Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 November 2022 doi:10.20944/preprints202211.0438.v1

Article

Analysis of the Drivers of the Adoption of Intelligent Construction Technology by Road Construction Enterprises

Zhou Zhi-chao, Su Yi-kun*, Zheng Zhi-zhe and Wang Yi-lin

Civil Engineering Northeast Forestry University, Hei Long-jiang Harbin 150040; E-mail: zzc18545567775@163.com (Zhou Zhi-chao), yikunsu_nefu@163.com (Su Yi-kun), jasworkhard@126.com(Zheng Zhi-zhe), wyl20080210@163.com (Wang Yi-lin)
* Correspondence: Correspondence: yikunsu_nefu@163.com.

Abstract: This study aimed to identify the influencing factors that drive the adoption of smart construction technologies by highway construction companies. Using expert interviews and expert scoring, interview data were collected from 25 experts in the field, and the TOSE framework was proposed based on the TOE framework, identifying four dimensions and fourteen influencing factors. The results were analyzed using the Fuzzy-DEMATEL-ISM method, and the findings were then summarized according to the evaluation criteria to determine the validity of the fourteen hypotheses and the extent to which they drive the adoption of intelligent construction technologies by motorway construction companies. The findings of this paper will be of great value to decision-makers and participants in highway construction companies, as well as to other companies in the construction industry, in their decision to adopt smart construction technologies.

Keywords: decision-making; Fuzzy-DEMATEL-ISM; highway construction companies; driving influences; intelligent construction technology

1. Introduction

By the end of 2020, the total mileage of roads in China exceeds 5.19 million kilometers, of which the highways have reached 161,000 kilometers, ranking first in the world [1]. However, with the progress of technology, intelligent construction is gradually replacing traditional construction methods with its advantages of high efficiency, low energy consumption, low loss, and low pollution [2]. Most of the technologies in intelligent construction technology are new, so many domestic highway construction enterprises still maintain an observant and hesitant attitude, while the construction of highways with long construction periods, large land areas and environmental pollution, the damage to the environment and the waste of resources, in the long run, will be serious and irreversible, which is also contrary to the concept of sustainable development in China [3]. Therefore, the integration of multidisciplinary knowledge and the development of intelligent construction technology is an issue that cannot be ignored by highway construction enterprises in China [4].

Oyewole et al. investigated the characteristics of smart construction, and nearly half of the respondents knew almost nothing about smart construction [5]. Gyamfi et al. delve into the current state of the construction industry in Ghana and found that most construction professionals fail to recognize the concept of smart construction [6]. Ahiabor et al. believe that smart construction technology has a large space for development in many developing countries, and it is necessary to give priority to understanding intelligent construction technology before application [7]. Chawla et al. discussed the knowledge system of green construction in the concept of smart construction, and the survey found that the adoption rate of smart construction technology in developing countries is very low [8]. De-Graft et al. used Ghana as an example to assess the level of decision-making in developing countries to adopt smart construction technologies and summarized the relevant decision-making factors [9]. Ghansah et al. investigated the level of awareness of smart construction technologies in developing countries such as Ghana and identified key factors that have a significant impact on the level of awareness [10]. Duan et al. investigated the application of BIM technology in intelligent construction technology in highway construction management, reflecting the practical application of BIM technology [11]. Wan et al. built an intelligent transportation system platform mechanism frame based on big data technology in intelligent construction technology [12]. He et al. applied constrained least squares to optimize intelligent video surveillance technology [13]. Arka et al. reviewed IoT technologies in smart construction technologies, analyzing key drivers and research trends [14]. Ali et al. summarized the integration of UAV technology in intelligent construction technology into seven dimensions and summarized the 3D modelling in detail [15]. The research of the above scholars analyzes the adoption factors and application status of intelligent construction technology from various angles, but the research on the driving factors for the adoption of intelligent construction technology by highway construction enterprises is rarely mentioned, which may also be the reason for the low level of intelligent construction of highways in China. Therefore, this paper aims to identify the driving factors for the adoption of intelligent construction technology by Chinese highway construction enterprises and determine the role of these factors in the adoption of intelligent construction technology by enterprises, to promote intelligent construction technology in highway construction enterprises and fill the research gap in this field.

2. Theoretical foundations

The Theory of Technology-Organization-Environment (TOE) framework was first proposed by Tornatzky in the 1990s [18]. The theory consists of three dimensions: the technology dimension, the organization dimension, and the environmental dimension. In recent years, the TOE framework theory has been applied to numerous smart construction technology adoption studies, including BIM technology [19], cloud computing technology [20], big data technology [21], Internet of Things technology [22], blockchain technology [23], etc. For example, Owusu-Manu et al. Analyzed and assessed the decision factors for the adoption of smart construction technologies in developing countries based on the TOE framework theory in the form of a questionnaire [10]; Badi et al. (2021) applied the TOE framework to conduct an empirical study on the determinants of smart contract adoption in the construction industry from the perspective of UK contractors [74]; Kim et al. Based on the TOE (2021) proposed variables that influence the adoption of blockchain technology and found that blockchain technology has a positive impact on logistics performance [75]; Ullah et al. proposed a multi-layered risk management framework based on the TOE framework to identify and manage the risks associated with smart city governance [76]; where the technology dimension mainly covers the internal and external dimensions of technology, such as the existing technology of the firm and the cost of adopting new technology; the organizational dimension The organizational dimension includes management-related structures, such as top management support and corporate culture, and the environmental dimension involves the external environment in which the company operates, such as the competitive peer environment and the policy environment of the company's location [19,24].

The main object of this paper is the drivers of the adoption of intelligent construction technology in highway construction enterprises, and the TOE framework theory is more organizational in perspective and widely applied; and this paper adopts Fuzzy-DEMATEL-ISM for model construction to analyze the influencing factors, while the TOE framework theory can provide a more comprehensive framework for the potential factors, so this paper finally chooses the TOE framework as the theoretical perspective [16,17]. Given that the subject of this paper is a highway construction enterprise with a wide range of technologies, a large organizational system, and a complex environment, the adoption of smart construction technologies is not limited to the technical, organizational, and environmental dimensions. Thus, after discussing with various experts and scholars, this paper adds the social dimension influencing factors to the TOE framework theory, in conjunction with the TOSE framework (i.e. Technical, Organizational, Social and Environmental Resilience) proposed by Bruneau to explain resilient cities [79].

This section identifies and determines the main influencing factors for the adoption of smart construction technologies in Chinese highway construction companies based on literature research and expert feedback. The literature research was conducted in May 2022 and the database was selected as Web of Sciences, and no time limit was set as research related to smart construction technologies and their adoption is an emerging topic. The keywords searched included "Smart build & adopt", "Smart build &Influencing factors", "Smart construction adopts the will", and "Build & adopt". To improve the quality of the study, the selection criteria were set: only journal and conference articles were retained, and only English-language literature was retained. 1802 papers were initially searched on the Web of Science, then duplicate papers and papers unrelated to the study were excluded, and finally, 34 papers were selected and retained by reading the titles, abstracts, keywords, and full text of the papers. In addition, 7 additional papers were expanded by reading PhD theses in related fields. Finally, 41 literature articles were identified as the drivers for identifying and determining the adoption of smart construction technologies by highway construction companies in China, with the process shown in Fig 1. Based on this, four dimensions of influencing factors were set for the hypothesis in this study: technical dimension, organizational dimension, environmental dimension, and social dimension.

