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UNVEILING THE BENEFITS OF RADIO FREQUENCY IDENTIFICATION (RFID) TECHNOLOGY FOR ENHANCING TECHNOLOGICAL APPLICATIONS IN SRI LANKAN CONSTRUCTION INDUSTRY

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ABSTRACT

The research delves into the underexplored realm of Radio Frequency Identification (RFID) technology within the Sri Lankan construction industry. Although it is relatively new to the construction industry, sectors such as healthcare and agriculture have effectively adopted RFID. For Sri Lanka's construction industry, a developing sector, integrating RFID could substantially advance its technological applications. Despite its potential, RFID implementation has not commenced in Sri Lanka's construction sector. Therefore, this study aims to investigate the benefits of RFID technology for enhancing technological applications in the Sri Lankan construction industry. An exploratory mixed research approach was used. Eleven semi-structured interviews were conducted during the preliminary survey with RFID technology experts. Subsequently, a questionnaire was distributed among 110 professionals in the Sri Lankan construction industry who are familiar with RFID technology. A total of 96 responses were collected resulting 80% response rate. The research findings revealed that the implementation of RFID technology has a higher potential to enhance the product quality and safety of the Sri Lankan construction industry. Theoretically, this study demonstrates the potential of RFID technology to enhance technological applications within the Sri Lankan construction industry. The findings of this study offer practical insights that can aid Sri Lankan construction industry practitioners in the successful implementation of RFID technology.

Keywords: *Benefits; Construction Industry; Radio Frequency Identification (RFID); Sri Lanka; Technology.*

1. INTRODUCTION

The construction industry is a vital contributor to economic growth, providing infrastructure and employment opportunities while increasing Gross Domestic Product (GDP) in developing countries (Alaloul et al., 2020). However, the industry encounters criticism for its lack of safety, productivity, output quality, and system performance (Bansal et al., 2019). It is reasonable to anticipate that the construction sector's success

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will be stimulated by Information Technology (IT) investments (Gaith, 2012). Effective management of the construction process is vital, and new technologies present one of the greatest chances to enhance the process via increased efficiency and greater integration (Holt et al., 2015). More importantly, advancements in technology offer the potential to address issues in the construction industry, particularly through the adoption of intelligent systems that utilise the Internet of Things, artificial intelligence, and Big Data (Kozlovska et al., 2021).

Among the studies on new technologies, Lanko et al. (2018) describe RFID as a technique that automatically identifies objects which use RFID scanners to read or write data stored in RFID tags using radio signals. RFID, a next-generation technology for tracking and data collection, has been successfully adopted across various industries, including manufacturing, retail, and logistics (Haddara & Staaby, 2018). RFID technology is a significant advancement in IT that presents new opportunities for the construction industry to enhance teamwork, communication, and information management (Tan & Sidhu, 2022). RFID can be used for sensing, detecting, identifying, tracking, and monitoring various items, making it particularly useful in construction projects (Kereri & Adamtey, 2019). Valero and Adán, (2016) mentioned that during the life cycle of a building, many different operations have been made simpler and even automated using RFID. Further, the adoption of RFID technology has the potential to improve efficiency, quality, safety, and economy in construction while reducing labour and material costs and optimising project timelines (Valero et al., 2015).

Over the past ten years, it seems that a reasonable amount of technology transfer was accomplished with a rather well-equipped technical and managerial basis, however, there is still much more to be accomplished (Santoso & Gallage, 2020). Although the IT sector is expanding rapidly, the use of IT in the Sri Lankan construction industry is still in its adolescent period (Atapattu et al., 2023; Manoharan et al., 2023). Furthermore, Sri Lanka's construction industry seldom ever uses automation and digital transformation, despite being a developing nation (Munmulla et al., 2023). At the same time, even if RFID technology has plenty of proven benefits, Sri Lanka has yet to implement RFID technology for the construction industry (Ruchiranga & Samarasekara, 2018). Therefore, in addressing this gap, this study aims to investigate the benefits of RFID technology for enhancing technological applications in the Sri Lankan construction industry. The main objective of the study is to investigate the significant benefits of RFID in Sri Lankan construction industry. This paper consists of an introduction, a literature review of the research area, a research method, data analysis and finally, the conclusions and recommendations.

