridge extracting statistically meaningful and reliable information as to how best to utilize RFID technologies in civil engineering construction such as a cable stayed bridge.	Resource Management
11.	Wide Strong Private RFID Identification based on Zero-Knowledge	Roel Peeters et. al.	This paper founds a new wide-forward-insider and a wide-strong private RFID identification protocol which is based on zero-knowledge. Security and privacy of these protocols and the optimised variant is of the standard model. All the proposed protocols are implemented on RFID tags by using only Elliptic Curve Cryptography	Security and Privacy Attacks and Solutions in RFID
12.	RFID Technology Based Attendance Management System	Sumita Nainan et. al.	The paper presented the feasibility of employing RFID technology and beneficial to improve efficiency at lowered costs. RFID technology increases effectiveness and improved efficiency for business processes and with reducing unit tag and reader costs, several businesses will be able to leverage the benefits of RFID technology.	RFID Application
13.	A 2G- RFID Based E-Healthcare System	Min Chen et. al.	This paper presented a concept for the second-generation RFID system and qualitatively demonstrated the value of its application in future e-healthcare systems also, discusses benefits to improve system scalability, information availability, automated monitoring and processing of sensitive information which can be achieved by employing RFID tags with more memory to encode information-rich data	Healthcare
14.	Radio-Frequency Identification Applications In Construction Industry	Edward J. Jaselskis et. al.	This paper states that Construction firms can save time, money, and effort with effective use of RFID technology, contractors must learn about this technology, successful implementation of an RFID system is the involvement of all who will be directly or indirectly using the technology	Construction Industry
15.	The Application of RFID Technology in JIT Production Control	Lingyu HUO et. al.	This paper identified the RFID technology used in JIT production management and proposed RFID-based JIT production system as RFID technology brings more accuracy, timely and rich data to manage which largely enriches the data source of production management. Real time tracking and supervision for production logistics also become easy.	Production Management
16.	Life-Cycle Approach for Implementing RFID Technology in Construction: Learning from Academic and Industry Use Cases	Nan Li et. al.	The paper identified potential benefits of integrated implementation, including data consistency, decreased investment, and better standards and interoperability, and raised a series of research questions to advance the consistent implementation of RFID	Construction Industry

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Vol 2, Issue 3, March 2017

			technology from a building life-cycle perspective.	
17.	Developing an RFID-Based Man–Tool Safety Management System on a Construction Site	Qian Chen et. al.	The paper found onsite safety inspection procedures and the neural network safety decision-making model integrated with RFID technology so that five subsystems (man-tool identification subsystem, safety status information transmission subsystem etc.) constitute a complete Man-Tool Monitoring and Management System, as to ensure accuracy and efficiency of onsite safety management	Safety Management in Construction
18.	Security In the Internet of Things (IOT) Based on RFID: Issues and Current Countermeasures	Xiao Nie et. al.	The paper concisely reviewed the security issues in the Internet of Things (IOT) based on RFID, and analyzed security features and threats, then discussed the countermeasures in this field. From the RFID system and the communication process it gives the corresponding solution to the security target.	Security Attacks and Solutions in RFID
19.	A Survey paper on RFID Technology, its Applications and Classification of Security/Privacy Attacks and Solutions	Neha Kamdar et. al.	The paper presented the RFID technology, their applications and a few potential attacks that is feasible in RFID. To counter RFID attacks efficient and valuable algorithms, techniques and procedures to combat these attacks may be developed.	Security Attacks and Solutions in RFID
20.	The Use of RFID in Manufacturing and Packaging Technology Laboratories	Jay Singh et. al.	Bridges many areas of manufacturing including inventory management, assembly operation, material handling, packaging and shipping. And also presented four laboratories projects including a variable speed conveyor, smart dock doors and automated package sorting for teaching RFID technology in engineering or technology programs	Manufacturing and Packaging
21.	Automated Toll Collection System Using RFID	Pranoti Salunke et. al.	Highly reliable data collection, provides new capabilities and an efficient method to collect, manage,	RFID application
			disseminate, store, and analyze information, eliminates manual data entry errors, generate better market intelligence, leading to lower operational costs and increased revenue generation	
22.	Six Steps to a Successful RFID Asset-Tracking System	Keith Jones et. al.	This paper provides a brief history of RFID as well as an overview of how it works and common applications. It then covers the six most basic steps required to successfully deploy an RFID asset-tracking system, along with appropriate caveats. Although RFID is used in a wide variety of applications, one of the most common is asset-tracking.	Asset-Tracking System
23.	Designing Your RFID Solution	Harold Boeck et. al.	This paper describes the use of radio frequency identification (RFID) for use by constructors to improve the efficiency of construction site operations. This paper demonstrates the usefulness of this technology its more robust nature compared to bar code labels.	
24.	Improving On-Site Materials Tracking For Inventory Management In Construction Projects	Narimah Kasim et .al.	This paper provides a review of the existing issues in material tracking of inventory management process in construction projects. The tracking and locating of materials in construction jobsites has increase a great concern among construction entities The ICT applications in construction project can have a good impact especially in improving construction activities. Several researches that have been conducted shows that RFID, barcodes, GIS, GPS, and other technology has potential to contribute a great impact in inventory management especially in materials tracking process.	Inventory Management in Construction industry
25.	Multi resonator-based Chipless RFID System for Low-Cost Item Tracking	Stevan Preradovic et. al.	A fully passive printable chipless RFID system is presented in this paper. The chipless tag uses the amplitude and phase of the spectral signature of a multiresonator circuit and provides in correspondence of	Low-Cost Item Tracking
			data bits. In this paper, we present a novel fully printable chipless RFID system based on multiresonators and cross-polarized ultra-wideband (UWB) monopole antennas where the tag's unique ID is encoded as a spectral signature.The tag has potentials for low-cost item tagging such as banknotes and secured documents.	
26.	Critical management issues for implementing RFID in supply chain management	Bharatendu Srivastava	The paper discussed that the companies should carefully assess the viability, risk, potential benefits and the impact of RFID technology on the industry and supply chain management.	Supply chain Management
27.	Radio Frequency Identification in Construction Operation and Maintenance – Contextual Analysis of User Needs	Kristian Birch Sorensen et. al.	A number of needs can be identified such as easier on-site information access, increased focus on documentation, education of users and reuse of knowledge across organizations by new services.	Operation and Maintenance
28.	Radio Frequency Identification Application For Constructors	Edward Jaselskis et. al.	The paper states the use of radio frequency identification (RFID) for use by constructors as a way to improve the efficiency of construction site operations	Construction Industry
29.	RFID Technology for Materials Management in Construction Projects – A Review	Mohamad Syazli Fathi et. al.	In this paper, the emerging technologies such as RFID are discovered to be a potential for improving materials management especially for tracking of materials.	Construction Industry
30.	Design of an RFID-based Inventory Control and Management System (RICMS):	Jacky S.L. Ting et. al.	RICMS improves management system in eliminating errors, speeding up operations and significantly reducing operation costs	Inventory Management

VI. CONCLUSION

Out of the 30 research paper reviewed some of the common factors which are responsible for the lack of smooth application of RFID Technology in construction sector as compared to other sectors are :-

- RFID systems are often more expensive than barcode systems.
- RFID technology is harder to understand.
- Can be (debatably) less reliable.
- RFID tags are usually larger than barcode labels.
- Tags are application specific. No one tag fits all.
- Possibility of unauthorized reading of passports and credit cards.
- More than one tag can respond at the same time.

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