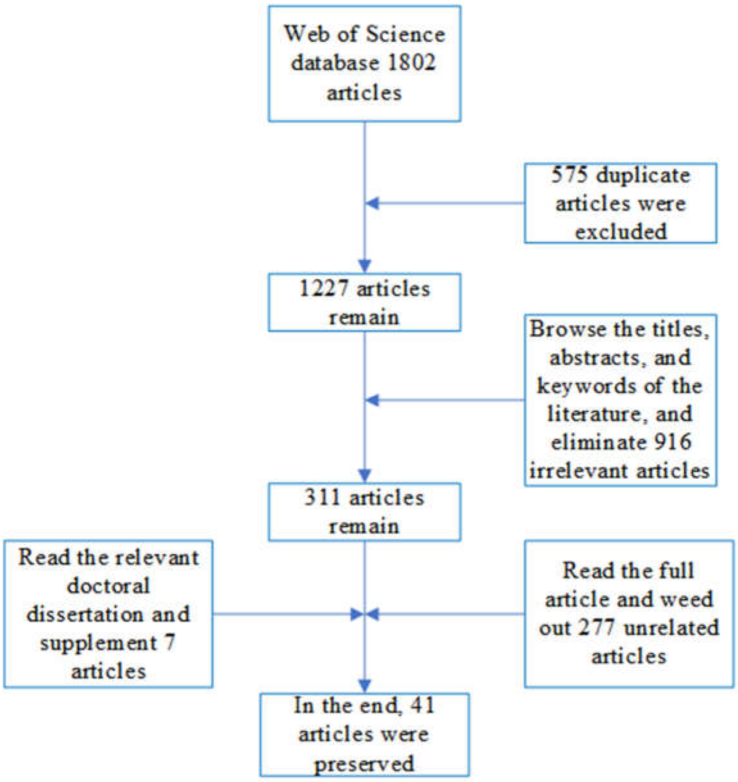

Figure 1. Literature selection process.

3. Influencing factor identification and assumptions Identification of technical dimensional influences

Compared with traditional construction technology, intelligent construction technology has the advantages of high efficiency, low energy consumption, low pollution, etc. Mastering and applying intelligent construction technology can bring long-term benefits and sustainable development to highway construction enterprises [25,26,40,62,63]. The adoption of intelligent construction technology requires not only the purchase of new

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 November 2022 doi:10.20944/preprints202211.0438.v1

equipment but also the investment in the training of technicians, maintenance of equipment, and the hiring of experts. The application of intelligent construction technology can achieve unified management of the construction progress of highway projects by sharing engineering construction data on the system platform while improving the speed of information transfer and enhancing the privacy of information storage. However, the complexity and risks involved in implementing smart construction technology require careful planning and management [9, 34-36]. The application of smart construction technology will inevitably conflict with the application of the original technology, which includes not only the compatibility of software and data but also the hindrance in the management process of the highway construction process. However, whether this compatibility issue will hinder the adoption of intelligent construction technology by highway construction enterprises needs to be further explored [19,77,78].

3.1. Assumptions about the factors influencing the technological dimension

These include factors such as 'technological advantage', 'technological cost', 'complexity', and 'compatibility'. Therefore, the following hypotheses are proposed in this study.

H1a: Better technological advantage has a significant positive effect on driving the adoption of smart construction technologies by highway construction firms.

H1b: There is a significant positive impact of lower technology costs on driving the adoption of smart construction technologies by highway construction companies.

H1c: lower complexity has a significant positive impact on driving the adoption of smart construction technologies by highway construction firms.

H1d: Good compatibility has a significant positive impact on driving the adoption of smart construction technologies by highway construction companies.

3.2. Identification of influencing factors in the organizational dimension

A company with a solid, conservative mindset is often lagging or even refusing to adopt new technologies; whereas a company with an innovative mindset is always ahead of the curve and planning when it comes to adopting new technologies. Thus, corporate culture is also one of the important influencing factors in determining the adoption of intelligent construction technology in highway construction enterprises [37-39]. Adequate reserves of talent, capital, technology, and other resources can enable highway construction enterprises to integrate and apply intelligent construction technology more quickly and steadily, while enterprises with a lack of or insufficient resources may have certain obstacles and difficulties in adopting intelligent construction technology [9, 40-42, 72]. Top management support for smart construction technologies can stimulate the potential of employees, improve productivity, and make them feel trusted and more focused on their work; at the same time, top management stimulates change through communication and reinforcement of company values, thus influencing the adoption of new technologies [9, 43-48, 51]. The attitude of technical professionals towards the adoption of new technologies is important, including but not limited to software technicians in the design and planning phase, equipment technicians in the construction and maintenance phase, etc. Their ability to coordinate and collaborate with experts and academics influences the adoption of smart construction technologies. The adoption of intelligent construction technologies in highway construction companies requires the training of existing staff in the operation of new software or equipment, or the recruitment of specialist technicians, which will not only increase the size of the company to a small extent but also improve its core competitiveness [9, 31-33, 49-51,].

3.3. Hypotheses about the influencing factors of the organizational dimension

These include factors such as 'corporate culture', 'resource readiness', 'top management support' and 'employee support'. Therefore, the following hypotheses are proposed in this study.

H2a: Better corporate culture has a significant positive impact on driving the adoption of smart construction technologies in highway construction firms.

H2b: better resource readiness has a significant positive impact on driving the adoption of smart construction technologies in highway construction firms.

H2c: there is a significant positive impact of top management support on driving the adoption of smart construction technologies in highway construction firms.

H2d: Employee support has a significant positive impact on driving the adoption of smart construction technologies in highway construction firms.

3.4. Identification of environmental dimensional influences

Environmental dimension influencing factors are mainly divided into competitive pressure, policy environment, and economic environment. Among these, the competitive market environment refers to the competitive pressure felt by firms when competitors in the same industry have adopted or are preparing to apply new technologies and is an inevitable product of competition in the industry. When this competitive pressure arises, firms may apply innovations in the industry, which in turn reduce the competitive market pressure and change the competitive market environment [19,26,52-54,73]. The policy environment refers to mandatory policies or recommendations related to smart construction in the locality or country where the firm is located. Government incentives, subsidies, and support for new technology can have a significant impact on the adoption and diffusion of the new technology by firms [54-56,69-71]. Economic environment includes pressure from customers and pressure from partners. For example, if smart construction technology is recognized by customers or applied by partners, to ensure the technical concept and goals, the company is likely to use it to better communicate and cooperate, or to meet customer needs [38-42,74]. To achieve the application of smart construction technologies for highway construction, highway construction companies need to collaborate with external parties, where stakeholder involvement and support will play an important role; in making stakeholders aware of, it is familiar with, and then mastering and using smart construction technologies is an important influencing factor for the adoption of smart construction technologies [9, 80].

3.5. The hypothesis of environmental dimension influencing factors

These include factors such as "competitive market pressure", "policy environment", "economic environment" and "stakeholder ", therefore the following hypotheses are proposed in this study.

H3a: Competitive market pressures have a significant positive effect on driving the adoption of smart construction technologies by highway construction firms.

H3b: A good policy environment has a significant positive impact on driving the adoption of smart construction technologies by highway construction firms.

H3c: a good economic environment has a significant positive impact on driving the adoption of smart construction technologies by highway construction firms.

H3d: Stakeholder involvement has a significant positive impact on driving the adoption of smart construction technologies in highway construction enterprises.

3.6. Identification of social dimensional influencing factors

Due to the strict site selection, long construction period, high cost, large investment, and large scale of construction, highway construction enterprises are required to strictly comply with laws, regulations, industry standards, and other institutional requirements during the design and construction stages. As a result, companies with a better sense of social responsibility are more likely to give preference to the application of intelligent construction technology to ensure that the highway schedule is not delayed, the project quality is high, and the social people are better served [81,82]. Sustainable development refers to meeting the needs of the present generation for economic, environmental and social, development without preventing future generations from meeting their needs [83]. The adoption and application of smart construction technologies can help companies to transform and innovate [84, 85].

3.7. The hypothesis of social dimension influencing factors

These include factors such as 'corporate social responsibility and 'sustainable development' and therefore the following hypotheses are proposed in this study.

H4a: Better corporate social responsibility has a significant positive impact on driving the adoption of smart construction technologies in highway construction companies.

H4b: Sustainable development has a significant positive impact on driving the adoption of smart construction technology in highway construction companies.

In summary, after discussions with industry experts and scholars, this study proposes a framework for analyzing the drivers of smart construction technology adoption in highway construction enterprises based on the TOE framework theory, including 14 key drivers in four dimensions, including technology, organization, environment, and society, as shown in Table 1, to analyze the mechanism of the impact of driving smart construction technology adoption in highway construction enterprises.

Table 1. Summary of drivers for the adoption of smart construction technology in China's highway construction companies.

