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Making Investment Decisions on RFID Technology: An Evaluation of Key Adoption Factors in Construction Firms

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ABSTRACT The importance of RFID technology is increasing as a means of enhancing productivity and efficiency, and reducing costs. The purpose of this research paper is to study the influence of technological, organizational, environmental, and innovation factors on the adoption of RFID technology by construction companies in Australia. With the growth of Australia's economy, in particular, the construction sector, the logistics departments in construction companies should pay attention to the adoption of more efficient technologies to provide better services for their customers. This paper provides a consolidated framework of RFID technology adoption based on studies on RFID technology adoption in particular from an IS perspective. The paper combines an integrated model of the Technology-Organization-Environment framework, the Diffusion of Innovation theory, and Actor-Network Theory to establish a more comprehensive innovation adoption framework for RFID technology. The data gathered to study the factors affecting the adoption of RFID technology are analysed from the results of a survey of construction companies in Australia, in which 297 Information Technology (IT) staff were participants in this research. The research results show that the factors which had a statistically significant and positive impact on the adoption of RFID services in construction companies were: relative advantage, compatibility, cost, expected benefits, top management support, external support and organization size. The findings from this research study have the potential to provide insights to firms seeking to make investment decisions on the adoption of RFID technology.

INDEX TERMS RFID technology, adoption, technology-organization-environment (TOE) framework, diffusion of innovation (DOI) theory, actor-network theory, construction companies.

I. INTRODUCTION

Effective management of logistics has surfaced as one of the strategic elements that offer a competitive edge to an organization at the global level [1], [2]. According to [3], the efficient functioning of logistics is considered one of the predominant elements for effective management of the supply chain [4], [5]. As [6] pointed out, providing the right services or products with the right amount, and the specified quality, along with the right cost at the right place and the right time to the receiver or the consuming unit, are the main objectives of logistics. The management of logistics involves implementation and control of the flow of processes from the initial point to final consumption, including storage, raw materials, linked procedures, and information [7]. It aims to satisfy the requirements of the customer [8]. Agreeing with [9], [10], it can be argued that logistics is considered an integral part of corporate

strategy in response to the globalisation of the supply chain. Many industries, including construction companies, outsource their logistic services to maintain the effective delivery of goods and services. Moreover, this approach is also helpful in meeting the logistical demands of the consumer [11].

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The exponential growth in the construction industry in Australia has considerably increased the demand for logistic services [12]. For this reason, there is a yearly increment in the total value of logistic services. For instance, in 2018 there were 48,747 registered businesses in road freight transport. These businesses range from operators of a single truck to large corporations at the multinational level [12]. As stated by [13], thirty percent of the transport tasks related to domestic freight are carried by road, comprising 726 billion tonne-km. As mentioned in a report by [14], by the year 2023 the cost of congestion on transport infrastructure is estimated to be around $53 billion a year. However, in 2017, the estimated total annual revenue of the logistics industry in Australia was $96.65 billion, which contributed $39.95 billion to the Australian economy [12].

Furthermore, there has been a noticeable increase in the construction of modernised distribution facilities and warehouses [15], [16]. Several companies have invested significantly in technological advancements related to information and logistics [17]. Despite the evident usefulness and increasing need and demand for logistic services, as stated by [18], the Australian Government is mainly utilising traditional means for the transfer of material at a commercial level, including the construction industry. The government is presently considering the initial steps for adopting and implementing the technology of RFID in industrial institutions. Based on the results of research conducted by [4], [19], [20], it can be argued that current and ongoing research would provide support to enhance supply chain management and performance, including the integration of logistic services in the construction sector [19]. According to [21], construction companies in Australia do not deploy technology at a significant level; therefore, several Australian companies face significant issues related to delays in access to the required material at the right time. More importantly, availability of and access of material is a major issue in remote areas. This leads to high financial and credibility loss between the construction companies, suppliers and the customer [20].

While the body of current and previous research in this area has focused on demonstrating the application and vitality of RFID, two important elements missing from the discussion are the factors and influential drivers that are key elements in inhibiting or fostering the more widespread integration of RFID technology in the construction industry [22]. Despite the significance of the role of RFID as identified in these studies, many of the studies are focused on the specifications and applications of RFID to resolve supply chain problems mainly related to cost-cutting and time saving [23]–[25]. According to [26], [27], cost is the key factor for the extensive utilisation of RFID technology. Nevertheless, the roles of other technological elements and organizational and environmental factors in the adoption of RFID technology need to be further investigated. This gap in the research is addressed in this study by the following research question: *What factors should the construction industry focus on in adopting and integrating RFID technology in the supply chain and logistics processes?* A framework to understand this phenomenon was developed for the purposes of this study, using an adaptation of three well-established theoretical models: The Technology-Organization-Environment (TOE) framework [28]; the Diffusion of Innovation (DOI) [29]; and Actor-Network Theory (ANT) [30]. This framework is intended to provide an improved and comprehensive understanding of factors critical for investment decisions related to RFID technology in terms of usability in the construction industry. This study aims to make a major contribution to the betterment of investment decision making in RFID technology. It investigates the major effects of organization, technology and environmental factors, along with innovation and benefits helpful in making investment decisions in favour of RFID technology. In order to evaluate the model of research, data were collected from 297 employees working in a range of construction organizations in Australia. The key factors that may pose a significant impact on investment in RFID technology in the construction industry are investigated using this sample of participants.

In the following section of the study, the theoretical groundwork will be introduced, related to determinants for adopting RFID technology. The third part of the study will describe the methodology of the research, while the fourth part will focus on data analysis along with the discussion of the findings. The final part will conclude with a discussion of further research in this domain, including recommendations based on the findings.

II. RELATED WORK

In the last ten years, several logistic services companies indicated that their supply chains were not meeting their targets in terms of responsiveness [17], [31]. As evident in studies by [17], [32], if logistics companies are willing to operate more efficiently and responsively, they should enhance adaptability and encourage advancement in technology that will help supply chain stages such as manufacturers, warehouses and retailers to communicate with each other effectively. During the 21st Century, with encouraging improvements in the dynamics of technology, the social and economic aspects are also undergoing a dramatic change process. In this rapidly changing and uncertain business environment, it is essential to gain a competitive advantage and increased market share. The adoption and implementation of innovation and technological developments can help in this regard [33]. Research studies have shown that companies or logistics departments within an organization tend to improve their performance by implementing modern technological advancements [34]. Research conducted by [35] states that various companies in the construction industry had integrated uninterrupted execution of information and automation technologies. These steps have radically improved the state of performance and efficiency of construction companies. As pointed out by [36], organizations should consider technological advancement, along with the implementation of IT, to elevate their capabilities and efficiencies related to the provision of service in the current age of digitalisation. Moreover, [37] pointed out that making an effort for technological advancement is a significant variable and provides a point of differentiation among organizations. In addition, [38] recommended that logistic units of organizations affiliated with the construction industry should innovate their technological services; and innovation changes in logistic services will be coordinated effectively through the implementation of technology, knowledge and networking. In light of the above mentioned evidence, it can be concluded that innovation in technology is crucial for the construction industry within Australia. Continuous advancement in technology can help the Australian construction industry to modernise both operations and business activities.

