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THE IMPACT OF PROFESSIONALS' KNOWLEDGE ON INNOVATION ADOPTION IN THE CONSTRUCTION INDUSTRY: A CRITICAL LITERATURE REVIEW

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ABSTRACT

The construction industry is one of the leading economic sectors in any country yet is renowned for its reluctance to adopt novel innovations. Meanwhile, research has found that the decision of any industry on the adoption or rejection of innovations depends on its positive or negative perception, which is stipulated by industry professionals' knowledge. Therefore, this research aims to disclose how the professionals' knowledge affects successful innovation adoption specific to the construction industry. A qualitatively based extensive literature synthesis has been conducted concerning three concepts to provide a holistic view of innovation decisions. Namely, the Technology Acceptance Model (TAM), Technology-Organisation-Environment framework (TOE), and Diffusion of Innovation theory (DOI). The findings revealed that the "existing knowledge" of professionals was a key factor in innovation decisions. Accordingly, five main perceived attributes (relative advantage, compatibility, complexity, trialability and observability) have been identified through Roger's innovation-decision model, and decisively common measurement items have been documented under each perceived attribute that comprehensively endorses the "existing knowledge" of construction professionals. Furthermore, this contemporary study found that all the recognised measurement items extensively affect innovation-decision. In the absence of a pragmatic decision framework, this article provides a clear impression for both technology developers and their users/stakeholders on crucial elements of innovation adoption that have been concerned via decision makers' technological perception.

Keywords: *Diffusion of Innovation (DOI); Innovation Adoption; Innovation Decision; Technology Acceptance Model (TAM)*

1. INTRODUCTION

The construction industry contributes greatly to economic growth and social development while operating in a hyper-competitive environment (Boadu, Wang and Sunindijo, 2020). It is common knowledge that constant growth in the construction industry is critical for

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the national economy to fulfil a nation's rising needs. The effective and dynamic development of the construction industry depends on the formation of modern innovations that satisfy its technical and scientific development on a commercial basis (Timchuk, Nikityuk and Bakhtairova, 2021). Accordingly, various tactics are used by construction organisations to monitor their quality and productivity. Some organisations are focused on cost management, while others are concerned with design strategies, and yet others regulate their productivity by modifying the quality of their services. Although these practices have improved productivity so far, most of these strategies will not be able to survive the forthcoming market competition due to digitalisation (Odubiyi, Aigbavboa and Thwala, 2021). Because market competition in the 21st century's construction industry is highly dependent on new technologies, such as drones, machine learning, artificial intelligence (AI), offsite construction, and BIM, that promote productivity (Odubiyi, Aigbavboa and Thwala, 2021). This compels construction firms to invest in new technologies and technical skill development to leverage the innovations. The trend of digitisation, automation, information and communication technology (ICT) has been anticipated to be the soul of the Fourth industrial revolution (Industry 4.0) (Timchuk, Nikityuk and Bakhtairova, 2021). Moreover, different technologies as a part of Industry 4.0 are permissible to address productivity issues in construction projects.

For example, the internet of things (IoT) has already been used in the construction industry for smart homes, environmental monitoring, and energy management, yet there is a significant lack of willingness to incorporate IoT applications (Chen, et al., 2020). Qin, et al. (2020) stated that BIM technology has brought remarkable innovations in terms of productivity to the construction industry. Subsequently, the author stated BIM has intended and successfully proven to improve productivity through waste minimisation but there is a lack of adoption without much details of benefits. However, the authors further stated that poor compatibility in the application, a shortage of professionals, resistance to changes, the weak willingness of corporations among project stakeholders, and difficulty in coordination as barriers to BIM adoption. Furthermore, McNamara and Sepasgozar (2021) emphasised that the main reasons for resistance to change for innovation adoption are an aversion to new challenges and an unwillingness to change one's current working pattern.