Main factors	No.	Sub-factors	Description of influencing factors
Technical dimension	H1a	Technical advantages	The technology dimension influences factors meant to influence the adoption of smart construction technology by motorway construction companies. The intelligent construction of motorways is achieved through the capture, collection, integration and analysis of information.
	H1b	Technical costs	
	H1c	Complexity	
	H1d	Compatibility	
Organizational dimensions	H2a	Corporate Culture	The organizational dimension is influenced by the acceptance and support factors at various levels within the organization when adopting smart construction technologies.
	H2b	Resource Readiness	
	H2c	Senior management support	
	H2d	Staff Support	
Environmental dimensions	H3a	Competitive market pressures	The environmental dimension influences factors that affect the collaboration between companies and external parties, which in turn support and help each other to adopt smart building technologies.
	H3b	Policy environment	
	H3c	Economic environment	
	H3d	Stakeholder engagement	
The social dimension	H4a	Corporate Social Responsibility	The social dimension affects mainly means that corporate strategies and behaviors are transformed under the constraints of the social dimension.
	H4b	Sustainable development	

Through the above analysis, a system of drivers for the adoption of intelligent construction technology in China's highway construction enterprises is established, as shown in Fig 2.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 November 2022 doi:10.20944/preprints202211.0438.v1

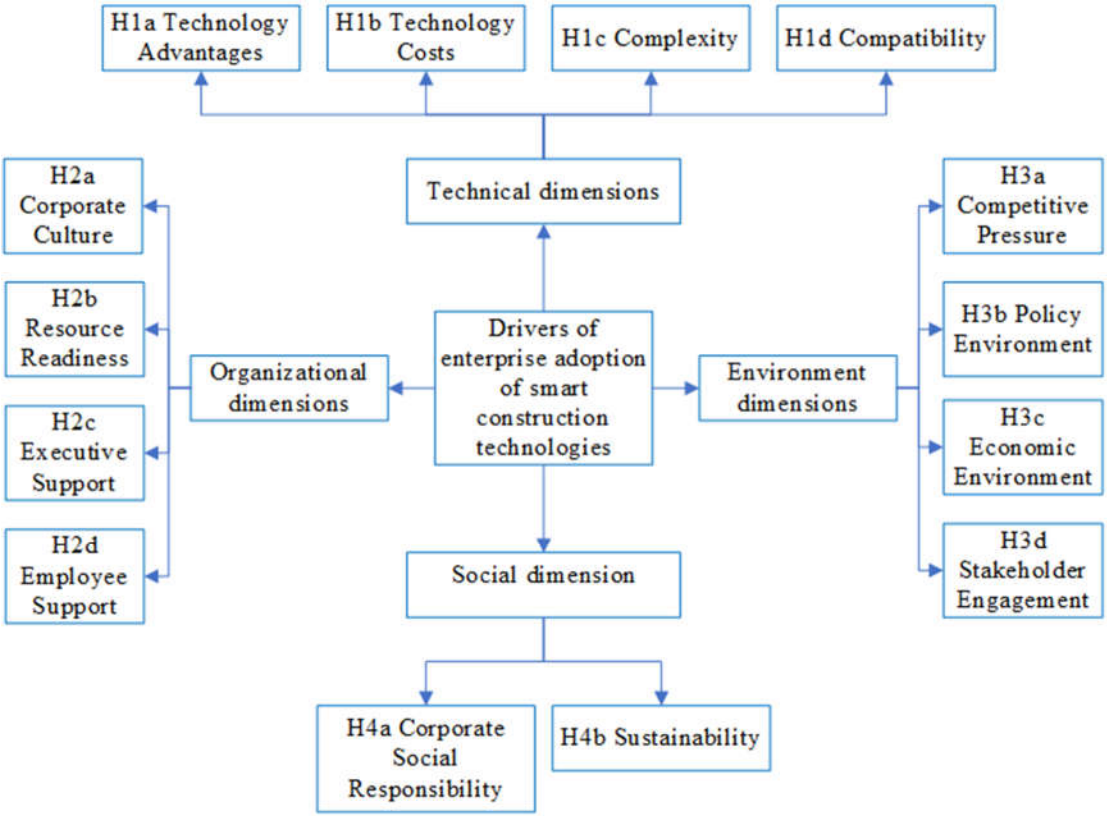

Figure 2. System of driving influences on the adoption of intelligent construction technology by highway construction enterprises in China.

4. Research methods and calculation processes

This study applies the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method of analysis. This method makes full use of experts' knowledge and experience to identify and analyze complex factor networks and explores the causal relationships between factors by establishing relationship matrices through matrix and graph theory [86]. However, this method is too subjective and expert judgments vary greatly, and the research results are somewhat biased. Therefore, this paper combines fuzzy set theory, so that the triangular fuzzy numbers in it are combined with DEMATEL to form the Fuzzy-DEMATEL method. The method fuzzifies the direct influence matrix by transforming the expert semantics into the corresponding triangular fuzzy numbers, while the CFCS method is later applied to defuzzify and further process and clarify the hierarchical relationships [87].

Research process.

This study established a system of driving influences and conducted research using expert interviews and expert scoring. Thirty-five experts with relevant experience were contacted for this research effort, and the support of 25 experts was eventually obtained after consultation. These experts were from leading construction companies, research institutes and universities. The research was based on a scale scoring principle and the average conversation time was 15 minutes. The specific background information of the experts is shown in Table 2. After collating the experts' scores, reliability and validity analyses were conducted, and the results are shown in Table 4. The Cronbach alpha coefficient of 0.870 was greater than 0.8 and the KMO value, of 0.823 was greater than 0.7, fully demonstrating the validity of the questionnaire.

Table 2. Background information on experts.

Features	Features	Number of people
Educational background	Undergraduate	1

	Masters	9
	PhD	15
Relevant work experience	5-10 years	6
	10-15 years	6
	More than 15 years	13
Work Unit	Constructor	5
	Designers	9
	Higher education institutions	11
Jobs	Technical positions	6
	Management positions	8
	Technical + management positions	11
Title	Intermediate title	8
	Senior title	17

Table 3. KMO and Bartlett's test.

Projects		Test value
KMO	Metrics	0.823
Bartlett's test for sphericity	Approximate cardinality	992.052
	Df	270
	Sig.	0

The specific process of trigonometric fuzzy number transformation is as follows.

1. Based on the construction of the driver indicators, an expert semantic scale was constructed. The influencing factors are classified into five levels: no influence "0", weak influence "1", average influence "2", strong influence "3 ", strong influence "4".

2. Based on the scoring results of each expert, construct an initial matrix of order n $C=|c_{ij}|_{n\times n}$

c_{ij} means the degree of influence of factor F_i on factor F_j. factor F_i.

3. the initial direct influence matrix is transformed into a triangular fuzzy number, which is expressed as $X=(l,m,r)$, with l being the left-hand side value, i.e. the conservative value; m being the middle value, i.e. the closest to the actual value; and n being the right-hand side value, i.e. the optimistic value, and satisfying both $X_{ij}^{k}=(l_{ij}^{k},m_{ij}^{k},n_{ij}^{k})$, as shown in Table 4. The final result is intended to be the degree to which the kth expert believes that factor i influences factor j.

Table 4. Semantic conversion table.

Semantic variables	**Triangular fuzzy number**
No impact	(0,0,0.25)
Weaker impact	(0,0.25,0.5)
General Impact	(0.25,0.5,0.75)
Stronger impact	(0.5,0.75,1)
Strong Impact	(0.75,1,1)

The CFCS method was applied for defuzzification to obtain the direct influence matrix Z.

The process is as follows.

1. Normalize the triangular fuzzy number $ls_{ij}^{k}=(l_{ij}^{k}-\min l_{ij}^{k})/\Delta_{\min}^{\max}$

$$\mathrm{ms}_{ij}^{k} = (m_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}$$

$$\mathrm{rs}_{ij}^{k} = (r_{ij}^{k} - \min l_{ij}^{k}) / \Delta_{\min}^{\max}$$

$$\Delta_{\min}^{\max} = \max r_{ij}^{k} - \min l_{ij}^{k}$$

ls_{ij}^{k}, ms_{ij}^{k}, rs_{ij}^{k} are the normalized value of the left-hand side of the triangular fuzzy number l_{ij}^{k}, the middle value m_{ij}^{k} and the right-hand side of the triangular fuzzy number r_{ij}^{k} respectively; $\Delta_{\min}^{\max}$ is the difference between the right-hand side and the left-hand side.