2. LITERATURE REVIEW

2.1 INTRODUCTION TO RFID TECHNOLOGY

According to Costa et al. (2021), RFID has become popular since it is a viable alternative to conventional barcode technology, offering more benefits compared to other alternatives. Due to its minimal expense, passive wireless power transfer capability, adaptability, and non-line-of-sight communication, RFID technology is viewed as a new sensing prototype (Dobkin, 2012; Suresh & Chakaravarthi, 2022). The components of an RFID system are designed to fulfil the purpose of identifying people and objects (Kereri & Adamtey, 2019).

RFID uses radio waves for tracking or identifying objects with attached tags (Gao et al., 2022). In RFID systems, there are tags or transponders, a reader or transceiver and an antenna where the reader and transponder communicate data (Kereri & Adamtey, 2019). The tags or transponders are responsible for identifying the location of an object or person (Dobkin, 2012). Readers or transceivers are used to read the information encoded on these tags (Patil & Shelake, 2021). The computer database stores and analyses the data received from the tags, enabling effective data management and utilisation (Borda et al., 2019). The antenna plays a critical role by providing an electromagnetic field that activates the tags, facilitating communication between the tags and the readers (Roh et al., 2009).

2.2 APPLICATIONS OF RFID TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

RFID has been successfully utilised for many applications in the construction industry (Domdouzis et al., 2007). There are several countries including Turkey (Hamadneh et al., 2021), the United States of America (USA) (Kereri & Adamtey, 2019), Malaysia (Huang et al., 2019) and the United Kingdom (UK) (Valero et al., 2015) that have initiated the implementation of RFID technology in their construction industries. Li and Becerik-Gerber (2011) have identified twelve countries where RFID is currently used in the construction industry to manage equipment, tools, inventories and workforce and to improve the safety of construction sites. Moreover, to track machinery and tools and minimise loss, misplacement, or theft, RFID tags can preserve a record of borrowing and returning them (Kereri & Adamtey, 2019). Locating equipment and tools can be performed using RFID technology. With its wavelength and contactless advantages, RFID technology can aid in resolving issues with machine and tool tracking (Huang et al., 2019). Patil and Shelake (2021) mentioned that the employment of RFID is done to support current practices of materials management on the construction site and is considered to improve the effective management of construction materials on site. An efficient access control system can help effective labour management by securing the site, staff, and assets (Lake & Jaselskis 2000). RFID systems can be used in conjunction with an attendance checking system, which can provide time and attendance records that can be used as a foundation for other purposes, such as allocating tasks and determining pay (Huang et al., 2019).

Multiple subcontractors and employees are using an RFID card that can be combined with an existing card to store their IDs, and photographs, and provide access information to government agencies and businesses (Valero & Adán, 2016). The information is retrieved, compared, and either granted or denied access is determined by a reader at the construction site's entrance and exit (Ergen et al., 2017).

2.3 BENEFITS OF RFID TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

Valero and Adán, (2016) mentioned that during the life cycle of a building, many different operations have been made simpler and even automated using RFID. However, RFID technology is not entirely new to the construction sector (Lu et al., 2011). RFID has been successfully utilised for many applications in the construction industry (Valero et al., 2015). The potential applications of RFID technology have offered the most significant benefits and values for the construction industry (Roh et al., 2009). Hamadneh et al. (2021) mentioned that first, construction industry practitioners must be convinced about the benefits before justifying the need to implement new technology.