In addition, McNamara and Sepasgozar (2021) have discovered that despite technical, organisational, financial, and environmental assistance being given, construction industry practitioners are hesitant to embrace new technologies owing to behavioural aspects influenced by technology perception. As emphasised by Li, et al. (2019), in the current knowledge economy era, the construction industry has highly depended on intangible assets such as knowledge, human creativity and innovations. Further, the authors stated that existing knowledge would be replicated and exploited in perceptions in innovation decisions. Hence, knowledge impacts innovation decisions either positively or negatively. As a result, the purpose of this paper is to identify how knowledge interacts with professionals' innovation decisions and knowledge constructs for innovation adoption.

2. RESEARCH METHODOLOGY

The qualitative research approach has been adopted for its potential to achieve an in-depth analysis of theoretically based concepts, models, and frameworks (McNamara and Sepasgozar, 2020). Accordingly, this paper aims to answer the research problem of "how professionals' knowledge affects successful innovation adoption specific to the construction industry" through a qualitatively based extensive literature synthesis.

Hence, to achieve the aim, this paper presented the literature synthesis and arguments on the following themes: current construction industry behaviour in innovation decisions; the Technology Acceptance Model (TAM); the Technology-Organization-Environment Framework (TOE); Diffusion of Innovation Theory (DOI); and Knowledge Impact in Innovation Decisions Concerning Perceived Attributes and Measurement Items. By following the process with inductive reasoning, the basis was drawn from existing literature on the topic (Azungah, 2018). An in-depth study of the models, frameworks, and concepts was carried out with a cross-reference to the sources that have been used to describe innovation adoption with respective technologies. Accordingly, TAM (refer to section 4.1) was connected to TOE (refer to section 4.2) through external variables. Afterwards, with the main focus on technological variables, the perceived attributes were connected to the TOE framework. Following that, the existing knowledge via perceived attributes was recognised as the heart of the research topic by a comprehensive study using DOI theory (refer to section 4.3). The study's available knowledge was gathered from a variety of sources, including journal articles, conference papers, e-books, and other publications. Finally, a conceptual framework was developed by compiling pertinent literature findings to have a better understanding of how professionals opted to adopt innovations based on their behavioural factors, which originated from "existing knowledge".

3. CURRENT CONSTRUCTION INDUSTRY BEHAVIOUR IN INNOVATION ADOPTION

Technology adoption in the construction industry is accelerating at a slower rate compared to other industries (Timchuk, Nikityuk and Bakhtairova, 2021). However, industries like manufacturing and automobiles keep exploring innovations as a way of maintaining industry productivity (Belle, 2017). Hence, individuals and organisations in the construction industry have a huge responsibility towards the industry's digitalisation. Table 1 presents reasons for the lack of adoption of innovations in the construction industry from individuals' perspectives.

Table 1: Reasons for lack of adoption for innovations in the construction industry - individuals' perspective

Reasons for lack of adoption for innovations in the construction industry – individuals' perspectives	[1]	[2]	[3]	[4]	[5]	[6]
Resistance to change behaviour	✓	✓	✓	✓	✓	✓
Lack of knowledge and competencies	✓	✓	✓	✓	✓	✓
Negative prior experiences	-	✓	-	✓		-
Social factor and networking	✓	✓	-	-	✓	✓
Fear of failure	✓	-	✓	✓	-	-
Lack of trust	-	-	-	-	-	✓
Perception of unusefulness	✓	✓	✓	-	✓	-
Perception of difficulty of use	✓	✓	✓	-	✓	-

Sources:[1] Kassem,Brogden and Dawood, 2012; [2] Eadie, et al., 2013; [3] Yusof, et al., 2014; [4] Lines, et al., 2015; [5] Borhani, 2016; [6] Alizadehsalehi and Yitmen, 2019)

As illustrated in Table 1, "resistance to change behaviour" is a prudent reason for the lack of adoption of innovations. Consequently, "lack of knowledge and competencies" is having a direct effect on "resistance to change behaviour". Further, individuals' roles are significant if the construction organisations are ready for digitalisation (Lin and Chen, 2012). Accordingly, the perception of either "usefulness" or "ease of use" derives from an individual's knowledge. Therefore, the black and red arrows in Table 1 indicate that "knowledge" has a significant effect on innovation adoption as a whole. To identify the way of overcoming "resistance to change", the individuals' technological acceptance behaviour that is saturated with "knowledge" should be sequentially analysed, and the origin of the problem should be identified. Therefore, the theories related to innovation adoption were discussed in the below sections to provide a theoretical background for the research problem with the use of existing literature.