2. Normalization of left-hand and right-hand values $\mathrm{u}_{ij}^{k} = ms_{ij}^{k} / (1 + ms_{ij}^{k} - \mathrm{ls}_{ij}^{k})$

$$\mathrm{v}_{ij}^{k} = rs_{ij}^{k} / (1 + rs_{ij}^{k} - \mathrm{ms}_{ij}^{k})$$

u_{ij}^{k} and v_{ij}^{k}2 are the normalized values for the left-hand and right-hand values, respectively.

3. Calculating clear values

$$\mathrm{z}_{ij}^{k} = \min c_{ij}^{k} + \Delta_{\min}^{\max}\left[\min u_{ij}^{k}(1 - u_{ij}^{k}) + v_{ij}^{k} v_{ij}^{k}\right] / \left[1 - u_{ij}^{k} + v_{ij}^{k}\right]$$

4. Calculate the mean of the clear values to obtain the direct impact matrix. $\mathrm{z}_{ij} = (\mathrm{z}_{ij}^{1} + z_{ij}^{2} + \ldots + z_{ij}^{k}) / k$

$$Z = \left|\mathrm{z}_{ij}\right|_{n \times n}$$

By aggregating and collating the scoring results of the 15 experts and scholars, each scoring result was transformed into a triangular fuzzy number and later de-fuzzified to obtain the direct impact matrix.

The direct impact matrix was standardized as follows, and the direct impact matrix was standardized as shown in Table 5.

$$\lambda = 1 / \max_{1 \le i \le n} \sum_{j=1}^{n} z_{ij}, G = \lambda Z$$

Table 5. Standardization of the direct impact matrix of factors driving the adoption of smart construction technologies by enterprises.

Factors	**H1a**	**H1b**	**H1c**	**H1d**	**H2a**	**H2b**	**H2c**
H1a	0	0.1021	0.0743	0.0625	0.0721	0.0650	0.0721
H1b	0.0828	0	0.0728	0.0577	0.0460	0.0554	0.0734
H1c	0.0841	0.0777	0	0.0754	0.0582	0.0797	0.0863
H1d	0.0799	0.0748	0.0601	0	0.0706	0.0643	0.0863
H2a	0.0565	0.0614	0.0637	0.0428	0	0.0702	0.0642
H2b	0.0603	0.0645	0.0670	0.0594	0.0763	0	0.0652
H2c	0.0837	0.0577	0.0798	0.0546	0.0821	0.0748	0
H2d	0.0738	0.0747	0.0711	0.0766	0.0676	0.0754	0.0741
H3a	0.0708	0.0955	0.0748	0.0705	0.0666	0.0647	0.0683
H3b	0.0755	0.0552	0.0615	0.0755	0.0711	0.0863	0.0835
H3c	0.0748	0.0777	0.0528	0.0568	0.0459	0.0763	0.0670
H3d	0.0537	0.0777	0.0537	0.0542	0.0570	0.0835	0.0799
H4a	0.0633	0.0542	0.0437	0.0609	0.0704	0.0633	0.0805
H4b	0.0886	0.0944	0.0559	0.0672	0.0556	0.0732	0.0763
Factors	H2d	H3a	H3b	H3c	H3d	H4a	H4b
H1a	0.0490	0.0843	0.0879	0.0692	0.0505	0.0494	0.0944
H1b	0.0518	0.0806	0.0964	0.0921	0.0792	0.0720	0.0813

H1c	0.0741	0.0621	0.0762	0.0655	0.0799	0.0732	0.0835
H1d	0.0577	0.0598	0.0750	0.0741	0.0639	0.0864	0.0992
H2a	0.0724	0.0730	0.0774	0.0471	0.0628	0.0948	0.0963
H2b	0.0595	0.0734	0.0685	0.0850	0.0568	0.0850	0.0848
H2c	0.0697	0.0813	0.0742	0.0680	0.0570	0.0592	0.0770
H2d	0	0.0543	0.0661	0.0628	0.0583	0.0826	0.0719
H3a	0.0781	0	0.0973	0.0792	0.0676	0.0708	0.0732
H3b	0.0528	0.0857	0	0.0811	0.0921	0.0992	0.0754
H3c	0.0630	0.0679	0.0892	0	0.0736	0.0706	0.0550
H3d	0.0550	0.0706	0.0752	0.0728	0	0.0764	0.0717
H4a	0.0609	0.0473	0.0790	0.0884	0.0712	0	0.0906
H4b	0.0690	0.0641	0.0878	0.0736	0.0692	0.0748	0

The combined impact matrix was calculated as follows, as shown in Table 6.

$$T = G(1-G)^{-1}$$

Table 6. Composite impact matrix of influencing factors driving the adoption of smart construction technologies by enterprises.

Factors	H1a	H1b	H1c	H1d	H2a	H2b	H2c
H1a	0.8799	0.9866	0.8436	0.8195	0.8487	0.9241	0.9687
H1b	0.9610	0.8983	0.8458	0.8199	0.8306	0.9215	0.9754
H1c	0.9903	0.9986	0.8033	0.8597	0.8672	0.9701	1.0157
H1d	0.9652	0.9740	0.8406	0.7704	0.8586	0.9353	0.9934
H2a	0.8839	0.9008	0.7905	0.7604	0.7393	0.8815	0.9123
H2b	0.9064	0.9232	0.8101	0.7911	0.8267	0.8345	0.9325
H2c	0.9409	0.9323	0.8347	0.7993	0.8448	0.9181	0.8855
H2d	0.9220	0.9354	0.8174	0.8093	0.8228	0.9080	0.9443
H3a	0.9817	1.0168	0.8754	0.8582	0.8765	0.9600	1.0030
H3b	1.0003	0.9975	0.8769	0.8753	0.8953	0.9943	1.0320
H3c	0.8940	0.9092	0.7763	0.7674	0.7781	0.8811	0.9086
H3d	0.8795	0.9127	0.7803	0.7681	0.7913	0.8910	0.9237
H4a	0.8798	0.8841	0.7638	0.7667	0.7957	0.8658	0.9158
H4b	0.9714	0.9899	0.8363	0.8327	0.8444	0.9418	0.9834

Factors	H2d	H3a	H3b	H3c	H3d	H4a	H4b
H1a	0.8045	0.9217	1.0548	0.9610	0.8722	0.9622	1.0515
H1b	0.8108	0.9228	1.0674	0.9865	0.9020	0.9865	1.0450
H1c	0.8548	0.9335	1.0802	0.9917	0.9281	1.0173	1.0791
H1d	0.8219	0.9107	1.0558	0.9771	0.8940	1.0063	1.0691
H2a	0.7835	0.8637	0.9908	0.8921	0.8369	0.9517	1.0002
H2b	0.7886	0.8825	1.0046	0.9446	0.8495	0.9628	1.0109
H2c	0.8097	0.9037	1.0249	0.9433	0.8624	0.9547	1.0199
H2d	0.7349	0.8694	1.0059	0.9289	0.8538	0.9643	1.0046
H3a	0.8608	0.8778	1.1023	1.0068	0.9211	1.0190	1.0729
H3b	0.8526	0.9715	1.0346	1.0244	0.9562	1.0596	1.0924
H3c	0.7690	0.8548	0.9949	0.8459	0.8409	0.9240	0.9573
H3d	0.7660	0.8605	0.9870	0.9132	0.7759	0.9332	0.9761
H4a	0.7640	0.8322	0.9809	0.9174	0.8345	0.8539	0.9834
H4b	0.8302	0.9138	1.0657	0.9761	0.8978	0.9950	0.9767

The process for calculating the degree of influence and the degree of being influenced is as follows.

$$e_i = \sum_{i=1}^{n} t_{ij}, i = 1,2,\ldots n$$

$$f_i = \sum_{j=1}^{n} t_{ij}, i = 1,2,\ldots n$$

t_{ij} is the influence value of element i on element j in the integrated image matrix T; f_i is the degree of influence of element i; e_i is the degree of element i being influenced.

The degree of influence is the sum of the rows in which the factors are located and is the combined influence of the corresponding factor in that row on all other factors. Influencedness is the sum of the columns in which each factor is located and is the combined influence of the factors in that column on all other factors.