Radio Frequency Identification (RFID) is among the most competitive technologies that are supportive in operations related to logistics and management of the supply chain [7], [18], [39]. RFID is a form of automated identification technology that works through radio waves for the identification of individual physical objects [40].

The functions of the RFID system include three aspects: monitoring, tracking, and supervising [41]. Monitoring generally means to be aware of the state of a system, by repeated observation of the particular conditions, especially to detect them and give warning of change. Tracking is the observation of persons or objects on the move and the provision of a timely ordered sequence of respective location data to a model. Supervising is the monitoring of the behaviors, activities, or other changing information, usually of people.

As explained by [42]–[44], two main components of RFID technology include an antenna and a chip that contains an electronic code for a product. The antenna and sensor communities have witnessed a considerable integration of RFID tag antennas and sensors because of the impetus provided by the Internet of Things (IoT) and cyber-physical systems [45]. Such types of sensors can find potential applications in some industries because of their passive, wireless, simple, and multimodal nature, together with their compact size, particularly in large scale infrastructures during their lifecycle [46].

Enabling the sensing ability in RFID technology can enable the system to know the state of the real-world objects [47] and seamlessly integrate them within the global cyber-physical systems and IoT [48]. The sensing capabilities provided by RFID tag antennas in the ultra-high frequency (UHF) bands are an exciting research trend [49]–[52], with significant applicability to the emerging paradigm of the IoT as a green technology [53].

There are two main types of RFID tag-based sensing systems: *Analog RFID sensing*: These systems perform an analog processing of the physical signals related to the communication between the reader and the tag, with no dedicated sensing electronics [48]. The reader is able to obtain much more information about the target, more than just identification, without the need for additional electronics. Analog RFID sensing relies on the knowledge that the performance of an RFID tag is affected by the hosting object, and hence it is possible to retrieve sensing data simply by evaluating the variation of the signals backscattered from the tags. Sensitive coating materials or lumped components displaced over the antenna are also used to achieve a more specific response of the device [54]. *Digital RFID sensing*: Tags are integrated with electronic components, such as sensory material, analog-to-digital converters, and a microcontroller, to make an integrated sensor module [55], [56]. These systems are referred to as Computational RFID (CRFID). CRFID systems permit the running programs on embedded computers using only scavenged Radio Frequency (RF) energy. Battery free, ''invisible'' sensing and computation is key to truly ubiquitous computing applications for the IoT. The CRFID tag is used as a communication interface for transmitting data. Passive RFID sensors harvest the RF energy from RF radiation to power the circuit, perform the sensing task, and save the data in the RFID chip to be accessed by RFID readers [56].

The IoT is a global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. It will offer specific object identification, sensor and connection capability as the basis for the development of independent cooperative services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity and interoperability [41].

Considering functionality and identity as the basic features, the IoT could be defined as ''the network formed by things/objects having identities, virtual personalities operating in smart spaces using intelligent interfaces to connect and communicate with user, social and environmental contexts''. Using this network, mobile robots and wireless identifiable smart devices will be able to seamlessly interact and communicate with the environment, thereby contributing to the efficient, secure and inclusive nature of our society. Wireless identifiable devices such as RFID-Radio Frequency ID will form the backbone of IoT infrastructure, allowing new services and enabling new applications that require extensive machine-to-machine communications [45]. The evolution of IoT coincides with that of RFID and sensor technologies. From supply-chain helper to vertical-market applications to ubiquitous positioning, and so on, the RFID technology is a very important and fundamental groundwork for IoT [41].

IoT-driven asset tracking and inventory management lay a solid foundation for industrial process improvements and enhance the way business works. Here are just a few benefits that allow enterprises to operate more smoothly: automation of asset tracking and reporting; constant visibility into the statuses and movements of the assets; and optimization of movable equipment utilization; and inventory optimization [57].

The modernised technology of RFID is compact and sturdy and is functionally implemented in various industries, including manufacturing, distribution, and supply of physical goods [58]–[60]. It helps with easy and efficient identification of each item within a supply chain [23], [61], [62]. The application of radio frequency will help to identify items without any physical contact and will assist in improving efficiencies related to product handling [63], [64]. It is also significant to mention that RFID technology is a helpful tool for real-time communication of data and can fill the gaps in supply chain information, predominantly in retail and logistic services [65]. Therefore, effective control of the supply chain in response to effective sharing of information and communication of data in real-time can be achieved through the successful implementation of RFID technology [22], [66], [67]. As mentioned in the study by [67], RFID technology has been implemented in the supply chain systems of Proctor and Gamble along with European retail Group Metro. In addition, Wal-Mart has already implemented electronic data interchange (EDI) and a Bar code development system. Furthermore, at present, Wal-Mart is integrating RFID technology aimed at significantly improving the management of the supply chain [27], [67]. The directions for suppliers of Wal-Mart include implementation of RFID on each box and pallet shipped to Wal-Mart by January 2005 [27].

To sum up, some empirical studies use surveys and interviews to ascertain the perceptions of industry and academic experts and consumers on RFID [68], [69]. Other studies use a case study approach to investigate the value of RFIDs [70]–[72]. Other analytical studies have used mathematical models to compare across operations before and after RFID adoption in order to estimate the value of RFID from the difference in performance measures [73], [74], assuming some simplified conditions of the actual situations.

The majority of these empirical studies used a wide variety of methodologies focusing on the value derived from adopting RFID technology. However, there remains very limited research on understanding of the RFID adoption process and the factors that might influence its adoption in reference to the construction sector in Australia. The values derived from the adoption of RFID technology will be different depending on the adoption stage and the factors that might affect the adoption. This research study is an attempt to bridge that gap so that relevant questions regarding the value and the factors that might influence the RFID technology across all adoption stages are asked thus providing more insights. Such insights may contribute to more wide spread and well informed RFID adoption particularly by construction companies.

III. IT ADOPTION MODELS

The existing literature offers several theories of IT adoption and innovation diffusion [75], [76]. Key theories used to provide a framework for analysing technology adoption by individuals include the following:

- Theory of Planned Behaviour (TPB) [77], [78]. TPB is used to explain the impact of the adoption of new developing technology on individual performance, relying on an individual's feelings for behavior, social influence, and behavioral intention [79].
- The Unified Theory of Acceptance and Use of Technology (UTAUT) [80]. UTAUT has been used widely in clarifying technology adoption by individuals [81].
- The Theory of Reasoned Action (TRA) [82]; and the Technology Acceptance Model (TAM) [83]. Both models (TRA and TAM) are used to describe the relationship between the intent to use technology and user attitudes and beliefs [84].

The theories that provide a framework for technology adoption at an organizational level include the following:

- Diffusion of Innovation (DOI) theory [29]. DOI is one of the oldest social science theories that aims to convey how the likelihood of a new concept (*idea*) or product (*good or service*) gains momentum in its acceptance as it diffuses [29].
- The Technology-Organization-Environment (TOE) framework [28]. The TOE comprehensively defines the likelihood of a particular firm adopting and utilizing innovations based on technological, organizational, environmental, and sociocultural factors [28].

