2018 Volume 24 Issue 6: 457–468
https://doi.org/10.3846/jcem.2018.5186

EMERGING INFORMATION TECHNOLOGY ACCEPTANCE MODEL FOR THE DEVELOPMENT OF SMART CONSTRUCTION SYSTEM

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Received 03 December 2017; accepted 14 June 2018

Abstract. The potential of emerging information technology has been proposed by many researchers and practitioners in the construction industry, including smart construction. Meanwhile, emerging information technology acceptance and use is one of the major subjects for current smart construction study and practice. Furthermore, although there are many potential applications for and benefits of emerging information technology in the development of smart construction system, the current issue is that it is unclear why this technology is adopted, and that the factors that enhance its implementation are unknown. Therefore, an emerging information technology acceptance model (EITAM) was proposed, and our hypotheses were tested by structural equation modeling (SEM) based on an open-ended questionnaire survey. This study identified the factors that affect emerging information technology acceptance from engineering construction technology and innovation professionals. The EITAM evaluation results can be used to develop an emerging information technology acceptance strategy that is suitable for continual smart construction promotion. Finally, this study can provide guidance to smart construction developers to establish an effective technological integration plan.

Keywords: technology acceptance model (TAM), information technology, construction system, structural equation modeling (SEM).

Introduction

According to the seminal work of Davis (1989), the technology acceptance model (TAM) is an adaptation of the theory of reasoned action and a theory of planned behavior specifically tailored for modeling user acceptance of information technologies (Davis *et al.* 1989). As we know, the TAM provides an explanation of the determinants of technology acceptance that is capable of explaining user behavior. Meanwhile, behavioral intentions of technology acceptance are ultimately affected by perceived usefulness and perceived ease-of-use, which are indirectly influenced by several external variables. With the progress of acceptance behavior-related theories, at present, the TAM has been widely used to analyze acceptance behavior of new information technology (Legris *et al.* 2003).

TAM theory is the one of most widely applied models in building information system to predict the adoption behavior of new information technology (Mortenson, Vidgen 2016). Studies in many fields have been conducted to extend and extensively improve the TAM (Adams *et al.* 1992; Agarwal, Prasad 1997; Venkatesh, Davis 2000; Jokonya 2015). Meanwhile, study also demonstrated the feasibility and effectiveness of the TAM taking both human and social factors into consideration (Hamner, Qazi 2009). To date, the TAM has been subject to numerous additions and developments, which has involved multidisciplinary integration, such as health care (Aggelidis, Chatzoglou 2009; Holden, Karsh 2010), knowledge economy (Bach *et al.* 2016, 2017), and information and social

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science (Kakoli, Soumava 2010; Michel *et al.* 2014; Nikou, Economides 2017). Generally speaking, the TAM has been regarded as the most powerful approach to identify the behavior of new technology acceptance problem solving.

In construction field, the TAM has been used for the adoption behavior analysis of building information modeling (Lee *et al.* 2013), scanner technology (Sepasgozaar *et al.* 2017), and sustainable energy technology (Chin, Lin 2016; Chen *et al.* 2017). Aided by the fast development of emerging information technology such as Big Data, the Internet of Things, cloud computing, and artificial intelligence, smart construction theory and technology have been developed in engineering construction (Niu *et al.* 2016; Zhong *et al.* 2017). With the fast development of emerging information technologies (such as RFID, internet of things, ubiquitous computing, Wi-Fi, Bluetooth, ZigBee, near-field communication, and so forth), the conception and key features of the smart construction system have been illustrated and expounded widely. Nowadays, smart construction system is recognized as one of the powerful ways of modern engineering construction.

Therefore, it is significant and necessary to understand the process of emerging information technology adoption for the development of smart construction system. The main purpose of this research is to validate the acceptance model of emerging information technology in the development of smart construction system based on elementary and extended TAM. According to previous theoretical interpretations of the TAM, we can better understand the adoption behavior of emerging information technology in developing smart construction system by building an emerging information technology acceptance model (EITAM).

This paper will be presented as follows. First, the challenges of emerging information technology acceptance for the development of smart construction system will be identified. Second, a conceptual model for predicting emerging information technology acceptance by the user in the development of smart construction system and its comprehensive hypotheses will be proposed. Finally, the EITAM will be built, and the major factors influencing emerging information technology acceptance will be summarized.

1. Background

1.1. Emerging information technology in development of smart construction system

In recent years, because of the rapid development and maturing of emerging information technology, smart construction system has widely arisen in engineering construction management. According to Niu *et al.* (2017), construction resources can be made smart by augmenting them with capabilities of sensing, processing, computing, networking, and reacting, by using emerging information technology such as RFID, ubiquitous computing, Wi-Fi, Bluetooth, ZigBee, near-field communication, and so forth. His study also indicated that modern construction urgently needs smarter resources, but unfortunately smart construction in the construction sector is still in its infant stage nowadays.