RFID tag implementation comes with both fixed and recurring expenses, however, over time, these costs are reduced overall due to lower inventory stock levels and inventory handling costs (Li & Becerik-Gerber, 2011). Additionally, the techniques boost sales by lowering shrinkage and out-of-stock, increasing order fulfilment rates, increasing inventory turns, and generally providing better customer service (Piramuthu, 2008). Workflow is significantly accelerated as the first result of the use of RFID tag technologies (Kasim et al., 2013). Time can be greatly saved by automatically recording information such as the time of production, access to the customer's site, and departure from the concrete plant's territory (Sudarshan et al., 2022). Along with reducing time, accompanying document completion that is automatic or semi-automatic will help cut down on the number of workers needed for processing and control (Suresh & Chakaravarthi, 2022).

The key advantages of RFID are increased component traceability and visibility, process speed and accuracy, and a decrease in material losses (Lu et al., 2011). Material managers can control their inventories efficiently with the use of RFID systems (Valero & Adán, 2016). Productivity has been a problem in the building construction industry, and it has an impact on project costs and schedules (Lu et al., 2011). Performance and productivity are indirectly increased by RFID readings because they increase the accuracy of information communication and speed (Wang, 2008). Further, RFID technology increases efficiency by automating certain superfluous activities and reducing their number (Kereri & Adamtey, 2019).

2.4 NEED FOR RFID TECHNOLOGY IN THE SRI LANKAN CONSTRUCTION INDUSTRY

According to Rajakaruna et al. (2008), due to the fast rise in large-scale projects such as irrigation, electricity, and industrials, construction activity was undertaken, necessitating a vast technological input.

It did, however, show that the local building sector was not entirely equipped to fulfil this increasing technical demand (Jayasena & Weddikkara, 2012). Most of the large building projects were awarded to foreign contractors due to a lack of technological improvements in local construction organisations (Gunawardena et al., 2016). According to a study by Rajakaruna et al. (2008), approximately 90% of the Sri Lankan public sector projects encounter cost and time overruns due to the lack of technologies used for the construction mechanisms. The authors further state that this problem impairs the nation's construction projects' general efficacy and efficiency.

Research suggests that there are advanced technologies used in the Sri Lankan construction sector (Gamlath et al., 2020; Jayasena & Weddikkara, 2012; Rosayuru et al., 2022; Waidyasekara et al., 2020). Drone technology and Building Information Modelling (BIM) are two examples of technologies that are becoming more popular in the Sri Lankan construction sector (Perera et al., 2020). However, it is important to understand that, when considering the global context, these technologies can be regarded as antiquated. Furthermore, there are numerous resource management issues in the Sri Lankan sector due to the minor involvement of advanced technologies (Manoharan et al., 2023), which can be overcome by the implementation of novel technologies such as RFID technology (Zhu et al., 2012).

RFID technology is one of the main factors influencing the construction industry's ability to operate effectively (Patil & Shelake, 2021). Past research has been conducted on applying RFID technology to different countries' construction industries around the world (Lu et al., 2011; Roh et al., 2009; Valero et al., 2015). At the same time, the Sri Lankan construction industry is in dire need of adhering to new technologies for the improvement of the construction industry (Rajakaruna et al., 2008). According to Zhu et al. (2012), RFID technology improves efficient equipment use, labour tracking, and inventory management, yet there is no available literature on applying RFID to the Sri Lankan construction industry. Given this research gap and the need in the industry, it is crucial to investigate the applicability of RFID technology in enhancing technological applications in Sri Lankan construction industry since the advancement of the construction industry in developing economies such as Sri Lanka will have a remarkable impact on the growth of the particular local economy and indirectly to the global economy as well (World bank, 2021).