A combination of both of these theories is sometimes employed to achieve the same purpose [85]. However, in a recent survey of research into technology adoption, these researchers found that the vast majority of the articles they reviewed (82.5% of the 285 articles reviewed) lacked a theoretical framework [86]. Among the reviewed articles which used a theory, only 8.3% used DOI, TOE; or a combination of both [86].

A. TECHNOLOGY-ORGANIZATION-ENVIRONMENT FRAMEWORK

The TOE framework focuses on three distinct contextualising aspects: technological, organizational, and environmental contexts that affect the way organizations adopt advanced technologies [28]. The technological context includes the complexity, availability, and compatibility of the innovation; these factors affect the adoption of all new technology [87]. The organizational context includes the size, structural complexity, and human resources of the organization, potentially adopting the technology [28]. The environmental context signifies the industry's structure and competitiveness, as well as relevant government policies [88]. TOE is the only framework for research in this area which incorporates all three perspectives [87]. Extant literature offers strong empirical validation of the TOE framework [89].

Cost, security issues and privacy concerns can be incorporated as key elements within TOE's technological context [90]. These factors may influence the adoption of RFID technology [91], [92]. We, therefore, include these constructs in our assessment of the technological factors around RFID adoption, determining whether RFID can reduce costs, and assessing concerns around security and privacy.

We incorporate three constructs in the organizational context in our assessment of RFID: the size of the firm; prior employee experience with IT; and support from top management [93], [94]. Firm size is important because large firms have more resources and capacity to absorb risk [93]. Prior employee experience is important because firms with a higher rate of prior experience tend to be more willing to adopt new technologies; correspondingly, education of the firm's staff can increase the firm's willingness to adopt new technology [95]. Finally, top management typically directs the allocation of resources and the support of other services within the organization, greatly facilitating the adoption process or otherwise [87].

We added two constructs under the umbrella of the environmental context for our analysis. These were government regulation and external support [96]. Government regulations can discourage or encourage the adoption of new technology, including RFID. External support includes the availability of technical support outside the adoptive firm, making firms more likely to take up new technologies for which support is available [97].

B. DIFFUSION OF INNOVATION THEORY

The DOI theory attempts to explain the speed, diffusion method, and reasons for innovation spreading, considering both individual and organizational levels of adoption [98]. DOI theory sees innovation as transferring through channels over a long period [98]. DOI theory holds that people are willing to accept a specific rate of change and that most people, therefore, normally take a long time to adopt new technological innovations [98]. Most studies on organizational adoption of new technologies use or draw on the DOI model [99], [100]. The extant literature also offers strong empirical support for the validity of the DOI model [87].

This research study adopts four constructs from the DOI model: complexity, compatibility, observability, and relative advantages [99], [101]. Complexity could affect the adoption of RFID because the system can be sufficiently complex to require technological expertise within the organization. Organizations lacking skilled IT staff may resist the adoption of RFID [15]. Compatibility may also be significant because, in the majority of cases, supply chains require coordination and communication throughout the entire system. If RFID is incompatible with existing system components, this will form a barrier to the adoption of the technology [102]. Observability relates to the extent to which the elements of the supply chain can be seen, as well as the ease with which RFID use is observable. Both of these factors impact how quickly RFID may be adopted for the advantages it provides in the accessibility of information [103]. Relative advantages refer to the improved efficiency, economy, and popularity of innovation concerning existing or current technology; the cost of adopting the technology is the main consideration when assessing it against other technologies [100].

C. ACTOR-NETWORK THEORY

Actor-Network Theory (ANT) is a useful framework to describe how social contact influences technological uptake. It can indicate the value of analytical concepts and show the connections between the use and retention of technology [30]. Human actors exist in a network wherein they try to impose their values, ideas, and expectations on others – while in turn, being influenced by the values, ideas, and expectations of other actors [104]. If we take firms as our actors, those trying to spread their idea (the technology) will have less success if their interests and ideas do not conform with those of the actors they are trying to influence [105]. Actors whose offerings do not meet the needs of the main actor will be edged out of the network. ANT includes both social and technological factors as influencing outcomes [106]. ANT acknowledges the uneven interactions between actors and demonstrates how actors accept or reject the components integral to technological adoption [104]. The key benefit of including ANT in an analytical framework is that its scope is wide enough to encompass varied techniques of IT implementation and management to indicate what aspects affect adoption, and to accommodate academic research into the nature of linkages between actors [107].

D. OTHER FACTORS

Our conceptual framework also includes another dimension drawn from the literature: 'anticipated benefits', which measures the benefits associated with adopting the innovation [69], [88], [89], [108], [109]. Benefit characteristics are an important consideration as part of the technology adoption process as this dimension allows the model to incorporate information about the part of the business that is expected to benefit from the new technologies.

E. COMBINING TOE, DOI, AND ANT

Various researchers have asserted that an integrated combination of theoretical frameworks must be used in understanding the adoption of advanced technologies [110]. The process by which an innovation is adopted or rejected can be best understood through a comprehensive analysis of the literature, with relevant variables for the specific innovation under analysis being drawn from this body [85].

Some studies have only focused on the technological factors in innovation adoption [111]. When studies do include the organizational factors in the adoption of technologies, most draw either on DOI theory [28] [29], [100], [101] or TOE framework [90] [93]. Both models have strong empirical support [6], [89]. A combination of the two models has been shown to be more effective than either model alone in explaining the adoption of RFID technology [112]. This study further includes ANT, since its social contact modeling deepens our capacity to understand the spread of innovation [30], thus improving our understanding of the processes of adoption and any potential inhibitors.

The integration of TOE and DOI factors establishes a variable set with strong backing by extant literature [113]. Each theory has strengths in its variable set, which reflect its specific analytical framework: TOE, for instance, has a stronger validity in modeling intra-firm innovation, while the DOI model better captures factors related to the features of innovation in its adoption. Table 1 compares the benefits of combining the different models that being integrated for this research study. This table demonstrates the validity recommended by [15] which claims that the combination of theoretical frameworks provides a more comprehensive model for research in this area.

TABLE 1. Benefits of combining TOE, DOI and ANT.

Benefit	TOE	DOI	ANT	TOE+DOI+ANT
Focus on the environmental context of any new innovation technology adoption	✓			✓
Better able to explain intra-firm of any new innovation technology adoption	✓			✓
Focus on the innovation characteristics of any new innovation technology adoption		✓		✓
Useful combination framework for studying a variety of Information System (IS) adoption	✓	✓	✓	✓
Empirical support and theoretical basis	✓	✓	✓	✓
Focus on the human interaction which linked with the use of technology			✓	✓
Provision of a better understanding of the whole IS adoption phenomenon				✓

Adapted from [15][30][113]

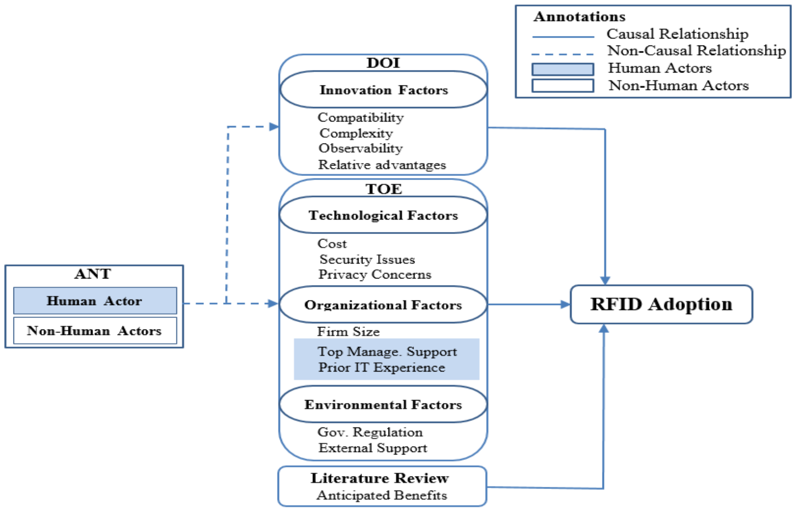

FIGURE 1. The conceptual research model.