However, more and more studies have shown that with the increasing influence of deeper applications of emerging information technology on the operation of a smart construction system, smart construction system has more smartness. Furthermore, several smart architectures for construction management have been formed, such as smart schedule management, smart decision-making, smart cost control, smart quality control, and smart safety diagnosis and alarm systems. Meanwhile, the practical values of applying emerging information technology to the development of smart construction system include improving working efficiency of staff, obtaining information easily and timely, improving the comprehensive management level of smart construction sites, enhancing construction efficiency, optimal allocation of construction machinery, updating information in a timely manner, optimal allocation of material resources, improving multi-source information communication, and so forth.

Above all, there is no doubt that emerging information technology is the core driving force to promote smart construction system building and system development. Furthermore, based on the theoretical foundation of former research, such as by Park *et al.* (2014), Wu and Wang (2016), in this paper, a proposed structure of emerging information technology applied to the development of smart construction system is shown in Figure 1. It can help us better understanding the dominant position of emerging information technology in a smart construction system.

Furthermore, although a series of emerging information technologies (such as BIM5D, cloud computing, Internet of Things, Big Data, near field communication, wireless fidelity (Wi-Fi), barcodes (QR Code), mobile internet, Bluetooth, radio frequency identification (RFID), ZigBee, ultra-wide band, wireless sensor networks, and laser distance and ranging)and other automatic or intelligent technologies can be gradually fused in the development of a smart construction system, systematic and comprehensive analysis of its acceptance is lacking.

According to the above discussion, the limited understanding and acceptance of these technologies are related to understanding their perceived usefulness and ease-of-use in the development of smart construction system. Thus, through the theoretical study of the TAM, we will explore an effective solution.

1.2. Theoretical perspectives

In addition to the previously mentioned TAM, multi-theory integration in the TAM has also been proposed, such as the Theory of Planned Behavior, Theory of Reasoned Action, Innovation Diffusion Theory, Self-Determination Theory, TAM2, TAM3, and so forth (Venkatesh *et al.* 2003; Venkatesh, Bala 2008; Marangunić, Granić 2015; Nikou, Economides 2017). Furthermore, there are several other

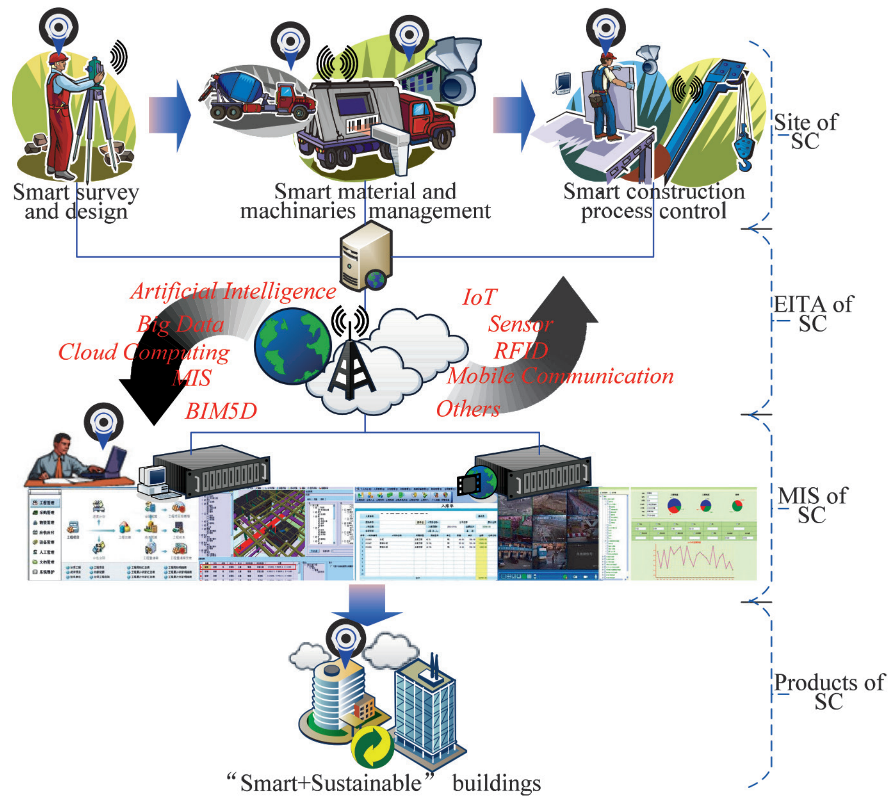

Figure 1. Basic structure of emerging information technology applied to the development of smart construction (abbreviated as SC) system

motivational theories, such as the multi-level framework of technology adoption and neo-institutional theory (the core of them is still TAM), which is almost beyond the TAM, and its related theories can help us to study technology implementation in an institutional environment (Beglaryan *et al.* 2017). Although there are many extensions of TAM have been applied, its main conception is that external variables indirectly affect attitude toward use. This can affect intentions to use information technology by influencing perceived usefulness and perceived ease-of-use. The basic architecture is shown in Figure 2.