The process for calculating centrality and causality is as follows.

$$M_i = f_i + e_i, i = 1,2,\ldots n$$

$$N_i = f_i - e_i, i = 1,2,\ldots n$$

Centrality is expressed as the position of the factor in the system and the strength of its influence and is the sum of the degree of influence and the degree of being influenced. The degree of cause is the difference between the degree of influence and the degree of being influenced, representing the causal relationship between the influencing factors. If the degree of cause is greater than 0, it is the causal factor, and if it is less than 0, it is the effect factor. The degree of influence, degree of being influenced, degree of centrality and degree of cause are calculated, as shown in Table 7. And accordingly, make the causality diagram of influence factors as shown in Fig 3.

Table 7. Indicators of the comprehensive impact matrix analysis of the factors driving the adoption of smart construction technologies by enterprises.

Projects	Degree of impact	Degree of being influenced	Centrality	Degree of cause
H1a	12.8990	13.0565	25.9555	-0.1575
H1b	12.9733	13.2595	26.2329	-0.2862
H1c	13.3896	11.4950	24.8846	1.8946
H1d	13.0722	11.2981	24.3702	1.7741
H2a	12.1876	11.6199	23.8075	0.5676
H2b	12.4678	12.8271	25.2950	-0.3593
H2c	12.6743	13.3943	26.0686	-0.7200
H2d	12.5210	11.2514	23.7724	1.2696
H3a	13.4321	12.5185	25.9507	0.9136
H3b	13.6629	14.4496	28.1124	-0.7867
H3c	12.1016	13.3089	25.4105	-1.2074
H3d	12.1586	12.2251	24.3838	-0.0665
H4a	12.0381	13.5905	25.6285	-1.5524
H4b	13.0553	14.3389	27.3942	-1.2837

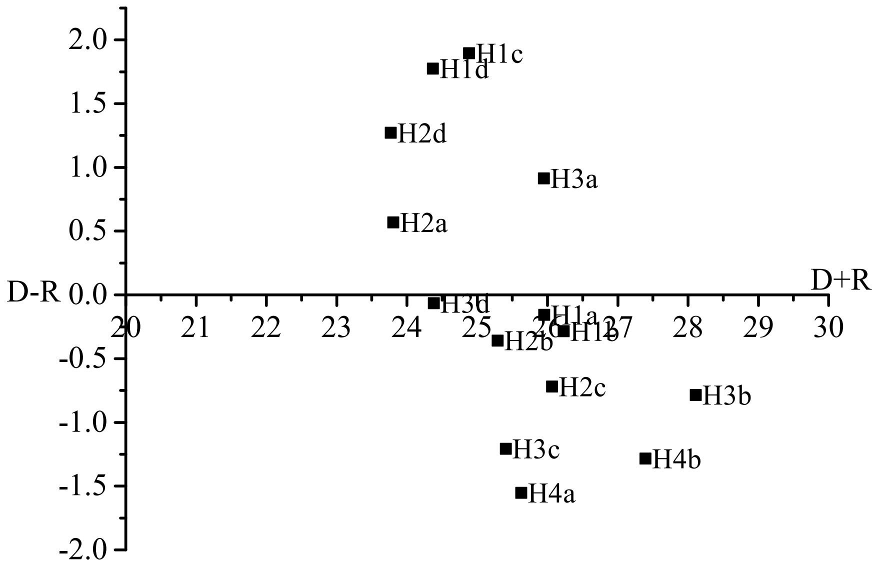

Figure 3. Causal relationship of driving influences.

The integrated impact matrix was transformed into an overall impact matrix, and based on expert advice and several trial calculations, a threshold value of λ = 1.01 was determined, and the process for calculating the reachable matrix was as follows.

$$k_{ij} = \begin{cases} 1, h_{ij} \geq \lambda \\ 0, h_{ij} \leq \lambda \end{cases} (\mathrm{i,j} = 1,2 \ldots \mathrm{n}), \mathrm{K} = [k_{ij}]_{n\times n}$$

λ is the threshold value, the larger the value of λ the more obvious it is for structural simplification, in the actual analysis the size of λ needs to be determined specifically according to the complexity of the system; kij is the value of the association between factor i and element j. The obtained reachable matrix is shown in Table 8.

Table 8. Reachable matrix.

Factors	H1a	H1b	H1c	H1d	H2a	H2b	H2c
H1a	0	0	0	0	0	0	0
H1b	0	0	0	0	0	0	0
H1c	0	0	0	0	0	0	1
H1d	0	0	0	0	0	0	0
H2a	0	0	0	0	0	0	0
H2b	0	0	0	0	0	0	0
H2c	0	0	0	0	0	0	0
H2d	0	0	0	0	0	0	0
H3a	0	1	0	0	0	0	0
H3b	0	0	0	0	0	0	1
H3c	0	0	0	0	0	0	0
H3d	0	0	0	0	0	0	0
H4a	0	0	0	0	0	0	0
H4b	0	0	0	0	0	0	0

Factors	H2d	H3a	H3b	H3c	H3d	H4a	H4b
H1a	0	0	1	0	0	0	1
H1b	0	0	1	0	0	0	1
H1c	0	0	1	0	0	1	1
H1d	0	0	1	0	0	0	1
H2a	0	0	0	0	0	0	0
H2b	0	0	0	0	0	0	1
H2c	0	0	1	0	0	0	1
H2d	0	0	0	0	0	0	0
H3a	0	0	1	0	0	1	1
H3b	0	0	1	1	0	1	1
H3c	0	0	0	0	0	0	0
H3d	0	0	0	0	0	0	0
H4a	0	0	0	0	0	0	0
H4b	0	0	1	0	0	0	0

The process for creating antecedent and reachable sets is as follows.

$A(s_i) = \{s_j \in S | k_{ij} = 1\}$

$R(s_i) = \{s_j \in S | k_{ji} = 1\}$

$A(s_i)$ is the set of antecedents, the set of elements corresponding to all rows in the S_ith column of the reachable matrix whose elements are 1.

$R(s_i)$ is the reachable set, the set of elements corresponding to all columns in the S_ith row of the reachable matrix whose elements are 1.

If $B(s_i) = \{s_j \in S | R(s_i) \cap A(s_i) = A(s_i)\}$, then $B(s_i)$ is the highest level factor set. The antecedent set, the reachable set and their intersection sets are shown in Table 9.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 23 November 2022 doi:10.20944/preprints202211.0438.v1

Table 9. Predecessor sets and reachable sets and their intersections.

Factors	Preliminary review A(s_i)	Accessible collection R(s_i)	Intersections B(s_i)
H1a	1 7 10 11 13 14	1	1
H1b	2 7 10 11 13 14	2 9	2
H1c	3 7 10 11 13 14	3	3
H1d	4 7 10 11 13 14	4	4
H2a	5	5	5
H2b	6 7 10 11 13 14	6	6
H2c	7 10 11 13 14	1 2 3 4 6 7 9 10 14	7 10 14
H2d	8	8	8
H3a	2 7 9 10 11 13 14	9	9
H3b	7 10 11 13 14	1 2 3 4 6 7 9 10 14	7 10 14
H3c	11	1 2 3 4 6 7 9 10 11 14	11
H3d	12	12	12
H4a	13	1 2 3 4 6 7 9 10 13 14	13
H4b	7 10 11 13 14	1 2 3 4 6 7 9 10 14	7 10 14

The hierarchy of influencing factors driving the adoption of intelligent construction technologies by enterprises is constructed according to the reachable matrix as shown in Table 10, and the ISM model diagram of influencing factors driving the adoption of intelligent construction technologies by enterprises is shown in Fig 4.

Table 10. Hierarchy table.