IV. THE RESEARCH MODEL

The theoretical framework employed by this study is formed by integrating the TOE framework and the DOI model and, to a lesser extent, by drawing on the ANT. Figure 1 displays the research model, indicating the four dimensions believed to influence the adoption of RFID technology by construction companies: technological, organizational, environmental, and innovation factors.

Our comprehensive framework combines the technological, organizational, and environmental fields from the TOE framework, the innovation characteristics of DOI theory, and the impact of human actors from ANT theory, to facilitate analysis of the diffusion of technological innovation [114].

A. HYPOTHESES ANALYSIS

Thirteen hypotheses were generated and tested in order to analyse the theoretical research model expounded in the previous section. Survey data was collected from companies in the construction industry; and this study was limited to the construction industry.

Relative advantage is the degree to which adopting/using the IT innovation is perceived as being better than using the practice it supersedes [15]. It also refers to the perceived benefits of innovation in comparison to existing technology [15], [69], [98], [109]. These benefits include efficiency, economy, and popularity, as well as the cost of adopting the innovation [15], [100]. When the user believes that the innovation provides a greater relative advantage than the existing technology, the innovation is usually adopted [100], [103]. It is therefore hypothesized that where customers believe RFID provides a high relative advantage, they will be more likely to adopt it.

H1 *The relative advantage of RFID positively affects the adoption of RFID.*

Compatibility: Drawn from the DOI theory, this factor significantly influences the rate, location, and intensity of implementation of an innovation [15], [98], [115]–[117]. The compatibility of RFID with the working environment greatly influences the likelihood of its adoption [99], [100], [118].

H2 *The compatibility of RFID with an organization's existing technologies positively affects the adoption of RFID.*

Complexity: Also drawn from the DOI theory, complexity is a significant influencer potentially hindering the adoption of new technology [15], [87]. Higher complexity can lead to problems around information availability and innovation usage; additionally, the time taken to utilize the innovation's interface forms a cost of adoption [119]. New technologies are more easily adopted when they are simple or at least simple to interact with [99]–[101]. It is therefore hypothesized that the perceived low complexity of RFID will enhance its rate of adoption.

H3 *The perceived low complexity of use of RFID positively affects the adoption of RFID.*

Observability: This is the extent to which the innovation's outcomes can be perceived [120]. Observability can be separated into two categories: visibility and demonstrability. In regard to RFID, observability is an important frame of analysis because this is a key strength of its design – it can facilitate visibility across regions, reduce delay in observation time, and increase accessibility [103]. The observability of RFID is hypothesized to improve the chance of its adoption.

H4 *The perceived observability of RFID positively affects the adoption of RFID.*

Cost: Cost depends on the efficiency of operational processes. Cost-reducing innovations are typically more easily adopted [93], [94], [108]. RFID adoption can substantially reduce the IS cost within an organization [121]. Cost has been used in many previous studies as a significant factor to investigate the adoption of several different technologies [93], [94], [108]. In this context of RFID, the following hypothesis is built:

H5 *The potential of cost reduction by using RFID positively affects the adoption of RFID.*

Security issues: Security in the context of RFID refers to the security of data. Extant literature has shown that security concerns impact on the adoption of innovations [88]–[90]. Consequently in the RFID research framework, the following hypothesis evolves:

H6 *The potential of improving data security by using RFID positively affects the adoption of RFID.*

Privacy concerns**:** This is a related topic to security issues. Privacy and confidentiality of data are important to organizations and, as data-handling systems, these are, therefore, key issues in the adoption of RFID [15]. RFID systems can improve their privacy by adding security elements, such as mutual authentication, key establishment, and data confidentiality in internet data storage [91], [92], [122]. In this context, the following hypothesis is built:

H7 *The potential for improving data privacy by using RFID positively affects the adoption of RFID.*

Firm size: The scale of the enterprise within the organization is a key element in the spread of new IT [15]. Smaller firms are less able to adopt new technologies since they have less flexibility due to their smaller resource base [123]. Larger firms, by contrast, have more capacity to absorb risk and more resources to devote to technological pivots, making them far more likely and willing to adopt innovations [124]. The size of firms' has been investigated in many studies on the adoption of previous technology [88]–[90], [93], [94]. Thus, the next hypothesis is recommended:

H8 *The size of firms is positively linked to the adoption of RFID.*

Top management support: The leadership of an organization has a large impact on the adoption of innovative technology within the firm. Research has shown this to be the mechanism by which organization culture impacts IT adoption [125]. Other studies have shown that a lack of top management support for technology adoption reduces the tendency of organizations to adopt new innovations [117]. The impact of top management support in the adoption of new technology has been investigated in many previous studies [87], [90], [93], [94]. In the context of the goal to undertake RFID, the following has been hypothesized:

H9 *Top management support positively affects the adoption of RFID.*

Prior IT experience**:** The experience of the workforce of an organization with IT, along with their ability to work creatively and collaboratively together in their development of systems using IT, increases organizational likelihood to adopt innovative technology [126]. These factors help teams to understand the tasks necessary for successful adoption, and to improve their systems in dealing with the technology [95], [127]. Several studies have shown the links between prior IT experience and the adoption of new technologies [87]–[89].

H10 *The workforce's prior RFID experience positively affects the adoption of RFID.*

Government regulation**:** Governments can encourage or discourage the adoption of new technologies in general, or a specific new technology, through their regulatory frameworks for industry [128]. Industries take these regulations, rules and guidelines into account when assessing whether to adopt new technology [129]; regulation has, therefore, been considered by numerous previous studies in this area [88], [108].

H11 *Favourable government regulations positively affect the adoption of RFID.*

External Support: For some technologies, external help is available to facilitate firms' introduction and use of an IS [130], often in the form of technical support. This can lead to an increase in the adoption of RFIDs [97]. Hence, in the environmental context, this paper predicts that:

H12 *Availability of external support to facilitate RFID implementation positively affects the adoption of RFID.*

Anticipated benefit**:** The decision made by a firm to adopt RFID is crucially connected to that firm's perception of the benefits which may be drawn from the integration of RFID [5], [69], [109]. Depending on the firm's needs and current strengths and growth areas, it may regard different elements of RFID as most beneficial, and value specific benefits more highly [131]. Potential benefits may include reduced cost [69], [109], [132] or improved standardization of service [133]. Many studies have mentioned anticipated benefits as a key element in understanding the adoption of technological innovation [69], [88], [108], [109].