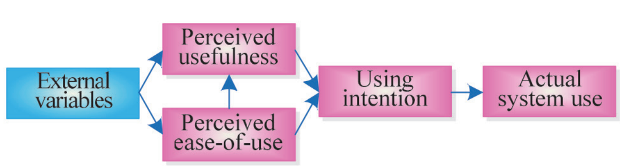

Figure 2. Technology acceptance model

However, in reality, although many researchers are in agreement about emerging information technology, such as those shown in Figure 1, having potential applicability and benefits in the development of smart construction system, it is still unclear how this information could actually be used in the development of smart construction system. Thus, adopting emerging information technology in the development of smart construction system remains a central concern of engineering construction technology study and practice. As we presented earlier, the TAM is a widely prevalent theoretical method that can help us explore the factors that affect an individual's intention to use a particular technology (Ghazizadeh *et al.* 2012). The theoretical principle of the TAM has developed and formed a mature theoretical system nearly over the past thirty years, and has served as a successful and stable basis for dealing with behavior intentions and the usage of emerging information technology. Therefore, it would benefit us to study the acceptance behavior of emerging information technology in the development of smart construction system.

Certainly, the TAM has a lot of deficiencies. Several studies have critiqued the traditional TAM, and its numerous extensions also have some limitation. Firstly, the traditional TAM lacks a complete scope of social and political processes related to emerging information implementation. Secondly, the organizational value and economic consequences of new technology have a strong influence on an individual's reactions toward new technology and their using intentions. Specifically, according to Abrahamse and Lotriet (2012), the traditional TAM and its extensions do not account for the motivations of acting and how different reasons for acting interact to emerge as using intentions in brand-new or specific branch of scientific and technological fields.

For these reasons, in this paper, we not only considered the unique aspects of particularity and universality of emerging information technologies in the development of smart construction system, but also took into account the fundamental functions of the market and policy and industrial values. Thus, the EITAM in the development of smart construction system was built by highlighting the following major principles. Firstly, the environment which can directly influence emerging information technology acceptance in development of smart construction system was taken into consideration. Secondly, in order to avoid individual prejudices, the disintermediation of the conceptual model was maximally eliminated. Furthermore, we focused on the core values of emerging information technology in the development of smart construction system. The proposed EITAM and its factors are presented in the next section.

2. Proposed EITAM and hypotheses

2.1. Overview of conceptual model

Based on the above discussion, in this section, the conceptual model of emerging information technology acceptance for the development of smart construction system will be summarized. The major factors of our conceptual model were inspired by the TAM, and include three essential factors and their relations to TAM: perceived usefulness, perceived ease-of-use, and using intention. There are several TAM extensions with external variables, which we considered according to the psychology of value and investment, guidance of social influence (market and policy) (Malhotra, Galletta 1999), selective perception (Dinev, Hu 2007), and viability (Turner *et al.* 2010) of the emerging information technology in smart construction. In this paper, we considered all the major factors that can affect the application of modern information technology for construction enterprises in a smart construction system. This is summarized in Figure 3.

According to the relationships which are proposed in Figure 3, we put forward related hypotheses for the external and internal variables of the conceptual model in the following subsection.

2.2. Hypotheses of variables

2.2.1. Technology usefulness

Currently, emerging information technologies, which are shown in Figure 1, are applied deeply and widely in the smart construction system. Zain *et al.* (2008) indicated that information technology usage directly affected organization. Mooney *et al.* (1996) and Lin *et al.* (2010) thought that we could get more value from new technologies, and actual usefulness of technologies can affect the perceived usefulness. Additionally, Froese (2010) and Xue *et al.* (2012) considered the advantage of emerging information technology in construction. Based on these past studies, we suppose H1 as the emerging information technology usefulness has a positive influence on perceived usefulness.

2.2.2. Policy

Based on the research results of Bhattacherjee and Sanford (2006), policy tools of a particular industry can influence on IT acceptance. For most enterprises that need to build a smart construction system, national policy, local policy, and industrial policy can undoubtedly affect their comprehension and the perceived usefulness of emerging information technology. Therefore, in this study, we suppose H2 as the policy has a positive influence on perceived usefulness.

2.2.3. Market

Morell (1994) indicated that market structure is an important factor that can encourage information technology acceptance. With the gradual development of the construction market, it is particularly important for smart construction enterprises to get more economic benefits and value through technological innovation. Meanwhile, an open market can promote the innovation of emerging information technology, which can thus promote smart construction enterprises to perceive increased usefulness of emerging information technology in system building. In this study, we suppose H3 as the market has a positive influence on perceived usefulness.

2.2.4. Perceived value

According to Barua *et al.* (1989), Wang *et al.* (2012), Mavaahebi and Nagasaka (2013), the value of information technology is based on the market economy. As an economic behavior, whether smart construction enterprises apply an emerging information technology depends on its expected value. Therefore, the perception of an emerging information technology's value may also directly determine perceived usefulness; the positive relation between them is represented as H4.