4. THEORIES ON TECHNOLOGY ADOPTION

The acceptance, adoption, and use of technologies at an individual level have become ripe topics in the construction industry due to the high resistance to change among construction industry stakeholders (Hong and Yu, 2018). After introducing new technology, various factors influence their decision on how and when to use it (Woosley, 2011). Figure 1 illustrates the evolution of theories about technology acceptance. Accordingly, the reason for the selection of TAM for this study has been justified under section 4.1.

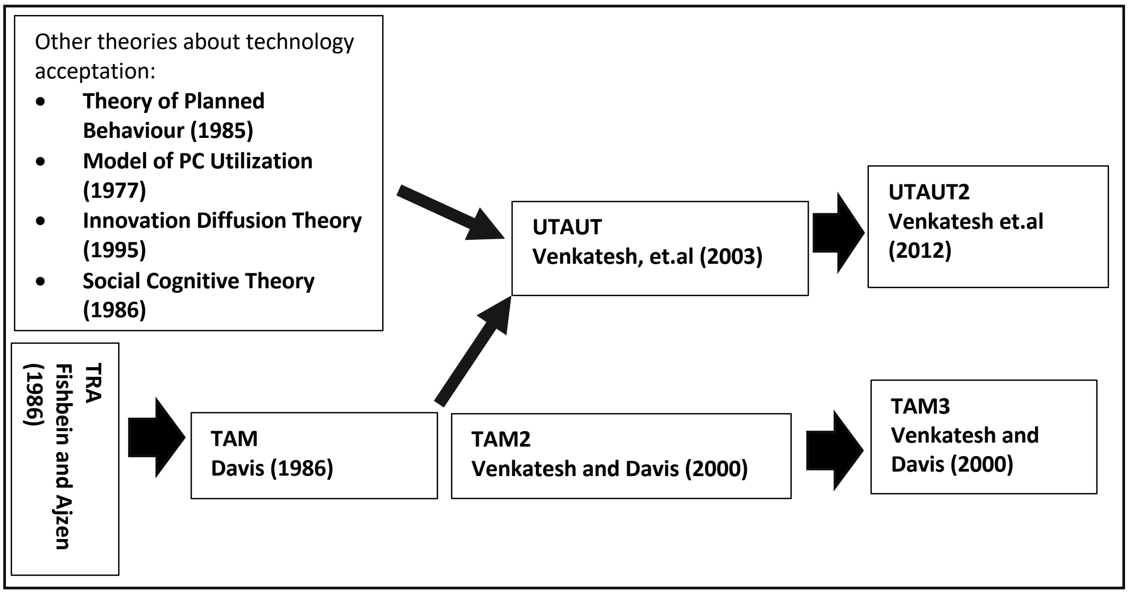

Figure 1: Evolution of theories about technology acceptance

Source: Rondan-Cataluña, Arenas-Gaitán and Ramírez-Correa (2015)

TAM was introduced by Davis (1986), which was an adopted theory from the Theory of Reasoned Action (TRA) and Theory of Planned Behaviour (TPB) (Rondan-Cataluña, Arenas-Gaitán and Ramírez-Correa, 2015). All other models were built upon the basis provided by TAM.