3. METHODOLOGY

This study aims to investigate the benefits of RFID technology for enhancing technological applications in the Sri Lankan construction industry. Considering the limitations to achieve this aim, the study adopted an exploratory mixed-method approach, which allowed to collection of both qualitative and quantitative data. The study included a review of the literature, semi-structured interviews and a questionnaire survey. Toit (2012) justified this method by asking respondents to apply results from the literature to their own experiences, therefore, providing a platform for an exploratory and thorough assessment of their real-life experiences. The study used purposive sampling to select professionals involved in the construction industry during Phase 1. In the preliminary survey, eleven semi-structured interviews were conducted with a group of experts in RFID technology. Table 1 provides a summary of the details of the experts who participated in the preliminary survey.

Table 1: Details of the interviewees

Interviewee ID	Discipline	Designation	Experience	Country
E1	Civil Engineering	Senior professor	15 years	USA
E2	Civil Engineering	Senior Civil Engineer	18 years	Nigeria
E3	Civil Engineering	Senior Civil Engineer	10 years	Sri Lanka
E4	Civil Engineering	Senior professor and Consultant	16 years	Malaysia
E5	Quantity Surveying	Senior quantity surveyor	23 years	USA
E6	Quantity Surveying	Project quantity surveyor	10 years	UAE
E7	Quantity Surveying	Project quantity surveyor	09 years	Nigeria
E8	Quantity Surveying	Senior professor	16 years	China
E9	Quantity Surveying	Project Manager	23 years	USA
E10	Quantity Surveying	Senior professor	10 years	Australia
E11	Quantity Surveying	Consultant Quantity Surveyor	13 years	UK

During Phase 2 of data collection, a questionnaire survey was designed to collect quantitative data. The questionnaire was based on a Likert scale and consisted of closed-ended questions. It was distributed as an online survey among Sri Lankan construction

industry professionals who had an awareness of RFID technology. The questionnaire was completed with a response rate of 80%, since out of 120, 96 professionals had responded. Figures 1 and 2 illustrate the industry experience of the respondents and their level of awareness of RFID respectively.

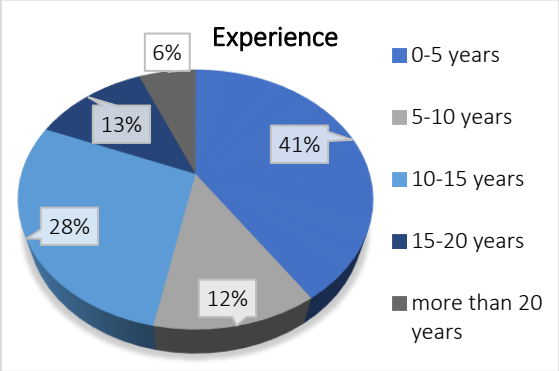

Figure 1: Experience of respondents

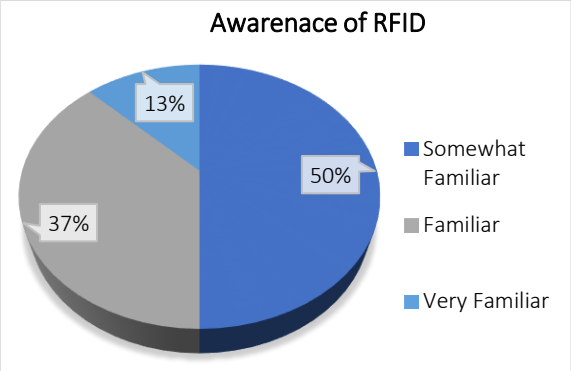

Figure 2: Level of awareness

The qualitative data collected from the preliminary survey were analysed using content analysis to identify themes and patterns related to the adoption of RFID technology in the Sri Lankan construction industry. The quantitative data collected from the questionnaire survey were analysed using the Relative Importance Index (RII) technique to identify the most important benefits that influence the adoption of RFID technology in the Sri Lankan construction industry. Factors with RII values of 0.800 or more than 0.800 are considered highly significant factors in this study (Akadiri et al., 2013). Whereas RII values between $0.6 \leq RII < 0.8$ and less than 0.600 are considered significant and not significant respectively.