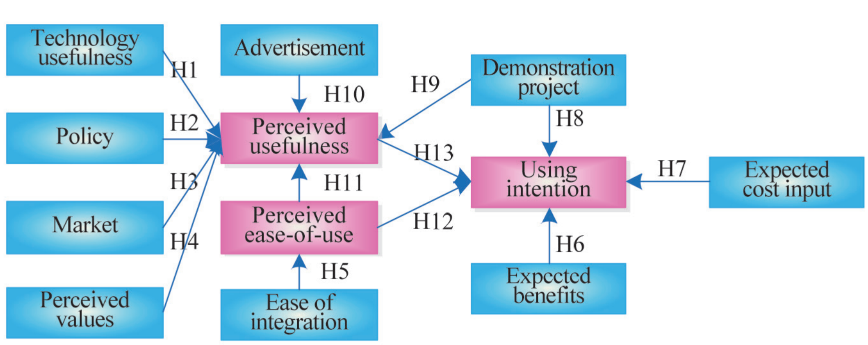

Figure 3. Conceptual model

2.2.5. Ease of integration

Most studies not only took usefulness into consideration, but also considered ease-of-use factors (McCloskey 2008; Tsai *et al.* 2011). In the current open technological innovation environment, construction enterprises that plan to build smart construction system will consider the ease or difficulty of technology integration. If the emerging information technology is easily integrated into the basic smart construction system, the perceived ease-of-use will be positively impacted; this is supposed as H5.

2.2.6. Expected benefits

The smart construction system is considered a new technical innovation in modern engineering construction that can integrate many emerging information technologies (Figure 1). Predictably, the successful application of the smart construction system by integration with emerging information technologies can not only improve the efficiency of engineering construction, but may also reduce the construction costs and risks of engineering construction (Yang *et al.* 2012). Furthermore, a series of emerging information techniques integrated into the smart construction system can result in innovation achievements that are then extremely supported by the government; therefore, a reasonable smart construction system can obtain both economic and social benefits (Ford, Pena 1994; Wu 2015; Liang 2017). Finally, according to the expected utility hypothesis, these above expected benefits may have an effect on the using intention. We set H6 as the positive impact of these expected benefits on using intention.

2.2.7. Expected cost input

As previously studied, a large number of emerging information technologies must be continually integrated into a smart construction system. In such a situation, according to the investment theory of creativity, the construction enterprise undoubtedly needs to increase the cost investment (Dave 2009; Sternberg, Lubart 2010). With uncertain economic and social benefits, the rational reaction of a construction enterprise can delay or even abandon financial investments. In short, the increase of expected cost input can lead to the unwillingness to use emerging information technology. We set H7 as the positive impact of expected cost input on using intention.

2.2.8. Demonstration projects

In various fields of social production and life, demonstration projects can affect technology choice behavior in a wide range of domains (Harborne, Hendry 2009; Smyth 2010; Ma, Jin 2011; Klitkou *et al.* 2013; Bagai *et al.* 2014). This is the same for construction industry technology innovation (Clausen 1999). Through a completed demonstration project of smart construction, the construction enterprise can see the feasibility and advantages of emerging information technology. In such situation, the perceived usefulness of emerging information technology will be greatly promoted by the implementation and operation of smart construction system. Meanwhile, using intention for emerging information technology can be directly influenced. The positive effects from the demonstration project on using intention and perceived usefulness are respectively presented as H8 and H9.

2.2.9. Advertisement

Existing marketing research has shown that advertising can affect our behavior and information technology acceptance (Tsui 2012; He *et al.* 2013). Advertising has an increasingly important influence on emerging information technology product diffusion, and it is vital to attract the attention of construction enterprises. Advertising can also influence perceived usefulness and directly or indirectly affect using intentions. Specifically, informal "word of mouth" advertising among construction enterprises can positively affect perceived usefulness. This is set as H10.

2.2.10. Other major factors of the emerging information technology acceptance model

According to the aims of this paper, the emerging information technology acceptance model for the development of smart construction system is an information systems theory that models how smart construction system builders and enterprises come to accept a series of emerging information technologies. Based on the technology acceptance model (TAM) theory, the using intention of emerging information technology in the development of smart construction system is mainly affected by two dimensions of the TAM: perceived usefulness, and perceived ease-of-use. Perceived ease-of-use can effectively predict and explain the willingness to adopt emerging information technology, and also influences on perceived usefulness and using intention. The hypotheses related to this are as following:

H11 represents the positive influence of perceived ease-of-use on perceived usefulness.

H12 represents the positive influence of perceived ease-of-use on using intention.

H13 represents the positive influence of perceived usefulness on using intention.

The above hypotheses were established based on the conceptual model presented in Figure 3. We will test all 13 of the hypotheses by Structural Equation Modeling (SEM) with IBM SPSS Amos 24.0 in following section. According to a study by Anderson and Gerbing (1988), two-phased approach should be established. First, the overall fit, validity, and reliability of a structural model were estimated by using confirmatory factor analysis (CFA). Second, the hypotheses were tested. Meanwhile, according to Hayduk and Littvay (2012), only an appropriate number of indicators were considered.