H13 *The anticipated benefits of using RFID positively affects the adoption of RFID.*

Drawing on their ontology, researchers must articulate a research philosophy to support the most appropriate methodology for their research area of interest [134]. The methodology is a theoretically-based system for the development and evaluation of knowledge [135]. This study uses a quantitative

TABLE 2. Reliability indicators.

Constructs	Cronbach's Alpha First Round	No. of items	Cronbach's Alpha Second Round	No. of items
Relative advantages	.852	9	.852	9
Compatibility	.678	5	.793	4
Complexity	.831	5	.831	5
Observability	.554	5	.760	4
Cost	.901	7	.901	7
Security issues	.597	8	.702	5
Privacy concern	.876	5	.876	5
Top management support	.693	6	.754	5
Firm size	.859	5	.859	5
Prior IT experience	.599	5	.772	4
Government regulation	.890	7	.890	7
External support	.821	5	.821	5
Anticipated benefit	.903	16	.903	16
RFID adoption	.674	7	.898	5
Total		**95**		**86**

method, gathering data through formal surveys of large numbers of participants. This methodology provides statistically significant and generalizable results [136].

V. RESEARCH METHODOLOGY

This research uses a survey instrument that is focused around constructs drawn from extant literature on the adoption of novel technologies in organizations [137], [138]. It explores the hypotheses listed above. A survey was chosen for the methodology because of its flexibility, low cost, and quick data collection [139]. Surveys are adaptable and allow respondents to integrate their qualities, knowledge, and disposition into their answers [140]. The questionnaire was intended to test the measurement framework and proposed conceptual framework. It consisted of a seven-point Likert scale for each measure, where '1' indicated strong disagreement and '7' represented strong agreement. This research used a 7-point Likert scale, because it is more likely to reflect a respondent's true subjective evaluation of a usability questionnaire item than a 5-point item scale [141]. The 7-point Likert scale is sensitive enough to minimize interpolations and is also compact enough to be responded to efficiently. Also, the 7-point Likert scale excelled not only in objective accuracy but also in perceived accuracy and ease of use [141]. The survey was delivered online to maximize its accessibility and reach [142]. It was available 24/7 over a three-month period (January, 15 to April, 14, 2020).

A pre-study was conducted first with academics from 6 universities who are experts in the area of this research topic (technology adoption). The pre-test was conducted to assess the survey's layout and validity, identifying weaknesses, and allowing the researchers to improve its efficacy [143], [144]. Then, a pilot study was distributed to people from top management and IT managers from several construction companies as recommended by [144]. A total of 19 (76%) surveys were returned from 25 surveys that were distributed. Cronbach's alpha was used to evaluate the reliability of the research instrument items in the conceptual framework [145]. Based on the results of Cronbach's alpha, the survey instrument was narrowed from 95 to 86 items. The table below compares their internal consistency using Cronbach's Alpha scores. The scores, post-refinement, ranged from acceptable to high (.702 to.903), indicating a good level of internal consistency for all measures [145], [146] (see Table 2).

The research participants were drawn from Australian construction companies, which engaged in construction engineering and house/office building. These construction companies are the primary sources of building and road construction services in their communities. They depend heavily on advanced technologies for their communication. This research focuses mainly on their IT departments as the target survey respondent demographic, which will elucidate whether they have the telecommunication infrastructure base to adopt RFID and show the factors in their decision-making processes regarding RFID adoption. The IT managers for each company were given a link to the survey, and asked to distribute that link throughout their IT staff. To ensure no respondent took the anonymous survey multiple times, the IP address of response computers was saved as log information for audit.

A. RESEARCH DATA

The survey distributed to Australian construction companies returned 297 individual responses from IT-related staff. Table 3 describes the demographics of respondents.

The key demographic information collected comprised the role of the respondent within IT, their knowledge of RFID, and their total number of years' experience in IT-related areas. Table 3 shows that 46.5% of respondents worked on system analytics and development, and 39.4% had 'little knowledge' of RFID. The highest proportion of respondents had between 2-5 years' experience in construction, with 1-2 years and 5-10 years being the next most common response categories. For IT, the highest proportion had 10-15 years' experience, while equal numbers had 2-5 years' and 10-15 years' experience.

TABLE 3. Sample characteristics ($N = 297$).

Demographics	Frequency	Percent
Roles in IT		
Management	84	28.3 %
Systems Analyst and development	138	46.5 %
Systems Operation	73	24.6 %
Other	2	0.7 %
Knowledge related to RFID		
Very little knowledge	58	19.5 %
Little knowledge	117	39.4 %
Some knowledge	68	22.9 %
Good knowledge	44	14.8 %
Excellent knowledge	10	3.4 %
Years' of experience in IT		
Less than 1 year	1	0.3 %
1-2	26	8.8 %
2-5	61	20.5 %
5-10	51	17.2 %
10-15	97	32.7%
More than 15 years	61	20.5 %
Years of experience in the construction industry		
Less than 1 year	9	3.0%
1-2	77	25.9%
2-5	104	35.0%
5-10	62	20.9%
10-15	39	13.1%
More than 15 years	6	2.0%
Total	**297**	**100 %**

VI. RESEARCH RESULTS

A. MEASUREMENT MODEL

This study used several statistical analytical techniques to measure the fit, reliability and validity of the proposed conceptual research model. We used factor analysis to measure the validity of the scales, including Confirmatory Factor Analysis (CFA). We also tested the reliability and validity of the scales, in order to demonstrate internal consistency.

1) FACTOR ANALYSIS

Factor analysis is a statistical technique used to ensure the validity of the scales. It can be used to improve and assess tests and scales [147]. This research includes CFA within this technique. The purpose of CFA is the examination of a theory. Its arithmetical methodology is a form of Structural Equation Modelling (SEM) [148]. CFA differs from EFA in that it draws its suppositions and prospects from existing theories about the number and relevance of factors [149]. In this study, CFA occurred using AMOS Graphics 22. There are three types of measurement model: tau-equivalent, parallel, and congeneric measurement. The latter type was used in this study to refine our measurements using fit measures. All thirteen constructs were separately tested with this technique, and we achieved fitness for the one-factor congeneric measurement model. As a result of this process, our conceptual research framework item number was reduced from 86 to 69. Then, overall measurement model tests as recommended by [150] were conducted on the remaining constructs of the conceptual research framework. As a result of this stage, about 22 items and 1 construct (prior IT experience) were removed from the conceptual research framework. This stage of the refinement left 47 items and 12 constructs in the research conceptual framework to be tested and validated in the SEM process. The proposed model can thereafter be expressed as follows: (GFI = 0.90, AGFI = 0.82, RMSEA = 0.061, RMR = 0.039, Chi-sq/DF = 4.421, IFI = 0.90, CFI = 0.90 and TLI = 0.89).