4.1 TECHNOLOGY ACCEPTANCE MODEL

Since the TAM is the most widely applied and most influential model to investigate individuals' behaviour on technology adoption and it provides more flexibility for researchers to select external variables relevant to the study area other than the TAM2, Unified Theory of Acceptance and Use of Technology (UTAUT), and TAM3, this study is also partially based on the TAM to study individuals' perception of innovation adoption. Several scholars have used the TAM to assess individuals' behaviour in innovative technology adoption for the construction industry, such as BIM applications for mobile devices (Hong and Yu, 2018), big data (Soon, Lee and Boursier, 2016), smart contracts (Badi, et al., 2021) and IoT (Chen, et al., 2020). Figure 2 demonstrates the TAM proposed by Davis (1986).

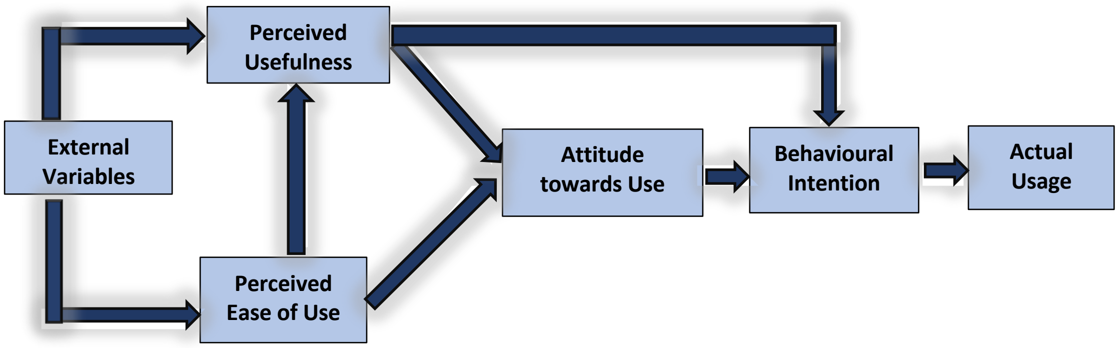

Figure 2: Technology acceptance model

(Source: Davis, 1986)

In the TAM, "perceived usefulness" (PU) and "perceived ease of use" (PEOU) are primary constructs concerning the acceptance of technology by an end-user. Further, those two primary concepts are influenced by the "external variables". As described by Davis (1986), PEOU is "the degree to which a person believes that using a particular technology would be free from effort" (p. 320) and PU is "the degree to which a person believes that using a particular system would enhance his or her job performance" (p. 320). The other two constructs in TAM are "attitude towards use" (ATU) and "behavioural intention to use" (BIU). The actual usage of the technology will depend on those two constructs. According to Woosley (2011), ATU means the user's desirability of using the system. BIU defines it as the measure of the likelihood that a person will use an application. Actual system usage is the dependent variable of TAM. As shown by Figure 2, all these constructs are influenced by the "external variables".

4.2 TECHNOLOGY-ORGANISATION-ENVIRONMENT FRAMEWORK

As an extension of the TAM, the TOE framework has been used in this study. The Technology-Organisation-Environment framework (TOE framework) was introduced by DePietro, Wiarda, and Fleischer in 1990 (Tornatzky and Fleischer, 1990) as an application-level framework to investigate from the perspective of both an organisational and an individual level (Chiu, Chen and Chen, 2017). TOE mainly illustrates the three facets of research into the factors that affect the acceptance of innovative technology by organisations (Baker, 2012). Figure 3 illustrates the TOE framework.

Moreover, the technological context comprises the characteristics and usefulness of the technology; the organisational context includes the organisation's nature, such as internal management, communication processes, size, and slack; and the environmental context consists of factors that affect the related business field, like competitors, partners, regulations, and market structure (Tornatzky and Fleischer, 1990; Baker, 2012).