3. Data collection and analysis

3.1. Data collection

In this paper, all of the measurements used a 5-point Likert scale from "strongly disagree" (1) to "strongly agree"

Table 1. Characteristics of respondents (N = 154)

Gender distribution		Occupation distribution	
Gender	Percentage	Occupation	Percentage
Male	50.91%	School student	15.53%
Female	49.09%	School teacher	18.56%
		Government	8.09%
		Construction enterprise	52.72%
		Others	5.10%

(5). The survey was conducted between June 18 and October 28, 2017 by e-mail to construction directors and experts, and by sharing questionnaires in the WeChat group of International Association of Chinese Construction Scholars to researchers and practitioners in the engineering construction field. Finally, a total of 178 questionnaires were collected. Among the 178 questionnaires, 154 were valid and the response rate was 86.5%. Table 1 shows the descriptive characteristics of the respondents. Most of the respondents were the staff of construction enterprises (52.73%). The number of males (50.91%) and females (49.09%) was almost equal.

3.2. Assessment of the measurement model

In order to validate the measurement model, the reliability and validity of the questionnaire were examined by the factor loading, the composite reliability (CR), the average variance extracted (AVE), and Cronbach's coefficient alpha based on the CFA results (Cronbach 1951; Barclay *et al.* 1995; Aibinu, Al-lawati 2010). According to Hair *et al.* (2009), factors loading and AVE should be totally lager than 0.5. Meanwhile, the CR for all the factors from the measurement model should be above 0.6 (Fornell, Larcker 1981). Furthermore, the Cronbach's alpha value is considered acceptable over 0.6 (Nunnalyy 1978). Table 2 shows the reliability and validity of the questionnaire.

The Pearson correlation coefficients of all factors are indicated in Table 3. Here, the square root of the AVE (in bold), which distributes on the diagonal line, is larger than all the other cross correlation coefficients, which are in the lower triangular matrix. Thus, the measurement model in this paper is quite effective.

Table 2. Reliability and validity of questionnaire

Latent constructs	Observed indicators	Factor loading	AVE	CR	Cronbach's alpha
Technology usefulness (TU)	TU1 TU2 TU3	0.700 0.713 0.719	0.505	0.754	0.813
Policy (P)	P1 P2	0.804 0.768	0.618	0.764	0.910
Market (M)	M1 M2	0.837 0.792	0.664	0.798	0.891
Perceived value (PV)	PV1 PV2 PV3 PV4	0.616 0.752 0.845 0.812	0.580	0.845	0.871
Ease of integration (EOI)	EOI1 EOI2 EOI3	0.810 0.760 0.795	0.622	0.831	0.889
Expected benefits (EB)	EB1 EB2	0.759 0.650	0.500	0.665	0.708
Expected cost input (ECI)	ECI1 ECI2	0.898 0.879	0.790	0.882	0.947
Demonstration project (DP)	DP1 DP2	0.698 0.800	0.564	0.720	0.758
Advertisement (A)	A1 A2	0.715 0.738	0.528	0.691	0.735
Perceived ease-of-use (PEOU)	PEOU1 PEOU2 PEOU3	0.750 0.838 0.677	0.574	0.801	0.857
Perceived usefulness (PU)	PU1 PU2	0.862 0.834	0.719	0.837	0.877
Using intention (UI)	UI1 UI2 UI3	0.574 0.744 0.685	0.451	0.710	0.720

Note: The detailed descriptions of observed indicators are included in Notation.

Table 3. Pearson correlation coefficients

	TU	P	M	PV	EOI	EB	ECI	DP	A	PEOU	PU	UI
TU	**0.711**											
P	0.626	**0.786**										
M	0.462	0.257	**0.815**									
PV	0.184	0.246	0.064	**0.762**								
EOI	–0.344	–0.186	0.561	0.239	**0.789**							
EB	0.082	0.198	0.154	0.140	0.127	**0.707**						
ECI	–0.044	0.080	0.058	–0.013	0.044	0.349	**0.889**					
DP	0.015	0.016	0.037	0.119	–0.062	0.384	0.100	**0.751**				
A	0.017	0.088	0.107	0.019	0.169	0.492	0.257	0.609	**0.727**			
PEOU	0.082	0.030	0.146	0.057	0.004	0.316	0.179	0.354	0.184	**0.758**		
PU	0.044	0.098	0.133	0.183	0.080	0.543	0.187	0.429	0.329	0.443	**0.848**	
UI	0.062	0.159	0.193	0.154	0.183	0.654	0.435	0.411	0.542	0.4673	0.570	**0.672**

3.3. Analysis of the structural model

As we know, SEM is an effective method in factor and path analysis based on previous analysis. Therefore, we processed data by using SEM with IBM SPSS Amos 24.0. According to the evaluation criteria of good SEM, which was proposed by Bollen (1989) and Xiong *et al.* (2015), in this study, the goodness-of-fit of EITAM and the acceptance levels were compared. According to the analysis results in Table 4, we know that X^2/df (2.570), NFI (0.912), CFI (0.936), IFI (0.941), RFI (0.937), and RMSEA (0.072) were all close to the acceptance level. Thus, the EITAM had good fitness, and the conceptual model and theoretical assumptions were established.

Table 5 shows the results of a discriminant validity test between external variables and internal variables for emerging information technology acceptance for the development of smart construction system. In addition to H2, H4, H5, H8, and H10, other 8 variables (H1, H3, H6, H7, H9, H11, H12, H13) of the original hypothesis in Section 3 were confirmed.