Levels	Elemental set	Level of impact
L1	H2a, H2d, H3a, H3d	Surface impact
L2	H1a, H1b, H1c, H1d, H2b	Mid-level impact
L3	H2c, H3b, H4b	Deep Impact
L4	H3c, H4a	Root Images

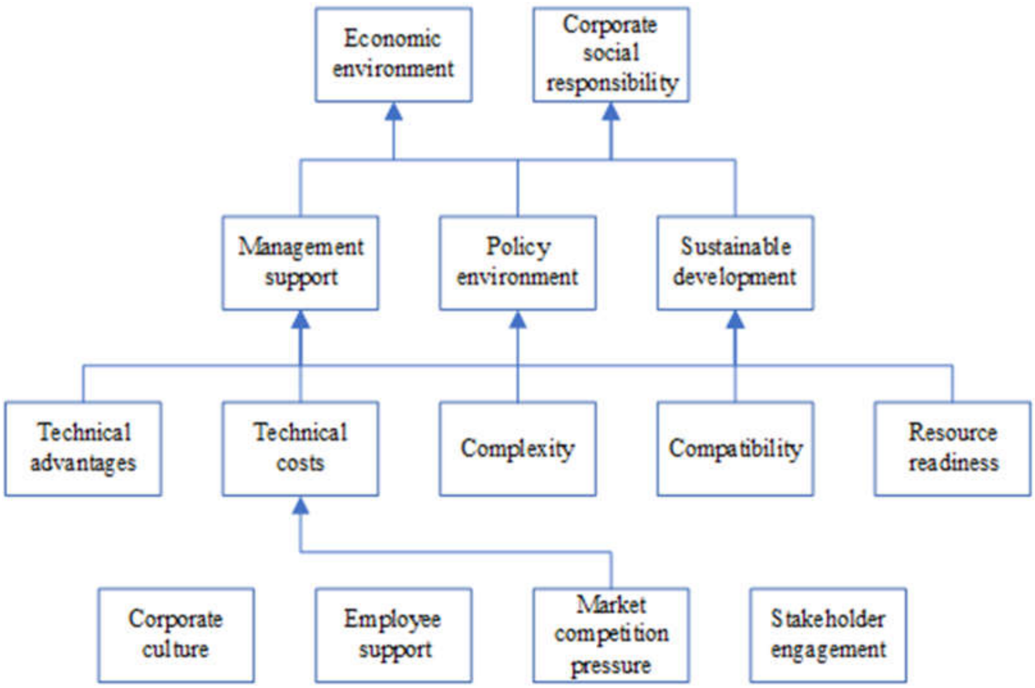

Figure 4. ISM Hierarchy Model of Influencing Factors Driving Enterprise Adoption of Smart Construction Technologies.

5. Research results

According to the Fuzzy-DEMATEL-ISM calculations, the 14 hypotheses of the four dimensions of technology-organization-environment-society proposed in this study based on the TOE framework all have varying degrees of driving influence and the hypotheses are largely valid. The specific findings of the study are as follows.

1. Policy environment (H3b), competitive market pressure (H3a), complexity (H1c), compatibility (H1d), and sustainability (H4b) have the highest degree of influence on other factors in the whole system of influencing factors, with the degree of influence being 13.6629, 13.4321, 13.3896, 13.0722, and 13.0553 respectively. policy environment the policy environment (H3b), sustainable development (H4b), corporate social responsibility (H4a), senior management support (H2c), and economic environment (H3c) were the five most influenced factors, with the following levels of influence: 14.4496, 14.3389, 13.5905, 13.3943 and 13.3089 respectively. This indicates that these five factors are the most influenced by other factors.

2. Policy environment (H3b), sustainability (H4b), cost of technology (H1b), senior management support (H2c), and technological advantage (H1a) were the most significant in the system of influencing factors driving the adoption of smart construction technologies by firms, with D+C of 28.1124, 27.3942, 26.2329, 26.0686, and 25.9555 respectively, Employee support (H2d), corporate culture (H2a), compatibility (H1d), stakeholder involvement (H3d), and complexity (H1c) were the five factors with the lowest D+C of 23.7724, 23.8075, 24.3702, 24.3838, and 24.8846, respectively, indicating a relatively weak influence in the system.

3. positive D-C values for complexity (H1c), compatibility (H1d), employee support (H2d), competitive market pressure (H3a), and corporate culture (H2a) indicate that these factors are causal factors and have an active influence on firms' adoption of smart construction technologies and are less influenced by other factors; stakeholder involvement (H3d), technological advantage (H1a), technology cost (H1b), resource readiness (H2b), senior management support (H2c), policy environment (H3b), economic environment (H3c), sustainability (H4b), and corporate social responsibility (H4a) have negative D-C values, meaning that they are outcome factors that are influenced by other factors and thus drive the adoption of smart building technologies.

4. A hierarchy based on the Interpretive Structural Model (ISM) classifies the influencing factors affecting the adoption of intelligent construction technologies by companies into four levels. The first level of influence is the surface level, which includes four factors: corporate culture (H2a), resource readiness (H2b), competitive market pressure (H3a), and stakeholder involvement (H3d). The second level of influence is the middle level, which consists of five factors: technological advantage (H1a), technological cost (H1b), complexity (H1c), compatibility (H1d), and resource readiness (H2b). The third level is the deeper level of influence, which consists of three factors: top management support (H2c), economic environment (H3c), and sustainability (H4b). The fourth level is the root cause, which includes two factors: economic environment (H3c) and corporate social responsibility (H4a).

5. Of the four influencing factors of the technology dimension including technology advantage (H1a), technology cost (H1b), complexity (H1c), and compatibility (H1d), two factors have positive D-C and are causal factors; two have a greater degree of influence, which indicates that the influencing factors of the technology dimension have the most significant degree of influence on driving the adoption of smart construction technologies by highway construction firms, which is in line with Owusu-Manu et al. Berst et al. Yang et al. Dewi et al. have found the same [9, 88-90].

6. The organizational dimensions of top management support (H2c) and employee support (H2d) have a high degree of influence on the system of factors driving the adoption of smart construction technology in highway construction enterprises, which means that the process of adopting smart construction technology in enterprises should focus on the training of enterprise personnel, especially when adopting innovative technologies,

the degree of personnel's understanding of the technology and the precise cooperation during operations can make The adoption of smart construction technology by companies is easier.

7. Among the environmental dimensions, competitive market pressure (H3a) and policy environment (H3b) have a significant impact on the adoption of intelligent construction technologies and other factors in the system. This suggests that the environmental dimension is a key consideration in the adoption of intelligent construction technologies.

8. This study innovatively presents the social dimension influencing factors, including corporate social responsibility (H4a) and sustainability (H4b). According to the results of the analysis, the degree to which sustainability (H4b) influences other factors in the system and drives the adoption of smart construction technologies is highly significant. Corporate social responsibility (H4a), on the other hand, belongs to the root influence level of the ISM hierarchy model. This suggests that the social-level influences proposed in this paper are important in the system of driving influences on the adoption of smart construction technologies by highway construction firms and provide empirical evidence and new research ideas for subsequent scholars.

6. Discussions and Conclusion

Based on national and international literature, this study first summarizes the multi-faceted nature of the motorway construction field. Then, to benefit from the rich theories developed in different knowledge systems, 25 experts, scholars, and professionals in the field were invited to participate in the study through expert interviews, summarizing and refining the driving influences in four dimensions: technical, organizational, environmental and social, and establishing the TOSE framework based on the TOE framework, which to some extent increases and expands the adoption of the intelligent construction field research in This adds to and extends the experience of applying the TOE framework to research in the field of intelligent construction. Although the number of experts involved was 25, which may be a limitation of this study. However, the focus of this study was on experienced experts in the field rather than the number of experts. Finally, applying the Fuzzy-DEMATEL-ISM method to analyze the results of the expert scoring, the results of the study show that the hypothesis of the 14 influencing factors holds true and that each factor has a driving influence on the adoption of smart construction technology by highway construction companies in China to varying degrees. Among them, the degree of influence of the technology dimension influencing factors is the strongest, coinciding with some of the previous research findings, which also laterally demonstrates the authenticity and reliability of the results of this study.

Because of the above findings, the results of this study will help the decision makers and managers of highway construction enterprises to understand and grasp the various influencing factors of the adoption of intelligent construction technology in their enterprises in future practice, which is an important reference value for the decision making of highway construction enterprises in the application of intelligent construction technology. In addition, this study has implications for the adoption of intelligent construction technology in other areas of the construction industry. Although this study focuses on highway construction companies, which is still different from other companies in the construction industry, the influencing factors presented in this paper can be added to and subtracted from future discussions to fill in the research on the influencing factors of other companies in the adoption of smart construction technology. To further develop and promote the application of smart construction technology in the construction industry, to achieve sustainable development of smart construction in buildings and to improve the intelligence of buildings, this study recommends that companies conduct training and learning about smart construction technology.

Acknowledgments: The authors thank the survey participants for taking the time to complete the interviews, and the experts and scholars for their suggestions for the indicator system of this study.