2) RELIABILITY AND VALIDITY

The constructs' reliability and validity were assessed through a range of measures.*Cronbac*'s *Alph*a returned measures within the recommended acceptable level of $\geq$.70 [146]– values for the constructs ranged from 0.794– 0.963. *Convergent Validit*y, assessed using Standardised Regression Weights (SRW), where the factor loading is recommended to be 0.50 or above[151], returned values from 0.604 to 0.983, which demonstrates convergent validity.*The Squared Multipl*e *Correlatio*n (SMC), which indicates dependency among items used in factor determination, has a recommended level of 0.30 or more [152]; it returned values from 0.494 to 0.882. Finally, the *Critica*l *Ratios* (CR), with a recommended standard value of 1.96 [152], returned values between 8.930 and 28.195. Collectively, the measures indicate a high level of regression validity in the research model.

B. STRUCTURAL EQUATION MODEL (SEM)

The intent of the research conceptual model was the establishment of key factors affecting the adoption of RFID technology by construction companies. The twelve factors were tested for their effect on the adoption of RFID technology.

TABLE 4. Results of the hypothesized path relationships.

Hypotheses	Path	Estimate (B)	S.E.	C.R. (t)	P	Result
H-1	Relative advantage	.542	.058	10.398	***	Supported
H-2	Compatibility	.439	.073	7.256	***	Supported
H-3	Complexity	.087	.051	1.706	.088	Not Supported
H-4	Observability	.049	.075	.650	.516	Not Supported
H-5	Cost	.071	.040	2.562	.038*	Supported
H-6	Security issues	-.105	.061	-1.722	.085	Not Supported
H-7	Privacy concern	.215	.074	1.841	.432	Not Supported
H-8	Firm size	.605	.075	7.926	***	Supported
H-9	Top management support	.154	.046	4.006	.002**	Supported
H-10	Prior IT experience	Been removed in the overall model test				
H-11	Government regulation	-.309	.038	-7.112	***	Supported
H-12	External support	.374	.056	6.289	***	Supported
H-13	Anticipated benefits	.118	.036	3.127	.002**	Supported

** = value is statistically significant at P < 0.05 level*
*** = value is statistically significant at P < 0.01 level*
**** = value is statically significant at p < 0.001 level*
 # standardized path coefficients are appeared as solid arrows. Non-significant paths appeared as dashed arrows.

According to [153], the SEM indicates the section of a methodology wherein the relationship between latent variables is determined. As defined by [145], SEM is an approach that is used in identifying factors which might directly or indirectly affect the values of other latent variables. Evaluation of the fit indices of the structural model indicates moderate to good fit (GFI = 0.89, AGFI = 0.84, RMSEA = 0.061, RMR = 0.040, Chi-sq/DF = 2.895, IFI = 0.90, CFI = 0.90 and TLI = 0.90).

In Table 4, the results of the regression analysis for the factors used in the innovation adoption model are collated, along with indications of whether the results support the 12 hypotheses. Table 4 shows the SEM results, measured using path coefficient (β) value with the critical ratio (t-value), and p-value. The standard decision rules t-value greater than 1.96, and p-value at < 0.01 or ≤ 0.05 are applied as measurements of the acceptability of each factor presented in the conceptual research framework as recommended by [151], [152].

Table 4 also shows the results of the regression tests. These confirm that seven out of twelve constructs, and the related hypotheses, can be accepted as significant and positively correlated to RFID adoption. These constructs are compatibility, cost, top management support, external support, relative advantages, firm size, and anticipated benefit. The other four constructs have been rejected as non-significant: complexity, security issues, observability, and privacy concerns. Only one construct was found to be significant but negatively correlated to RFID adoption: government regulation. IT experience was removed as a construct in the process of method development. In Figure 2 we display the path diagram for these final relationships.

C. HYPOTHESES RESULTS DISCUSSION

Despite the fact that RFID technology is time-saving and cost-effective and offers more efficient control of the mobility of products, various studies have been conducted that examine the elements influencing the adoption and utilization of RFID technology in different sectors [18], [20], but there is a dearth of studies relating to the Australian construction sector. This study investigates a range of factors that are anticipated to impact the adoption of services based on RFID technology. The influence of these factors, based on the results of our data collection, is explained here.

1) RELATIVE ADVANTAGE

The model predicted a significant and positive relationship of relative advantage with the adoption of the RFID technology. A statistical analysis produced a standardized coefficient (β) of 0.542 along with a t-value of 10.398, and a p-value $<$ 0.001 level which is *** significant (see Table 4). According to research conducted by [100], [103], the organization is more likely to adopt any new technology when it perceives the importance of usage and benefits over former means. Hence, the findings of the current research study confirm that there is a significant relationship of the relative advantage with the adoption of the new technology by the organization.

2) COMPATIBILITY

The model represented a significant and positive relationship of compatibility with the adoption of RFID technology. A statistical analysis produced a standardized coefficient (β) of 0.439 along with a t-value of 7.256 and a p-value $<$ 0.001 level, which is *** significant (see Table 4).

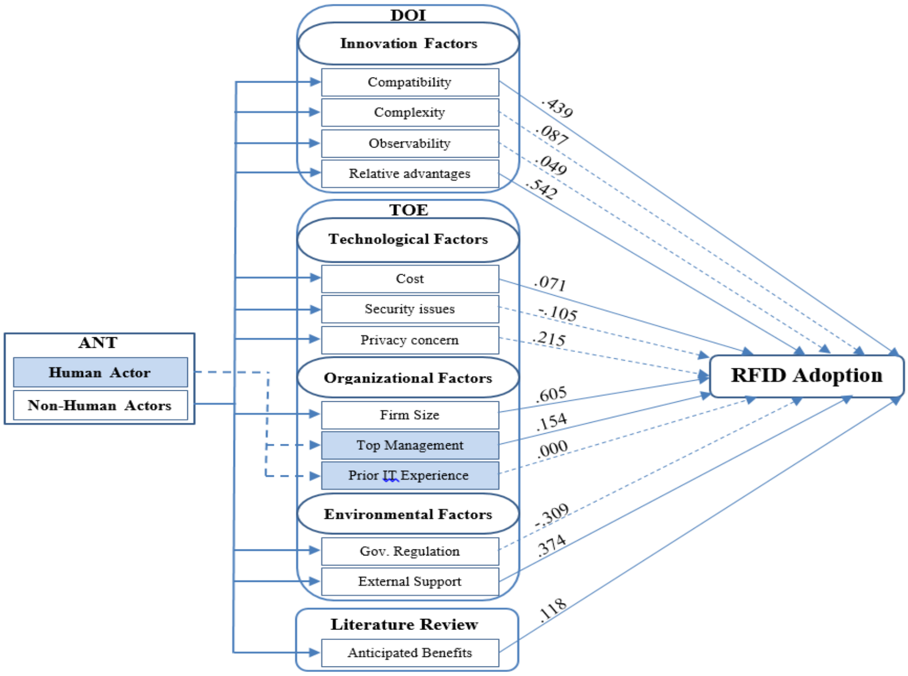

FIGURE 2. RFID adaption framework.

The review of the literature suggested that numerous studies were conducted to understand the role of compatibility and its relation with the adoption of IT [98], [115], [116]. According to [95], [118], [155], compatibility was among the significant determinants for innovation diffusion in its post-adoption phase. Hence, the results of this study confirm the findings of previous research.