4. DATA ANALYSIS AND FINDINGS

4.1 IMPLEMENTATION OF RFID TECHNOLOGY IN SRI LANKAN CONSTRUCTION INDUSTRY

During the preliminary expert survey, it was revealed that the USA, European countries, Middle Eastern countries, China, Malaysia, Singapore, and Australia have successfully implemented RFID technology in the construction industry. Experts highlighted their opinions regarding why Sri Lanka has not implemented RFID technology in the construction industry and most of them highlighted, as a developing country, Sri Lanka has financial and technical limitations when adopting new technologies. E3 elaborated "*construction companies in Sri Lanka do not have resources such as finances, technical staff, equipment related to this technology*". Additionally, E4 added "*developing countries most of the time prefer to stick to traditional methods rather than adopting innovative technologies. The construction industry is no different. People are reluctant to move from their comfort zones"*. Further, E2 highlighted that the younger generation prefers innovative technologies to senior professionals in the construction industry and they will be a greater influence when implementing RFID technology. According to E4, "*more benefits are available if we could implement the RFID technology. Therefore, it is beneficial to implement it in the construction industry*". Eventually, all the experts commented positively on introducing RFID technology to the Sri Lankan construction

industry. In this sense, it is worth noting E1's explanation where it was claimed that "*RFID improves the quality of the operation. RFID is a better technology available with many benefits which are essential for the development of the Sri Lankan construction sector*".

4.2 APPLICATIONS OF RFID TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

According to the responses of experts, they all agreed that RFID technology can be applied to **Machinery Management**. E5 mentioned, "*RFID is one of the most effective automated technologies used for machinery management*". However, experts did not agree with the guiding, operation as one of the RFID applications. E1 explained, "*guiding and operation is the same process done in tracking*". E2 and E4 had similar thoughts to E1. Additionally, E3 mentioned that the phrase guiding, the operation does not explain the exact application of RFID and he supported his view with an example that "*as an example machine used in a construction site can be tracked and operated using RFID technology. There is no need to repeat it".*

Five experts accepted that RFID can be used in **Material management**. E2 did not agree with the Logistic and Supply Chain Management (LSCM) application since he did not have any idea about it. E4 mentioned, "*applying RFID to ensure the quality assurance application is not that effective. There are other applications to which RFID technology can be applied*". Further E4, suggested that lifecycle information tracking using RFID technology is an additional application.

All the experts have agreed with **Labour management** as an application of RFID technology. **"***When it comes time to process payroll, this means that there will be more work for the person who needs to find these wayward employees and make the necessary repairs. Each employee's hard hat or employee ID card has an RFID tag attached to it. A portable reader or a gateway at the job site's entrance can be used to scan the tags".* E3 elaborated stating, "*there is an RFID solution to suit your demands, whether you want to increase efficiency, increase safety, or better manage your assets, personnel, and equipment".* Further, E5 mentioned that RFID technology can be applied to onsite inspections.

4.3 BENEFITS OF RFID TECHNOLOGY IN THE CONSTRUCTION INDUSTRY

The experts were requested to express their opinions regarding the benefits of RFID technology in the construction industry. All the experts agreed that **cost reduction** is a major benefit of RFID technology if implemented in the construction industry. E1 explained, "the *main purpose of applying a modern technology rather than forwarding through the traditional methods is to reduce the cost*". According to the opinion of experts, RFID technology **enhances product quality and safety**. It was acknowledged that RFID technology improves the services in the construction site in return which helps the outcome of the project to be an enhanced quality product.

All experts agreed that **inventory discrepancy reduction** is a benefit of RFID technology in the construction industry. Further experts mentioned that anything that is lost can be found using the RFID system which in return ensures security. Moreover, E3 agreed on the benefit mentioning *"definitely RFID improves inventory management*". All eleven experts accepted that **productivity improvement** is a benefit of RFID technology in

construction. E7 elaborated "*implementing RFID in a construction site would assist efficient work management and time management with its numerous applications. Therefore, the productivity of the construction would improve".* Every expert believes that the **availability of real-time data** is a benefit of RFID technology. E3 pointed out that using RFID staff, machine and material localisation can be done. Whenever someone needs to know the information, they are already available on the computer since tags are sending radio signals about their current location. Additionally, E4 stated, "*with one mouse click one can locate the person, material or machine without wasting time*".