At the same time, the survey participants are aware of and agree to the content and use of this research. Methodology: Zhou Zhichao; Supervision: Su Yikun; Writing – original draft: Zhou Zhichao; Writing – review & editing: Zheng Zhizhe, Wang Yilin.

References

1. Zhang Zhuo-qun. The Great Significance and Brilliant Achievements of the CPC's Leadership in the Construction of Urban Mobile Space are the Construction of Railways, Highways and New Infrastructure, Urban and Environmental Studies, (03) (2021)12-15.
2. Si Daoguang. Research on Technical Characterization and Development of Chinese Eastern Railway Early Modern Buildings, Harbin Institute of Technology, 2020.
3. Wang X C, Klemeš J J, Dong X, et al. Air pollution terrain nexus: A review considering energy generation and consumption, Renewable and Sustainable Energy Reviews. (105) (2019) 71-85.
4. Baleta J, Mikulčić H, Klemeš J J, et al. Integration of energy, water and environmental systems for a sustainable development, Journal of cleaner production. (215) (2019) 1424-1436.
5. Oyewole M O, Araloyin F M, Oyewole P T. Residents' awareness and aspiration for smart building features: the case of okota, Lagos, Nigeria, Nigerian Journal of Environmental Sciences and Technology (NIJEST) Vol. 3(1) (2019) 30-40.
6. Gyamfi S, Diawuo F A, Kumi E N, et al. The energy efficiency situation in Ghana, Renewable and Sustainable Energy Reviews. (82) (2018) 1415-1423.
7. Ahiabor, G. "Smart buildings are coming: but who holds the keys?" (2019).
8. Chawla, V., et al. "The sustainable project management: A review and future possibilities." Journal of Project Management. 3 (3) (2018) 157-170.
9. Owusu-Manu, De-Graft, et al. "Factors influencing the decision to adopt Smart Building Technology (SBT) in developing countries." African Journal of Science, Technology, Innovation and Development .14 (3) (2022) 790-800.
10. Ghansah, Frank Ato, et al. "Assessing the level of awareness of smart building technologies (SBTs) in the developing countries." Journal of Engineering, Design and Technology. 2021.
11. Duan, Rong Rong. "Research on Information Management of Traffic Highway Construction Safety Based on BIM Technology." IOP Conference Series: Earth and Environmental Science. Vol. 638. No. 1. IOP Publishing. 2021.
12. Wan, Fang, and Ming Li. "Research on Coordinated Processing Scheme of Intelligent Transportation under Big Data Structure." 2020 5th International Conference on Electromechanical Control Technology and Transportation (ICECTT). IEEE. 2020.
13. He, Fangcheng. "Intelligent video surveillance technology in intelligent transportation." Journal of Advanced Transportation 2020 (2020).
14. Ghosh, Arka, David John Edwards, and M. Reza Hosseini. "Patterns and trends in Internet of Things (IoT) research: future applications in the construction industry." Engineering, Construction and Architectural Management. 2020.
15. Keyvanfar, Ali, and Arezou Shafaghat. "Emerging Dimensions of Unmanned Aerial Vehicle's (UAV) 3D Reconstruction Modeling and Photogrammetry in Architecture and Construction Management." ACE: Arquitectura, Ciudad y Entorno. 2022.
16. Maruping, Likoebe M., et al. "Going beyond intention: Integrating behavioral expectation into the unified theory of acceptance and use of technology." Journal of the Association for Information Science and Technology. 68 (3) (2017) 623-637.
17. Venkatesh, Viswanath, James YL Thong, and Xin Xu. "Consumer acceptance and use of information technology: extending the unified theory of acceptance and use of technology." MIS quarterly (2012): 157-178.
18. Tornatzky, Louis G., and Katherine J. Klein. "Innovation characteristics and innovation adoption-implementation: A meta-analysis of findings." IEEE Transactions on engineering management. (1) (1982) 28-45.
19. Chen Yilin. Research on the Influencing Mechanism of Adoption and Innovation Support of BIM Technology in Chinese Construction Industry, Tianjin University of Technology. 2019.
20. Al Hadwer, Ali, et al. "A systematic review of organizational factors impacting cloud-based technology adoption using Technology-organization-environment framework." Internet of Things. (15) (2021): 100407.
21. Sun, Shiwei, Dianne J. Hall, and Casey G. Cegielski. "Organizational intention to adopt big data in the B2B context: An integrated view." Industrial Marketing Management. (86) (2020) 109-121.
22. Ehie, Ike C., and Michael A. Chilton. "Understanding the influence of IT/OT Convergence on the adoption of Internet of Things (IoT) in manufacturing organizations: An empirical investigation." (2020).
23. Fernando, Yudi, Nor Hazwani Mohd Rozuar, and Fineke Mergeresa. "The blockchain-enabled technology and carbon performance: Insights from early adopters." Technology in Society. (64) (2021) 101507.
24. Agarwal, Ritu, and Jayesh Prasad. "The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies." Decision sciences. 28 (3) (1997) 557-582.
25. Premkumar, G., and Margaret Roberts. "Adoption of new information technologies in rural small businesses." Omega. 27 (4) (1999) 467-484.
26. LI Lu. Research on influencing factors of Internet of Things RFID technology adoption in building construction enterprises, Shenzhen: Shenzhen University. 2020.

27. Brown, Irwin, and John Russell. "Radio frequency identification technology: An exploratory study on adoption in the South African retail sector." International journal of information management. 27 (4) (2007) 250-265.
28. Wamba, Samuel Fosso, et al. "RFID Adoption Issues: Analysis of Organizational Benefits & Risks." 2009.
29. Wu, Jen-Her, and Shu-Ching Wang. "What drives mobile commerce?: An empirical evaluation of the revised technology acceptance model." Information & management. 42 (5) (2005) 719-729.
30. Zhang, Ruixue, et al. "Factors influencing BIM adoption for construction enterprises in China." Advances in Civil Engineering 2020 (2020).
31. Guide, Smart Cities Readiness. "The planning manual for building tomorrow's cities today.(2015)." Smart Cities Council. 7 (2017).
32. Dewi, Made Ayu Aristyana, et al. "Smart city readiness model based on technology-organization-environment (TOE) framework and its effect on adoption decision." Twenty-Second Pacific Asia Conference on Information Systems, Japan. 2018.
33. Yang, Zhaojun, et al. "Understanding SaaS adoption from the perspective of organizational users: A tripod readiness model." Computers in Human Behavior. (45) (2015) 254-264.
34. Sun, Chengshuang, et al. "A literature review of the factors limiting the application of BIM in the construction industry." Technological and Economic Development of Economy. 23 (5) (2017): 764-779.
35. Mittal, Sameer, et al. "Smart manufacturing: Characteristics, technologies and enabling factors." Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture. 233 (5) (2019): 1342-1361.
36. Nnaji, Chukwuma, et al. "Development and application of safety technology adoption decision-making tool." Journal of Construction Engineering and Management. 146 (4) (2020) 04020028.
37. San Martín, Héctor, and Ángel Herrero. "Influence of the user's psychological factors on the online purchase intention in rural tourism: Integrating innovativeness to the UTAUT framework." Tourism management. 33 (2) (2012) 341-350.
38. LI Pengfei. Research on the willingness of small and medium-sized building construction enterprises to adopt BIM technology, Ji: Shandong Construction University. 2019.
39. Thong, James YL. "An integrated model of information systems adoption in small businesses." Journal of management information systems. 15 (4) (1999) 187-214.
40. LIU Shuang. Research on the influencing factors of BIM technology adopted by construction enterprises, Shenzhen: Shenzhen University. China, 2014, in Chinese.
41. Porter, Michael. "Competitive Strategy, New York Free Press." Porter Competitive Strategy1980 (1980).
42. Hannan, Michael T., and John Freeman. "The population ecology of organizations." American journal of sociology. 82 (5) (1977) 929-964.
43. Lee, Cheon-Pyo, and Jung P. Shim. "An exploratory study of radio frequency identification (RFID) adoption in the healthcare industry." European Journal of Information Systems. 16 (6) (2007): 712-724.
44. Xin, Mingdi, and Natalia Levina. "Software-as-a-service model: Elaborating client-side adoption factors." Proceedings of the 29th International Conference on Information Systems, R. Boland, M. Limayem, B. Pentland,(eds), Paris, France. 2008.
45. Ahuja, Ritu, et al. "Factors influencing BIM adoption in emerging markets–the case of India." International Journal of Construction Management. 20 (1) (2020) 65-76.
46. Eisenberger, Robert, et al. "Perceived organizational support." Journal of Applied psychology. 71 (3) (1986) 500.
47. McMillan, Rita Clay. Customer satisfaction and organizational support for service providers. University of Florida. 1997.
48. Lin, Hsiu-Fen. "An investigation into the effects of IS quality and top management support on ERP system usage." Total Quality Management. 21 (3) (2010) 335-349.
49. Yang, Zhaojun, et al. "Understanding SaaS adoption from the perspective of organizational users: A tripod readiness model." Computers in Human Behavior. 45 (2015) 254-264.
50. Sucahyo, Yudho Giri, et al. "Knowledge management adoption and its impact on organizational learning and non-financial performance." Knowledge Management & E-Learning: An International Journal. 8 (2) (2016) 387-413.
51. Wang, Yi-Shun, et al. "Factors affecting hotels' adoption of mobile reservation systems: A technology-organization-environment framework." Tourism Management. 53 (2016) 163-172.
52. Karahanna, Elena, Ritu Agarwal, and Corey M. Angst. "Reconceptualizing compatibility beliefs in technology acceptance research." MIS quarterly. (2006) 781-804.
53. Shibl R., Lawley M., Debuse J. Factors influencing decision support system acceptance[J]. Decision Support Systems, 2013, 54(2): 953-961.
54. Geng Biao. Research on Influencing Factors of BIM Technology Adoption in Construction Enterprises, Chongqing: Chongqing University. China, 2018, in Chinese.
55. Wu, A. Q., and S. H. Jia. "The research framework of foreign enterprise growth theory." Foreign Econ. Manag. 2 (2002) 2-5.
56. Janz, Brian D., Mitzi G. Pitts, and Robert F. Otondo. "Information systems and health care-II: Back to the future with RFID: Lessons learned-some old, some new." Communications of the Association for Information Systems. 15 (1) (2005) 7.
57. BENBASAT, I., P. CHWELOS, and A. DEXTER. "Research Report: Empirical Test of an EDI Adoption Model-May 2000." (2000).
58. Enders, Anselm, et al. "Loss of the pro-apoptotic BH3-only Bcl-2 family member Bim inhibits BCR stimulation–induced apoptosis and deletion of autoreactive B cells." The Journal of experimental medicine. 198 (7) (2003) 1119-1126.
59. Neirotti, Paolo, Emilio Paolucci, and Elisabetta Raguseo. "Is it all about size? Comparing organisational and environmental antecedents of IT assimilation in small and medium-sized enterprises." International Journal of Technology Management. 61 (1) (2013) 82-108.