Meanwhile, as shown in Table 5, all of the absolute values of statistically significant path coefficients (about 61.54%) were more than 0.2. This not only shows the closeness of the relationships between the external variables and internal variables, but also indicates that the corresponding hypotheses are acceptable and rational.

According to the squared multiple correlation coefficients (R^2), we can see the using intention is better explained by EITAM. The ease of integration, perceived usefulness, perceived ease-of-use, and expected benefits have significant influence on using intention. Since the emerging information technology in smart construction is still in the initial stage, and we only considered limited factors, so the explanatory power of perceived usefulness and perceived ease-of-use was low. Interpretation of these phenomena will be summarized in Section 5. In order to obtain clear relationships between external variables and internal variables, the standard path coefficients of EITAM are shown in Figure 4.

Table 4. Goodness-of-fit of EITAM

Fit indices	X^2/df	NFI	CFI	IFI	RFI	RMSA
Criteria	< 3	> 0.90	> 0.90	> 0.90	> 0.90	< 0.08
Fitness	2.570	0.912	0.936	0.941	0.937	0.072

Table 5. Results of discriminant validity test

Path	Path coefficients	S.E.	P	Discriminant validity
PU←TU	0.285	0.038	***	Acceptable
PU←P	–0.082	0.031	0.254	Unacceptable
PU←M	0.244	0.044	***	Acceptable
PU←PV	–0.081	0.040	0.240	Unacceptable
PEOU←EOI	0.095	0.073	0.290	Unacceptable
UI←EB	0.653	0.103	***	Acceptable
UI←ECI	0.403	0.043	***	Acceptable
UI←DP	0.121	0.088	0.095	Unacceptable
PU←DP	0.545	0.109	***	Acceptable
PU←A	–0.146	0.083	0.099	Unacceptable
PU←PEOU	0.326	0.052	***	Acceptable
UI←PEOU	0.508	0.062	***	Acceptable
UI←PU	0.216	0.057	*	Acceptable

Note: *** P < 0.001; * 0.01 < P < 0.05.