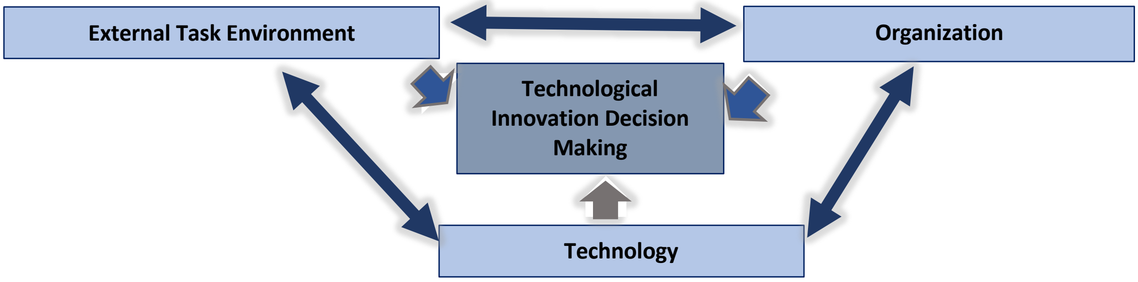

Figure 3: Technology-Environment-Organization framework

Source: Tornatzky and Fleischer (1990)

Accordingly, this study was mainly focused on the "technological perspective" with the incorporation of TAM to maintain the coherence of the in-depth literature findings.

4.3 DIFFUSION OF INNOVATION THEORY

The Diffusion of Innovation theory was developed by E.M. Rogers in 1962 (Chiu, Chen and Chen, 2017). As elaborated by Roger, innovation is "any idea, practice, or object that is perceived as new by an individual or another unit of adoption." Diffusion is defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1962, p.192). According to the DOI theory, "knowledge is an individual's initial exposure to the innovation's existence and understanding of how the innovation works" (Vejlgaard, 2018, p.6). Therefore, the requirement for knowledge on innovation adoption has been connected to integrated TAM-TOE through perceived attributes. Accordingly, the next section discussed the impact of knowledge on the decision-making process of any innovation.

4.3.1 Innovation Decision Model

Later, Rogers (1983) proposed a more improved model for identifying the stages of adoption called the "innovation-decision model." According to Roger, this is the process that individuals (or any other decision-makers on innovation adoption) follow to implement a new idea. The "innovation-decision model" is shown in Figure 4. As per the model (refer to Figure 4), the knowledge stage is the first step of an innovation-decision process. Then it is connected with the persuasion stage. Therefore, the persuasion stage follows the knowledge stage. Accordingly, an individual forms a favourable or unfavourable attitude toward innovation within the persuasion stage by further exploring knowledge under perceived attributes (refer to Table 3). The persuasion stage is more latent and depends on the individuals' perceptions, while the knowledge stage remains cognitive and well known (Wani and Ali, 2015). After that, Rogers (1983) described four outcomes via the knowledge stage and persuasion stage for technology adoption or rejection. Since this study is limited to technology adoption, only the knowledge stage to persuasion stage has been studied towards technology adoption.