60. Huang, Xiao-xing, et al. "The relationships between regulatory and customer pressure, green organizational responses, and green innovation performance." Journal of Cleaner Production. 112 (2016): 3423-3433.
61. Won, Jongsung, et al. "Where to focus for successful adoption of building information modeling within organization." Journal of construction engineering and management. 139 (11) (2013): 04013014.
62. Robinson, Les. "A summary of diffusion of innovations." (2009).
63. Azhar, S. "Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry, Leadership and Management in Engineering. 11 (3) (2011) 241-252.
64. M. E. Obiegbu and F. O. Ezeokoli, "Building information modeling, a panacea for timely project delivery," in Proceedings of the River State Quantity Surveyor's Week Holding at the Arena Event Centre, Port Harcourt, Nigeria. 2014.
65. Memon, Aftab Hameed, et al. "BIM in Malaysian construction industry: status, advantages, barriers and strategies to enhance the implementation level." Research Journal of Applied Sciences, Engineering and Technology. 8 (5) (2014): 606-614.
66. Balocco, Raffaello, Riccardo Mogre, and Giovanni Toletti. "Mobile internet and SMEs: a focus on the adoption." Industrial Management & Data Systems. 2009.
67. J. Li, Hinder Research of BIM Technology Diffusion, Harbin Institute of Technology, Harbin, China, 2014, in Chinese.
68. Y. Li, BIM Application in the Building Construction Enterprise, Wuhan University ofScience and Technology, Wuhan, China, 2015, in Chinese.
69. Hosseini, M. Reza, et al. "Barriers to adoption of building information modeling (BIM) in Iran: Preliminary results." The 6th International Conference on Engineering, Project, and Production Management (EPPM2015), Gold Coast, Australia. 2015.
70. Y. Wang, BIM Technology Adoption Model and Implication Research, Harbin Institute of Technology, Harbin, China, 2013, in Chinese.
71. Sun, Shiwei, Dianne J. Hall, and Casey G. Cegielski. "Organizational intention to adopt big data in the B2B context: An integrated view." Industrial Marketing Management. 86 (2020) 109-121.
72. Lam, Patrick TI, and Wenjing Yang. "Factors influencing the consideration of Public-Private Partnerships (PPP) for smart city projects: Evidence from Hong Kong." Cities. 99 (2020): 102606.
73. Topal, Hasan Fehmi, Dexter VL Hunt, and Christopher DF Rogers. "Urban Sustainability and Smartness Understanding (USSU)—Identifying influencing factors: A systematic review." Sustainability. 12 (11) (2020): 4682.
74. Badi, Sulafa, et al. "Technological, organisational and environmental determinants of smart contracts adoption: UK construction sector viewpoint." Construction Management and Economics. 39 (1) (2021): 36-54.
75. Kim, Seong Ho. "A Study on Relationship of TOE, Blockchain Technology, and Logistics Performance in Korean Logistics' Firms." Journal of the Korea Society of Computer and Information. 25 (5) (2020): 217-227.
76. Ullah, Fahim, et al. "Risk management in sustainable smart cities governance: A TOE framework." Technological Forecasting and Social Change. 167 (2021): 120743.
77. Son, Hyojoo, Sungwook Lee, and Changwan Kim. "What drives the adoption of building information modeling in design organizations? An empirical investigation of the antecedents affecting architects' behavioral intentions." Automation in construction. 49 (2015): 92-99.
78. Premkumar, G., K. Ramamurthy, and M. Crum. "Determinants of EDI adoption in the transportation industry." European Journal of Information Systems. 6 (2) (1997): 107-121.
79. Bruneau, Michel, et al. "A framework to quantitatively assess and enhance the seismic resilience of communities." Earthquake spectra. 19 (4) (2003) 733-752.
80. Lau, ChungMing, Yuan Lu, and Qiang Liang. "Corporate social responsibility in China: A corporate governance approach." Journal of Business Ethics. 136 (1) (2016) 73-87.
81. Liao, Lin, Teng Philip Lin, and Yuyu Zhang. "Corporate board and corporate social responsibility assurance: Evidence from China." Journal of Business Ethics. 150 (1) (2018) 211-225.
82. Baumgartner, Rupert J., and Romana Rauter. "Strategic perspectives of corporate sustainability management to develop a sustainable organization." Journal of Cleaner Production. 140 (2017) 81-92.
83. Bocken, Nancy MP, et al. "A literature and practice review to develop sustainable business model archetypes." Journal of cleaner production. 65 (2014) 42-56.
84. Lozano, Rodrigo. "A holistic perspective on corporate sustainability drivers." Corporate social responsibility and environmental management. 22 (1) (2015) 32-44.
85. Badi, Sulafa, et al. "Technological, organisational and environmental determinants of smart contracts adoption: UK construction sector viewpoint." Construction Management and Economics. 39 (1) (2021) 36-54.
86. Lin, Ru-Jen. "Using fuzzy DEMATEL to evaluate the green supply chain management practices." Journal of cleaner production. 40 (2013) 32-39.
87. Opricovic, Serafim, and Gwo-Hshiung Tzeng. "Defuzzification within a multicriteria decision model." International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems. 11 (05) (2003) 635-652.
88. Berst, J. "The planning manual for building tomorrow's cities today." Seattle: Smart City Council. 2013.
89. Yang, Zhaojun, et al. "Understanding SaaS adoption from the perspective of organizational users: A tripod readiness model." Computers in Human Behavior. 45 (2015) 254-264.
90. Dewi, Made Ayu Aristyana, et al. "Smart city readiness model based on technology-organization-environment (TOE) framework and its effect on adoption decision." Twenty-Second Pacific Asia Conference on Information Systems, Japan. 2018.