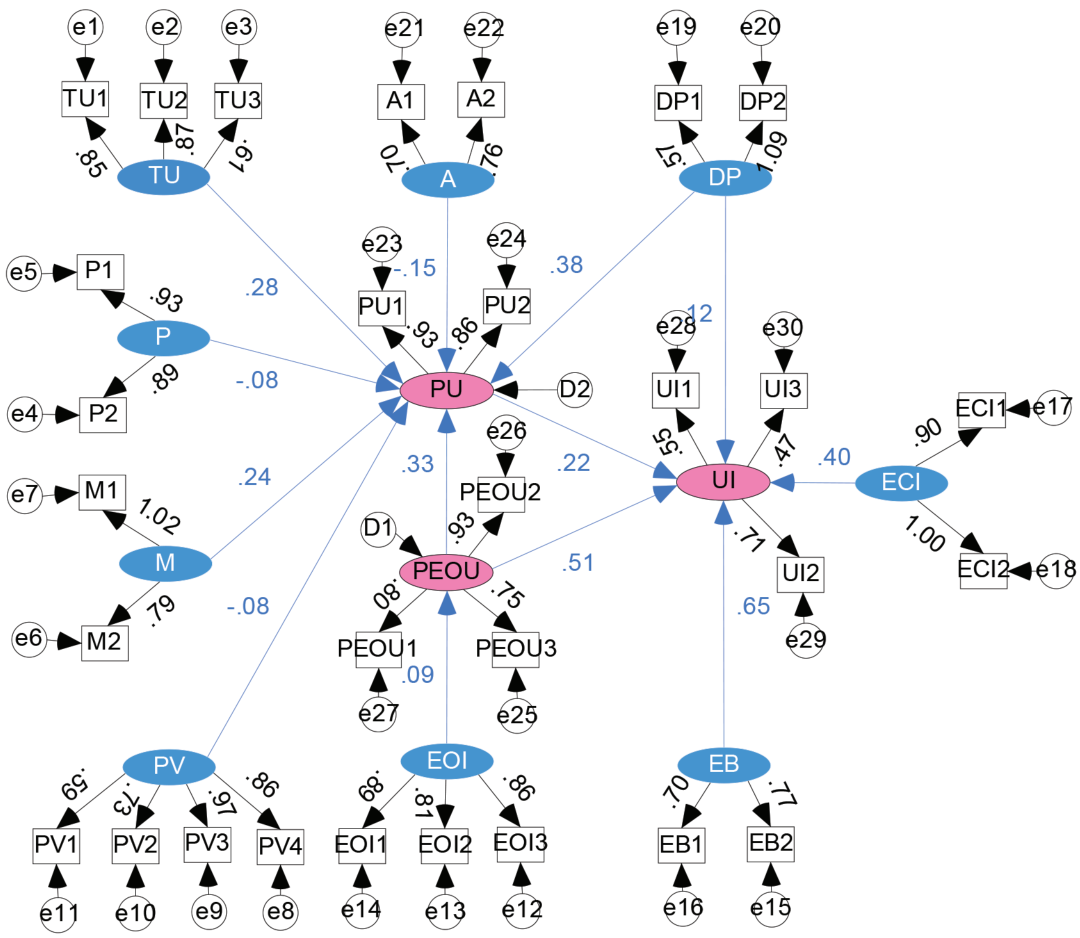

Figure 4. Path coefficients of EITAM

4. Results and discussion

4.1. Results

According to the results of Table 5 and Figure 4, the hypothetical relationship between the internal variables was effectively validated, this indicated that the proposed EITAM in the development of smart construction system is effective. Furthermore, these external variables such as expected benefits, expected cost input, demonstration project, technology usefulness, and the market will also certainly influence acceptance of emerging information technology in the development of smart construction system. Eight of the 13 hypotheses were supported at the 94.8% significant level. Meanwhile, the hypotheses about the relationship between policy and perceived usefulness (H2), perceived value and perceived usefulness (H4), ease of integration and perceived ease-of-use (H5), demonstration project and using intention (H8), and advertisement and perceived usefulness (H10) were not supported.

H1 was supported, which indicates that technology usefulness has significant impacts on perceived usefulness; it also shows that the more useful the emerging information technology, the stronger the perceived usefulness, and thus the stronger the willingness to adopt the technology. H3 was supported, which shows that the market has a significant impact on perceived usefulness; it further indicates that a good market can encourage emerging information technology innovation, and can influence perceived usefulness. H6 was supported, which indicates that expected benefits of using emerging information technology in the development of a smart construction system have a direct and positive effect on the using intention.

Meanwhile, although expected benefits and cost input are two key components of capital input, the expected cost input is different with expected benefits. According to the above research results, H7 was supported, which indicates that the using intention is higher with a much lower expected cost input. This result completely fits with theories related to the psychology of investing (Weng 2003; Nofsinger 2017). H9 was supported, which indicates that demonstration projects have significant impacts on perceived usefulness; however, this is an indirect influence. Furthermore, H11, H12, and H13 were supported, which is consistent with the hypothetical relationships that exist between usefulness, ease-of-use, and using intention presented in the original technology acceptance model in Figure 2.

The hypotheses of H2, H4, H5, H8, and H10 were not supported, which was mainly caused by the following two reasons: the experimental hypotheses were not reasonable; alternatively, the cognitive level of these factors was low at the beginning of the emerging information technology and smart construction system development. Above factors had already been pointed out by Davis since TAM was built. The major reason we should know is that there is no significant relationship with these hypotheses of variables when a person isn't intimately familiar with the emerging information technology, or a person has no opportunity to use smart construction system. At present, smart construction system is still in the initial stage with lots of limited scale, so it is necessary to apply more emerging information technology in the smart construction system, and let more people to know the smart construction system is practical and convenient.

4.2. Discussion

Based to the above study, in order to improve the overall goodness-of-fit levels of the EITAM in Figure 4, those insignificant hypotheses (H2, H4, H5, H8, and H10) are deleted one by one in this subsection. And according to the modification indices (MI) between perceived ease-of-use and expected benefits (MI value is 44.6), we will make connections between them. Finally, the optimal EITAM with the highest goodness of fit can be seen in Figure 5. The optimal EITAM in Figure 5 clearly indicates that with the improvement in expected benefits (EB), the significant level in perceived ease-of-use (PEOU) will be highly improved. Meanwhile, it further influences the using intention (UI) of emerging information technologies for the development of smart construction system.

According to the other previous TAM studies, several IT acceptance models have been proposed to explain and predict individual acceptance of new technologies. However, the application of TAM in construction is relatively less than that in some other fields, especially in the smart construction. In construction field, Lee *et al.* (2013) developed and validated a BIM acceptance model based on technology acceptance behavior-related theories. This study is the first time that we proposed the above EITAM for the development of smart construction system, so it has some innovative. We not only built the special technology acceptance model which conforms to the logical content of TAM models, but also had a clear understanding of the key factors which can affect the emerging information technology acceptance at the beginning of the smart construction system development.

In addition, compared with other TAMs, The EITAM in this study has many advantages, which as two following parts. First, in this study the EITAM obeys the law of market economy. The main reason is that both the technologies, policy and market environment are essential in the initial stage of the smart construction system development. Second, the expected benefits (EB) have main influences on using intention (UI) of emerging information technologies for the development of smart construction system, which is also fitting the innovation investment mechanism of construction enterprises.

Based on the above series of processes, the main work and contributions are as following: the EITAM in this study is significant in providing what factors should be more importantly managed over other factors affecting emerging information technology acceptance when building a smart construction system; the EITAM in this study also can be used to evaluate the influence factors of emerging information technology acceptance of the smart construction system building for an individual and construction enterprises; finally, this study can provide some theoretical guidance and support to build an emerging information technology acceptance strategy in smart construction development that is suitable for government and construction management department.