Though **tracking** is identified as a benefit of RFID technology in the construction industry by many researchers, four experts disagreed mentioning that it is an application of RFID rather than a benefit. However, E3 had a different opinion than the other four experts stating that tracking could be taken as a benefit of RFID. The common view of experts was that inventory discrepancy reduction is equal to an **error rate reduction.** E2 explained, "*as per my knowledge error reduction and discrepancy reduction are the same thing".* Therefore, it was removed from the benefits list since there is no need to repeat the same benefit twice.

As per the experts' opinion, **system automation** is a benefit of implementing RFID in the construction industry. E1, E3, and E4 highlighted the importance of implementing RFID technology in construction sites, as RFID tags help to identify objects, transmit information, and store the information automatically. Moreover, E5 explained, "*RFID technology acts as a base in the data acquisition, the automatic identification and analysis systems worldwide".* Further E2 mentioned that this is conservative with resources in the construction industry. All experts believe that the RFID technology in the construction industry offers **data backup** as a benefit. E6 explained, "*information gathered through RFID tags is stored in a database*". Further E5 added, "*daily backups are available in the database. Necessary information can be obtained easily*". Furthermore, the preliminary survey identified several benefits not mentioned in the literature survey, including better asset management and handling of returnable assets, improved efficiency of store operations, enhanced connections with suppliers, and improved time management.

4.4 SIGNIFICANT BENEFITS OF RFID TECHNOLOGY IN SRI LANKAN CONSTRUCTION INDUSTRY

The questionnaire was intended to collect information regarding respondents' opinions on the benefits which the Sri Lankan construction industry would gain from the implementation of RFID technology. Figure 1 and Table 3 illustrate the results of the respondents regarding the benefits that the Sri Lankan construction industry could gain if RFID technology is implemented.

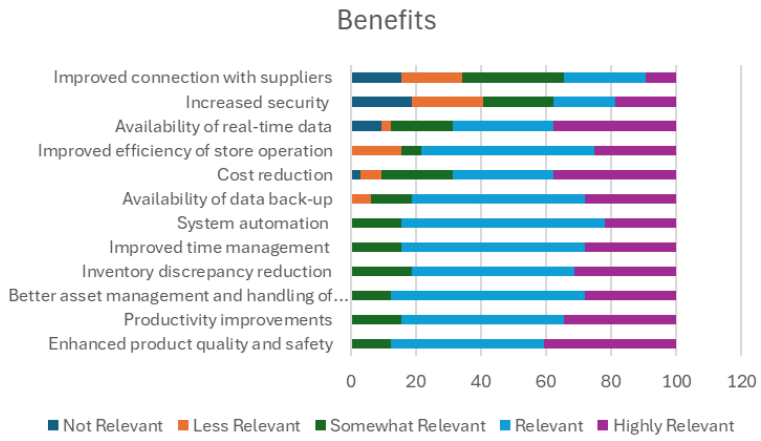

Figure 3: Relevancy of benefits of RFID

Table 2: Benefits of RFID

Benefits	RII value	Significance level	Rank
Enhanced product quality and safety	0.856	Highly Significant	1
Productivity improvements	0.838	Highly Significant	2
Better asset management and handling of returnable assets	0.831	Highly Significant	3
Inventory discrepancy reduction	0.825	Highly Significant	4
Improved time management	0.825	Highly Significant	4
System automation	0.813	Highly Significant	6
Availability of data back-up	0.806	Highly Significant	7
Cost reduction	0.788	Significant	8
Improved efficiency of store operation	0.775	Significant	9
Availability of real-time data	0.769	Significant	10
Increased security	0.594	Not Significant	11
Improved connection with suppliers	0.588	Not Significant	12