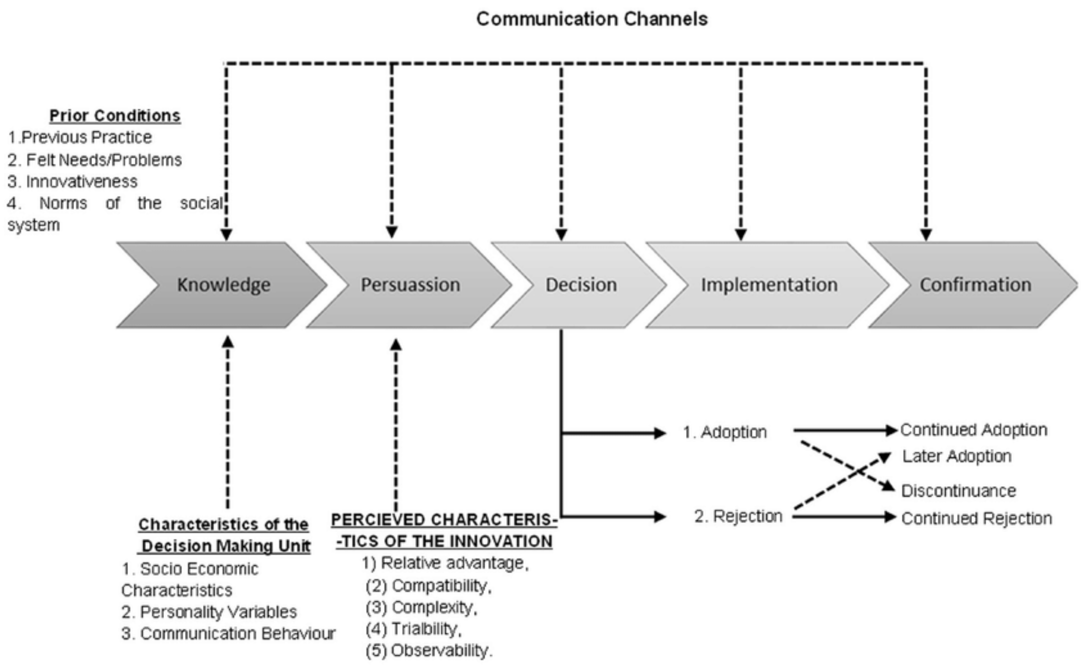

Figure 4: Model of five stages in the innovative-decision process

Source: Rogers (1983)

5. IMPACT OF KNOWLEDGE ON INNOVATION-DECISION

Howells (2002) prompted knowledge as a personal belief rather than the attribute of truth, which was justified by traditional epistemology. Moreover, Howells (2002) instigated "existing knowledge" to involve innovating, inventing, and discovering new knowledge while supporting the acceptance of new knowledge. Further, knowledge is primarily conceptualised as individual property as information (of a special quality) and located in a person's mind or memory. Thus, once the new knowledge arrives, it will be assessed with existing knowledge that is stored in an individual's mind (Howells, 2002). As per the DOI, once the knowledge is acquired on the knowledge stage, it is further discovered and justified through perceived attributes (relative advantage, compatibility, complexity, trialability, and observability) in the persuasion stage.

Even if the knowledge (in the innovation-decision model) has been given, the individuals may not be ready to adopt new technology. The persuasion stage occurs when individuals have a negative or positive attitude toward the innovation, but "the formation of a favourable or unfavourable attitude toward an innovation does not always lead directly or indirectly to an adoption or rejection" (Rogers, 2003, p. 176). Therefore, individuals' attitudes are shaped when they know about the innovation. Furthermore, Rogers (2003) declared that the knowledge stage is more cognitive (or knowing) centred, while the persuasion stage is more effective (or feeling) centred. Thus, individuals are persuaded more sensitively about the innovation at the persuasion stage. Rogers (2003) described the innovation diffusion process as "an uncertainty reduction process" (p.232), and the author stated that attributes of innovations (perceived characteristics or attributes) are facilitated to reduce the uncertainty about the innovation. The attributes of innovation include five characteristics. Rogers (2003) stated that "individuals' perceptions of these characteristics predict the rate of adoption of innovations" (p. 219). The knowledge that is directly related to those perceived attributes would be beneficial in increasing relevancy and productivity during the knowledge acquisition stage. Accordingly, those attributes were elaborated as follows:

- Perceived attributes and measurement items

Accordingly, Rogers (2003) explained that innovation proceeds through five stages of the adoption process: knowledge, persuasion, decision, implementation, and confirmation. Potential adopters will be more involved and seek out information about technology in the persuasion stage other than in the knowledge stage (Meyer, 2010). Thus, Roger has identified five perceptual characteristics of innovation (perceived attributes): perceived relative advantage, compatibility, non-complexity, trialability, and observability. Table 2 illustrates the definitions originally made by Rogers.

Table 2: Definitions for perceived attributes

Perceived Attributes	Definitions
Relative advantage	"The degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 2003, pp.229).
Compatibility	"The degree to which an innovation is perceived as consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003, pp.240).
Complexity	"The degree to which an innovation is perceived as relatively difficult to understand and use" (Rogers, 2003, pp.257).
Trialability	"The degree to which an innovation may be experimented with on a limited basis" (Rogers, 2003, pp.258).
Observability	"The degree to which the results of an innovation are visible to others" (Rogers, 2003, pp.258)

Further, the measurement items that determine the perception via identified attributes were discussed by several researchers. Table 3 illustrates those measurement items with their respective perceived attributes.