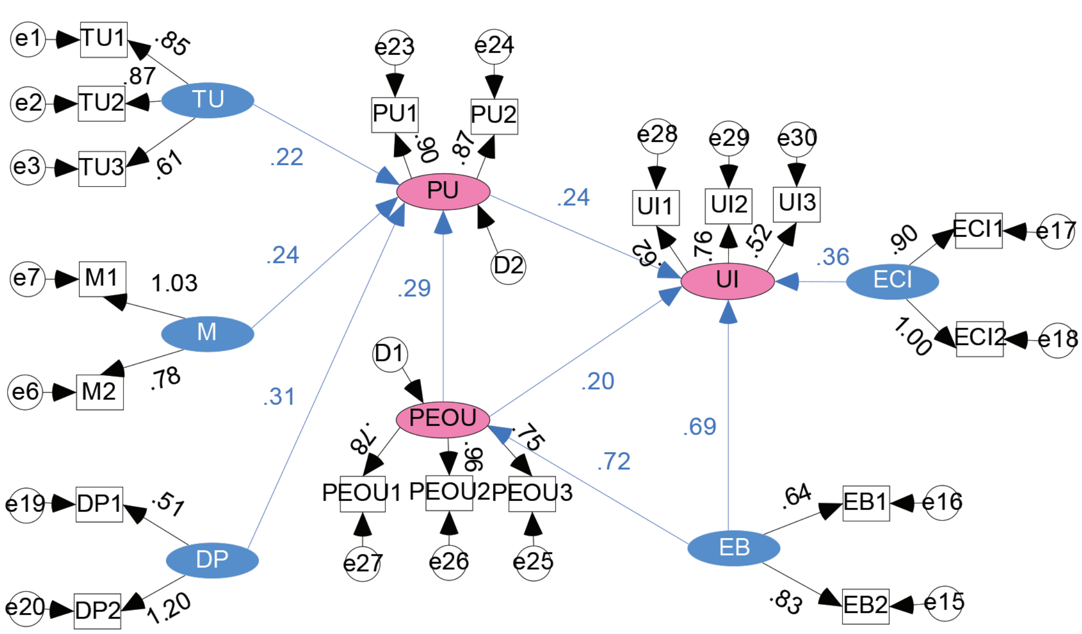

Figure 5. The optimal EITAM

Conclusions

This study revealed the core factors that can affect the acceptance of emerging information technology in the development of smart construction system. Hypothesis testing validated the relationships between perceived usefulness, perceived ease-of-use, and using intention. The results further illustrated that the proposed approach and EITAM in this study were effective.

Furthermore, other external factors, such as technology usefulness, the market, expected benefits, expected cost input, and demonstration projects, also affect the acceptance of emerging information technology in the development of the smart construction system. In this study, most of the hypotheses were effective and reasonable. The main contribution is that our approach provided a new way to assess the emerging information technology acceptance for high-tech construction enterprises for the development of smart construction system.

However, this study also has certain limitations. First, this empirical study was conducted in only one country. Thus, the interpretation of results should be confined to China, United States, Singapore, or other similar countries. Second, this research was only conducted using targeted smart construction organizations that were already utilizing emerging information technology.

In the future, we will not only focus on improving the R^2 value, but also investigating about the other hidden factors and non-significant hypotheses of the EITAM in development of the smart construction system. With the progress of emerging information technology and smart construction, we will continually expand of the EITAM by adding various new sub factors.

Acknowledgements

This work was supported by the National Natural Science Foundation of China (No. 51378160) and the National Key Research and Development Program of China (No. 2016YFC0701904). The authors also would like to thank LetPub (www.letpub.com) for providing linguistic assistance during the preparation of this manuscript.

Disclosure statement

All the authors have no conflict of interest.

Notation

(Note: The below “It” or “it” denotes emerging information technology adoption in the development of smart construction system)

TU1: we need fusion of emerging information technology in the development of smart construction system.

TU2: The importance of emerging information technology.

TU3: Emerging information technology is beneficial to developing smart construction system.

P1: It needs a good policy support.

P2: Whether the current policy is beneficial.

M1: It needs a good market environment.

M2: Whether the current market is favorable.

PV1: It can improve the level of system implementation.

PV2: It can bring economic benefits.

PV3: It can improve the competitiveness.

PV4: It can bring social benefits.

EOI1: It is a complicated system project.

EOI2: It needs for multi-technical cooperation.

EOI3: It needs for multi-sector coordination.

EB1: It can promote construction economic benefits.

EB2: It can improve the level of construction efficiency.

ECI1: It needs a lot of cost investments.

ECI2: The cost scale has a great impact of it.

DP1: It needs for us to Visiting Demonstration projects.

DP2: Visiting demonstration projects can enhance using intention of emerging information technology.

A1: Advertising can affect it.

A2: The “word of mouth” can affect it.

PEOU1: It is easy being integrated.

PEOU2: It is easy being operated.

PEOU3: It is easy being controlled.

PU1: It is just a matter of time.

PU2: It makes the construction process leaner.

UI1: The willing to use emerging information technology.

UI2: The willing to use emerging information technology to deal with engineering construction problems.

UI3: We will be getting more attention of it in the future.

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