According to Table 3, respondents have identified "enhanced product quality and safety" as the most significant benefit. This benefit had an RII of 0.856 which was the highest RII value. "Productivity improvement" was ranked number two among other benefits with a 0.838 RII value. Better asset management and handling of returnable assets, inventory discrepancy reduction, improved time management, system automation, and availability of data back-up are selected as highly significant benefits other than the above-mentioned benefits. Significant benefits of RFID were ranked after highly significant benefits. They had scored a range of 0.6-0.8 RII value. Respondents have identified cost reduction, availability of real-time data, and availability of real-time data as significant benefits to the Sri Lankan construction industry. However, increased security and improved connection with suppliers were identified as non-significant benefits of RFID technology to the Sri Lankan industry during the analysis of the questionnaire. Two benefits have scored RII of 0.594 and 0.588 respectively which were identified as a non-significant benefit to the Sri Lankan construction industry since it had less than 0.6 RII value.

5. DISCUSSION

Findings of the expert interviews and the questionnaire findings have elaborated similar concerns about benefits. Enhanced product quality and safety, productivity improvements, better asset management and handling of returnable assets, inventory discrepancy reduction, improved time management, system automation and availability of data back-up were identified as the significant benefits to the Sri Lankan construction industry through the questionnaire. More importantly, this study produced results which corroborate the findings of studies conducted in the global context (Valero & Adán, 2016; Wang, 2008). However, 'increased security' and 'improved connection with suppliers' were identified as non-significant benefits of RFID technology to the Sri Lankan industry during the analysis of the questionnaire. These benefits were suggested by the experts during the preliminary survey. However, most respondents believe RFID tags can be easily manipulated, and the database of the RFID can be hacked. Therefore, the respondents may not perceive RFID as a technology capable of enhancing construction site security.

According to the findings, it was revealed that enhanced product quality and safety are the most significant benefits of RFID in the Sri Lankan construction industry. Subsequently, material, labour and machinery tracking applications were identified as the most significant applications of RFID in construction. When RFID technology is applied to tracking resources, it would provide effective resource management in the construction site which would derive a product with high quality and safety. Moreover, this would result in better asset management and handling of returnable assets in construction sites and reduce the error rate. Lastly, this would enhance time management and productivity improvements of the construction projects. However, it is important to acknowledge that RFID technology faces challenges in indoor construction environments, such as signal interference and limited range, which can hinder its effectiveness. Addressing these limitations requires further research and development to optimise RFID performance in such conditions.

6. CONCLUSIONS AND RECOMMENDATIONS

The study revealed that RFID technology has several advantages over traditional methods, including cost reduction, improved productivity, automation, and real-time data availability. Among them, enhanced product quality, safety, and productivity improvements are identified as the most significant benefits of implementing RFID technology in the Sri Lankan construction industry. The other highly significant benefits revealed from this study include better asset management and handling of returnable assets, inventory discrepancy reduction, improved time management, system automation and availability of data backup. Eventually, the study recommends that Sri Lankan construction firms should consider implementing RFID technology to improve the efficiency and productivity of their construction processes.

Moreover, this study contributes to the theory by identifying the potential of implementing RFID technology in the Sri Lankan construction sector which can be used as a benchmark in a similar context. The research findings revealed that the implementation of RFID technology has a higher potential to enhance the product quality and safety of the Sri Lankan construction industry. Theoretically, this study serves by manifesting the potential of RFID technology in improving technological applications in

the Sri Lankan construction industry. However, the findings of this study are limited to the Sri Lankan context yet can be used as a benchmark study for similar construction contexts. Further studies are aimed at conducting comprehensive discussions on the application of RFID technology within the Sri Lankan construction industry, focusing on strategies to enhance its utilisation in the country.

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