Table 3: Perceived attributes

Construct	Measurement items	References
Perceived relative advantage		
PR1	It increases the efficiency and effectiveness	[R1], [R2], [R3], [R4], [R5], [R6]
PR2	It aids in economic gains	
PR3	It increases social prestige	
Perceived compatibility		
PC1	It is compatible with the organisation's existing values, experiences, work practices and norms	[R1], [R2], [R3], [R4], [R5], [R6]
PC2	It is compatible with the existing operating environment including hardware and software	
PC3	It is compatible with organisational needs	

Construct	Measurement items	References
Perceived non-complexity		
PNC1	It does not need greater technical skills	[R3], [R4], [R5], [R6]
PNC2	It does not require a lot of thinking an extra effort	
PNC3	It does not hard to understand and easy to reach up consensus	
Perceived trialability		
PT1	A trial period allows for checking whether the proposed technology is suited to the individuals' existing knowledge level	[R3], [R4], [R5], [R6]
PT2	A trial period reduces the perceived risks	
PT3	Being able to try out the innovative technology is important to adopt it in future	
Perceived observability		
PO1	Other industries using the same technology	[R3], [R4], [R5], [R6]
PO2	Other industries have positive consequences	
PO3	Understanding the positive effects of the proposed technology	

Sources: [R1] (Slyke, et al., 2008), [R2] (Mason, 2017), [R3] (Lin and Chen, 2012), [R4] (Pankratz, Hallfors and Cho, 2002), [R5] (Badi, et al., 2021), [R6] (Chiu, Chen and Chen, 2017)

Numerous scholars have identified that the previously mentioned perceived attributes (relative advantage, compatibility, non-complexity, trialability, and observability) are positively related to technology adaptation through hypothesis testing (Pankratz, Hallfors and Cho, 2002; Chiu, Chen and Chen, 2017). By using hypothesis analysis within the UK construction industry context, Badi, et al. (2021) recognised those perceived attributes are positively related to smart contract adoption. Therefore, those measurement items can be designed for respective innovation scenarios.

6. THE CONCEPTUAL FRAMEWORK-INTEGRATED TAM-TOE-DOI FOR INNOVATION ADOPTION

The developed conceptual framework of this study as an outcome of the integration of TAM, TOE, and DOI theories is shown in Figure 5. There were several pieces of literature exploring the adaptability of innovative technologies that combined the TAM with the TOE framework. Qin, et al. (2020) applied the TAM-TOE model to explore the factors of BIM adoption. Gangwar, Date and Ramaswamy (2015) used the TAM-TOE model to identify the determinants of cloud computing adoption. Further, as reported by Chiu, Chen and Chen (2017), DOI theory has been combined with the TOE framework to give a theoretical framework for assessing the adaptability of broadband mobile applications by enterprises.

Many research studies have been undertaken to integrate more than one model to provide a holistic evaluation of the determinants of technology adoption in terms of different technologies; for example, the integrated TAM-TOE-DOI framework for cloud computing adoption (Singh and Mansotra, 2019) and blockchain technology adoption in supply chains (Bhardwaj, Garg and Gajpal, 2021).

Accordingly, this conceptual framework (refer to Figure 5) promotes an in-depth investigation into the root cause of resistance to innovation adoption using well-established theories, which is an extension of existing studies.