3) COMPLEXITY

The model demonstrated that there is no significant relationship of complexity involved in the adoption of the RFID technology and its usability. A statistical analysis produced a standardized coefficient (β) of 0.078 along the t-value of 1.706, and the p-value of.088 (see Table 4). According to the research conducted by [156], the complex nature of innovation may hinder the adoption of new advancements in technology. Other research, such as that by [95], [157], signified that complexity has been reported to negatively influence the acceptability of advancements in technology. In contrast to this, many researchers claimed that complexity is not influential in relation to the acceptance of technological advancements [158], [159]. Nevertheless, several more research studies signified that the complex nature of technology plays an important role in decision making important for the adoption of the technology within a company [160]. The findings of this research study signified that the complex nature of technology is not a significant factor, and it has a negative influence on decision making for the adoption of RFID technology in terms of relatedness to the construction industry. This result affirms former research that signified that complexity has an adverse effect on decisions related to the acceptance of advancements in technology [95], [157]. On the other hand, the findings of this study do not support those of [160], as the complex nature of technology was extrapolated in these researches as a positive factor that affects the adoption of recent technology.

4) OBSERVABILITY

The model represented that there is no significant impact of observability on the adoption and use of RFID technology. Statistical analysis indicated that a standardized coefficient (β) was 0.049 along the t-value of 0.650, and the p-value level was 0.516 (see Table 4). In the area of RFID research, there is a need to demonstrate observability because the ability to access the facility without any delay throughout the region at any time has an impact. Transactional convenience and the transmissible nature of accessibility are considerable advantages [103]. Exposure and demonstrations of such services improve customers' understanding of RFID technology and its advantages. Moreover, they also facilitate the acceptance and adoption of technology. Nevertheless, the findings of this research study do not conform to previous studies, such as [103].

5) COST

The model demonstrated that there is a significant and positive relationship of anticipated cost with the adoption of RFID technology. Statistical analysis showed that the standardized coefficient (β) was 0.071 along t-value of 2.562, and the p-value $<$ 0.05 level was.038* (see Table 4). According to [93], for the most part, companies concentrate on the expected financial gains while considering the acceptability of operational models of RFID technology. Other researchers such as [121], [161] emphasised that people working with RFID technology observed that RFID adoption could considerably decrease the entire cost of ISs in an organization. Cost-effectiveness has been a significant matter of discussion in several previous research studies in relation to the degree of adaptability for any technology [94], [108]. Hence, the findings of this research study concur with the findings of earlier research in terms of the adoption of the latest technologies.

6) SECURITY CONCERNS

The model demonstrated that there is no significant and positive relation of security concerns with the adoption of the RFID technology. A statistical analysis showed that a standardized coefficient (β) was $-.105$ along with a t-value of -1.722 and a p-value level of.085 (see Table 4). In the context of the technology of RFID, security relates to the extent to which the security of RFID is considered to maintain a higher level of security in comparison to other models showing technological solutions. Security is highly critical for RFID technology in a way that is similar to other domains of ISs [92]. The issue of security has been previously discussed as a subject in several studies to investigate the effect on the adoption of recent technology [88]–[90], [155]. The findings of this research confirm that security concerns are not supported. Security concern is not an issue in the construction industry, specifically if these companies are using RFID to track equipments and materials.

7) PRIVACY CONCERN

The model demonstrated that there is no significant and positive relationship of privacy concerns with the adoption of RFID technology. A statistical analysis produced a standardized coefficient (β) of 0.215 along the t-value of 1.841 and the p-value level of.432 (see Table 4). Based on research conducted by [15] it is clear that privacy is a fundamental challenge in the adoption of RFID. The confidentiality and privacy of the company's data is critical for the security level of a company [92]. The findings of this research confirm that privacy concerns are not supported. Privacy concern is not an issue in the construction industry, specifically if construction companies are using RFID to track equipment - though it could be a concern if it was used to track employees on a job site.

8) TOP MANAGEMENT SUPPORT

The model demonstrated that there is a significant and positive relationship of top management support with the adoption of RFID technology. A statistical analysis produced a standardized coefficient (β) of 0.154 along the t-value of 4.006, and the p-value < 0.01 level of.002** (see Table 4). According to [125], going through predictors and factors in IT, it is evident that strategic management is a key connecting point for organizations and its adoption of IT innovation. Similarly, [117] found the same consistency in their studies, showing that organizations cannot effectively implement RFID technology without the facilitation of the strategic team. Previously, several studies have investigated the effects of the support of top management in the adoption of RFID technology [87], [90], [93], [94]. The results of this research study are consistent with the findings of the previous research.

9) FIRM SIZE

The model demonstrated that there is a significant and positive relationship between the size of an organization and the adoption of RFID technology. A statistical analysis produced a standardized coefficient (β) that was 0.605 along the t-value of 7.926, and the p-value < 0.001 level was *** significant (see Table 4). Based on the results of some previous researchers, for example, [155], [162], a positive relationship has been found between the size of an organization and acceptance of recent advancements in the technological industry. On the other hand, other researchers, for example, [163], concluded that there is a negative relationship between the two variables. In addition, other studies conducted by [164] also signified that the relationship is of significance. Nowadays, larger organizations have the advantage of having huge resources, skill sets, expertise and enhanced capabilities compared to organizations working at a smaller scale; therefore, they have the ability to deploy recent technological advancements.

In contrast, [123] emphasised that smaller organizations have the advantage of flexibility, and adjustments can be easily executed to meet their organizational goals. Therefore, they can be highly innovative and can make faster changes according to their needs. The size of an organization has been a topic of interest in several previous studies [88]–[90], [94].

In this research study, we observed that the framework deployed in this study detected a positive relationship between …and ….For the most part, small size construction industries based in remote areas have been struggling in search of the expertise necessary to execute any necessary support and recommendations. There is a likelihood that small organizations do not have expert professionals from the field of IT. However, if they hire dedicated professionals, the number of employees may be limited, or there is the chance that the professionals are not sufficiently well-informed about the skills required to help in the adoption of recent technology; or there is a lack of sufficient resources.

10) GOVERNMENT REGULATIONS

The model demonstrated that there is a significant but negative relationship of government regulations with the adoption of RFID technology. A statistical analysis produced a standardized coefficient (β) of 0.309 along the t-value of -7.112, and the p-value level of *** which was significant (see Table 4). The review of the literature suggests that the regulatory reforms of the government are influential factors in the adoption of IT in an organization [165]. In contrast, [129] suggested that specific reforms in regulatory requirements can help facilitate the organizational adoption of IT technology innovations. It will protect the organizational goals and businesses with the help of the integration of this form of technology. The findings of the study are limited because there is a noticeably restricted engagement of government bodies in the formulation of policies which results in a minimal effect on the adoption of RFID technology. One possible explanation may be that government regulations are pushing companies to redirect their resources (human and financial) towards the responses to the new requirements brought about by these regulations. Therefore, these organizations will view government regulations as a constraint in RFID adoption.