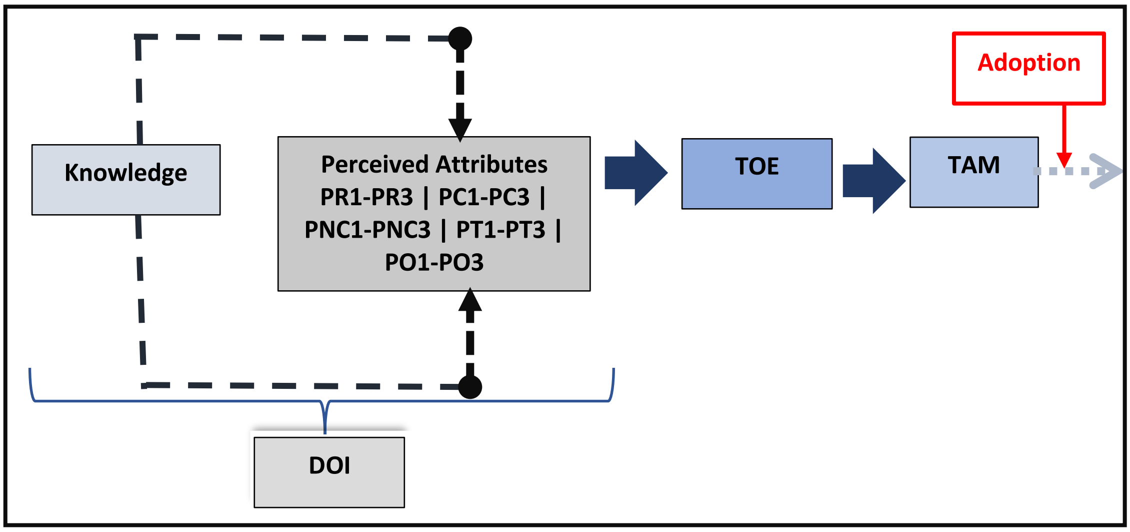

Figure 5: Conceptual framework-integrated TAM-TOE-DOI for innovation adoption

7. CONCLUSION AND THE WAY FORWARD

This extensive review of the literature was intended to understand how industry professionals make decisions on innovation adoption. It is beneficial to identify the way that either the adoption or rejection decision comes. Therefore, it is important to understand the relevant knowledge that is required to make the correct decision at a stipulated time. Accordingly, in the first part of this study, "innovation adoption" was discussed with the background findings under the section, "reasons for the lack of innovation adoption in the construction industry" and then TAM, TOE, and DOI theories. As per the TAM, individuals' "behavioural intentions to use," which are derived from "perceived usefulness" and "perceived ease of use," were identified. At the end of the model, TOE was connected through an external variable that is common for both TAM and TOE. According to the pre-defined scope of this study, the technological variables were mainly focused on, disregarding organisational and environmental variables. Thereafter, technological variables were further elaborated through perceived attributes (relative advantage, compatibility, non-complexity, trialability, and observability), which were identified through the innovation-decision model. Then, the second part of the study, "impact of knowledge in innovation decisions," was discussed concerning the identified perceived attributes and their measurement items, respectively. Those anticipated measurement items were presented as PR1-PR3, PC1-PC3, PNC1-PNC3, PT1-PT3 and PO1-PO3. Simultaneously, the integrated TAM-TOE-DOI conceptual framework was presented as a way of emphasising how the problem of this study has been identified. Further, that framework can be moderated by organisational, environmental, or any other external variable. Accordingly, the knowledge requirement can be identified through existing (already defined from the innovation-decision model) or separate perceived attributes and measurement items. Additionally, a separate model such as TAM2, TAM3, or UATUT (Unified Theory of Acceptance and Use of Technology) can be replaced with one relevant to the scope of the study.

Although this study has been given a holistic view of innovation adoption decisions from the technology perspective, the outcome of the study would be beneficial for construction industry practitioners, innovators, and decision-makers to have a clear image of the sequence of innovation adoption decisions related to their general parameters during the initial stage. Because this knowledge framework has targeted exact perceived attributes that are straightforwardly considered by the decision-makers. Furthermore, this paper is an initial conceptualisation of the impact of knowledge on innovation-decision. Therefore, perceived and measurement items can be identified for several technologies and prepared as knowledge frameworks concerning their innovation adoption as a way forward in this study.

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