11) EXTERNAL SUPPORT

The model demonstrated that there is a significant and positive relation of external support with the adoption of RFID technology. A statistical analysis produced a standardized coefficient (β) of 0.374 along the t-value of 6.289, and the p-value < 0.001 level is *** significant (see Table 4). The review of the literature identified external support for aiding with technical issues can be a factor in enabling organizations to accelerate the adoption of RFID technology within an organization [97]. The findings of this research study confirm that external support is positively associated with the adoption of RFID technology.

12) ANTICIPATED BENEFIT

The model demonstrated that there is a significant and positive relation of anticipated benefits with the adoption of RFID technology. A statistical analysis produced a standardized coefficient (β) of 0.118 along the t-value of 3.127, and the p-value < 0.01 level is *** significant (see Table 4). The review of the literature suggests that, under various circumstances, an organization may have different perceptions related to benefits and advantages, and may appreciate some of these benefits more compared to other benefits [5], [69], [109], [131]. For example, according to [132], the reduced cost at the initialization stage is considered as a perceived benefit by many organizations. However, [133] emphasised that the improved standardization of services is one of the major perceived benefits for many other organizations. The anticipated or perceived benefits were previously investigated in various studies to observe the effects on the adoption of technological innovations [69], [88], [108], [109], [155]. The findings of this research study confirm that the anticipated benefits support the adoption of RFID technology within organizations.

VII. IMPLICATIONS FOR THEORY AND PRACTICE

A. THEORETICAL IMPLICATIONS

A holistic approach was adopted to investigate the factors influencing the adoption of technology at the organizational level. To provide a broader view of the factors that are involved in the adoption of RFID technology, this research study focused on constructs related to organizational, technological and environmental innovation, and the potential benefits arising from the adoption of RFID technology. In order to achieve the research objectives, the study combined relevant frameworks from a review of the literature. The study focused not only on the elements important in the adoption of new technology, but also on the related advantages a business will gain. The frameworks included were the TOE framework [28], the ANT model [30], and the DOI theory [98], along with anticipated benefits as important factors [69], [109], [110]. With the help of these theoretical frameworks and factors a single unified conceptual model was developed for the purposes of this study. The combined aspects include technological, organizational, environmental, innovation and benefit factors at the company level (see Table 1). Many theoretical implications can be identified on the basis of the findings of this research study, confirmed and supported by the DOI [98], the TOE framework [28], and the ANT theory [30].

B. PRACTICAL IMPLICATIONS

The business sector is facing many challenges concerning adopting technology and taking advantage of the benefits it offers. This applies equally well to the uptake of RFID technology. This research study will assess the predominant factors involved in the decision-making phase of the adoption of new technology. The findings of this research signify the important perspectives for the strategic team to facilitate the informed decision-making process when considering the adoption of RFID technology. Four pragmatic guidelines are designed in this research study to help in RFID adoption by construction companies. These guidelines emerged from the analysis of this research study.

- *Evaluation of the compatibility of the present infrastructure of IS with RFID technology:* Collecting technical information related to the feasibility of adopting RFID technology and evaluating the compatibility with the current technology should be a priority focus of IT managers. To facilitate informed decisions on compatibility between the existing IT infrastructure and RFID technology, the acquisition of knowledge and information should be facilitated among these decision-makers. They should be encouraged and motivated to engage in discussions with the designers and developers of RFID technology. They should be assisted in working with IT professionals of other companies to gain knowledge and skills, along with dealing with third party consultants and stakeholders. They should also be encouraged to attend seminars and symposiums related to IS and recent advancements. Well trained and informed professionals can help reduce the perceived complexity of the RFID technology and will facilitate the process of its adoption 166], [167].
- *Development of budgetary projections to address cost-effectiveness:* The findings of this research study demonstrate that the implementation costs of RFID technology is an important factor affecting the decision-making

process of companies in the construction sector. Therefore, the details related to the cost of implementation and utilization of the RFID technology need to be evaluated and then integrated as part of the initial budget of the project. In addition, it should be part of the annual financial agenda and budget meeting. The approximated cost-saving and advantages in applying RFID technology should be comprehensively explained. It is suggested that the management of the IT department is best suited for initiating the discussions on financial projections related to any technology adoption. The IT department and strategic team should be well-versed with the financial implications of embarking on this process of adoption.

- *Procurement of external consultancy for issues related to security:* Apart from confidentiality, integrity, and accessibility, which are highly significant aspects of information security, the security threat level will increase through the use of RFID technology on account of the increased number and involvement of parties, equipment and software applications. Moreover, along with these vulnerabilities, RFID technology has an additional challenge in relation to privacy. Technology companies associated with the construction sector should collaborate on the critical issues of security trials and solutions. This will help in facilitating an environment of trust and will expedite the adoption of RFID technology.
- *Identification of a 'champion' for the adoption and monitoring of the project:* The findings of this research study revealed that the adoption of RFID technology is largely dependent on the initiatives of managers of the IT department in a construction setup. It is important that they excel in their knowledge and role as champions of the innovative technology of RFID. Knowledge and comprehensive understanding of the perceived benefits of technology will facilitate the decision-making process for the adoption of RFID technology. Therefore, taking the lead in such a project will be an integral part of the adoption of RFID technology where the advantages to the stakeholders are explained and professional teams, networking, and training of present staff of the IT department are established. In a well-equipped construction company, the champion will lead the completion of the project of RFID technology along with the guardianship and monitoring of the functionality of RFID. The project should be carefully and responsibly handed over to the current staff, working as IT professionals for routine operational activities, within a reasonable time frame, and with training and accessibility to support the new caretakers.

VIII. LIMITATIONS AND FUTURE RESEARCH

This research study is intended to provide a comprehensive understanding of the elements that might affect the adoption of RFID technology in organizations related to the construction sector. It will facilitate the successful integration of RFID technology in construction companies. This research study will also provide more inclusive aspects of the factors related to the adoption of RFID technology. These factors are theoretical integration frameworks of the TOE, DOI, and ANT. On the other hand, certain limitations were faced by the study during a cross-sectional survey. First and foremost, the collection of data was conducted with a selected few construction companies. Therefore, the data cannot be extrapolated to the complete population of the construction sector. Secondly, the sample was based on participants from different levels of responsibilities ranging from managers and developers to user support providers. The overall perceptions of the sampled populations were analysed in terms of knowledge and adoption of RFID technology. Nevertheless, the managerial roles were investigated differently to those working at the lower level of the IT department. Future studies should assess the level of knowledge and differences in different job categories.

IX. CONCLUSION

This research study formulated and assessed a combined framework of models, including TOE, DOI, and ANT, to explain the adoption of RFID technology by construction companies. The integrated model was supported by a number of hypotheses proposed for this research study. Innovation, technological, and organizational characteristics, along with environmental factors, were considered to be four significant dimensions in this model for evaluating the decision-making process for the adoption of RFID technology in construction organizations. The study gave support to the impact of the identified factors on the adoption decision of the RFID technology. It is also suggested that these factors may not only be explicitly related to the construction sector but could also have an impact on other economic sectors with similar characteristics of structure and business operations as the construction industry, as well as on similar entities in other countries. The results and findings of this research study can be used as a foundational theoretical tool for subsequent research into RFID adoption.

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