

Research Article

Exploring the Role of Lightweight AI Tools in driving Digital Transformation among Construction SMEs: A TOE Framework Perspective

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Abstract

This theoretical research discusses the potential for small and medium-sized enterprises (SMEs) in the Chinese construction sector, to break down pervasive barriers like data silos and funding constraints with the implementation of lightweight artificial intelligence (AI) technology. Based on the Technology–Organisation–Environment (TOE) theory, this research investigates three determinants of the digital transformation success, which are technological readiness, data management capability and government support, while this research proposes a research model in which the variables directly shape the success of digital transformation among construction SMEs in the capital city, Beijing. The measurement items for each construct are designed with the intention that they should be statistically validated for reliability and construct validity in actual empirical testing. The proposed framework contributes both theory and practice with the provision of an integrative understanding of the internal and external environmental determinants motivating AI-driven digital transformation. The research also provides practical suggestions for SME managers and policy planners with the aim of raising the level of digital readiness, optimising the use of data, and enhancing policy interventions in the promotion of sustainable digital innovation in the construction sector.

Keywords

Lightweight artificial intelligence (AI), Digital transformation, Technological readiness, Data management capability, Government support

1. Introduction

The global construction business is undergoing a historical digital revolution propelled by the

adoption of new technologies such as artificial intelligence (AI), building information modeling (BIM), and the Internet of Things (IoT). Technology is revolutionising project management, quality control, and operational efficiency across the industry. Small and medium-sized enterprises (SMEs) are under equipped to take full advantage of the shift due to the fragmentation of data, a shortage of technical capabilities, and finance challenges (Yu & Liu, 2022). In China, the digital transformation is a result of the nation's policy of achieving high-quality and sustainable growth where the construction industry has been pinpointed as a model industry for delivering modernisation and innovation to the economy (Xiang et al., 2024). Facing such a situation, construction SME firms in the city of Beijing which a very tech-savvy and policy-sensitive city in China, are front-runners in the adoption of lightweight and affordable AI solutions for driving productivity and project performance.

Digital transformation is the overall process of integrating digital technologies for enhanced business models, work processes, and organisational culture. Digitalisation for SMEs has the potential to boost transparency, collaboration, and decision-making but remains constrained by cost inhibitions and a shortage of human expertise (Yu & Liu, 2022). Lightweight AI tools that are defined by light computation demand, module-level design, and easy integration offer a realistic way for SMEs to digitalise their processes without considerable investment in infrastructure. With increased complexity in AI models, the implementation in low resource devices like smartphones, IoT sensors, and edge devices demands specific lightweight AI tools. Such tools and methodologies can limit computational, memory, and energy usage while ensuring excellent performance and facilitate wider implementation in real-world resource-limited settings. Lightweight CNNs and federated learning facilitate mobile phones, sensors, and embedded system real-time AI and applications ranging from health tracking to smart farming (Qi et al., 2025). In the construction industry, the tools have the potential to automate the process of data capture on the construction site, defect identification, and acceptance reporting and thereby reduce the inaccuracy and manual workload (Xiang et al., 2024).

The Technology–Organisation–Environment (TOE) framework (Tornatzky & Fleischer, 1990) offers a well-established theoretical lens for exploring organisation-level technology adoption determinants. It denotes that digital transformation takes place with technology readiness, organisation capabilities, and environmental conditions are jointly favorable. It highlights three key factors which determine digital transformation in construction SMEs: technological readiness (technology context), capability for data management (organisational context), and government support (environmental context). This framework facilitates a complete understanding of the internal and external factors affecting the deployment of lightweight AI tools and the successful implementation of digital transformation strategies in the construction sector. In the case of construction SMEs, access to appropriate digital infrastructure and the perceived ease of use of AI tools are associated with technology readiness, while internal data management capabilities and resource allocation are

associated with organisational capabilities. For environmental factors, policy support and institutional mechanisms for a city like Beijing are key motivators for the investment of SMEs in digital innovation. Under the direction of the TOE perspective, this research conceptualises how the adoption of lightweight AI could accelerate the digital transformation of construction SMEs and add theoretical contribution and practitioner insights for industry players and policy planners.

2. Literature review

Digital Transformation Success is the level to which a firm successfully embraces digital technologies so that operational efficiency increases, decisions are better informed, projects have improved outcomes, and its processes are aligned in a way that gives sustained business performance. Empirical work states that for Chinese SMEs in general, higher levels of digital transformation are strongly associated with the improvement of firm performance, profitability, and organisational capabilities (Teng et al., 2022). SME digital transformation encompasses the adoption of new tools together with upgrade of skills, strategic alignment, and digital culture (Yu & Liu, 2022). The advantages may be reduction of the costs, projects complete quicker, quality control improvements and competitiveness for markets where customers demand digitally enabled practices. Digital Transformation enhances operational efficiency, innovation, and firm performance such that the product and process innovation moderate these advantages (Weritz et al., 2024), it ensures the sustainability of the practices, cost reduction, and improved reputation when done together with active stakeholders' engagement (Martínez-Peláez et al., 2023).

2.1. Technological readiness

Technological Readiness refers to the SME's infrastructure, access to the right digital tools, its utilisation, and familiarity or ease of utilisation. It is a leading driver for the utilisation of lightweight AI tools. Studies show that SMEs that have higher digital infrastructure quality, higher security for their information technology infrastructure, and higher perceived digital technology utilisation ease are significantly more likely to experience stronger digital transformation effects (Teng et al., 2022). Chinese and global evidence empirically proves that technology preparedness strengthens the digital adoption-performance relationship (e.g. digital infrastructure as a key asset) (Wang et al., 2019). Recent frameworks are developed to add additional dimensions such as the society, security, legal, integration, commercialisation, and manufacturing preparedness dimensions to fill the gap in the typical TRL assessment to suit software-intensive or security-oriented projects (Jones, 2024; Salvador-Carulla et al., 2024).

2.2. Data Management capability

Data management capability encompasses the degree the firm aligns, consolidates, stores, and distributes data in the firm (presence or absence of data silos or otherwise), alongside data quality and information dissemination. Higher data management capabilities are preferable for light AI tool utilisation for process automation, defect identification, and acceptance on-site because light AI tools often require regular, pristine, and easily accessible data. While most studies have noted data constraints as a limitation, fewer empirical studies have explicitly operationalised data management capability as a variable. There is a related work that studies digital transformation in SMEs using employee digital capabilities and digital technology-aligned strategy that inevitably translates to the way data are managed (Teng et al., 2022). Data management capabilities are multi-dimensional, often covering data governance, technology infrastructure, human capabilities, organisational culture, and externality collaborations. Advanced models identify top management sponsorship, data-oriented culture, and externality collaboration for help aside from the traditional factors like data quality, security, and lifecycle management. Data management maturity models and taxonomies like the Data Management Maturity Model (DMMM) and Data Valuation Business Capability (DVBC) present formal models for the measurement and enhancement of Data management capabilities across industries (Pörtner et al., 2025; Hafner & Mira da Silva, 2024).

2.3. Government support

Government Support refers to external environmental enablers such as policies, subsidies, regulations, training, grants, or other institutional mechanisms that reduce barriers (especially funding barriers) and encourage technology adoption. In China, several studies show that public subsidies, tax incentives, and financial regulation positively influence innovation and tech adoption among SMEs (Xiang et al., 2025). For example, financing support schemes are aimed at reducing risk and easing liquidity constraints, forcing smaller firms to defer or forgo AI or digitalisation investments. Consequently, government support is important to alleviate the limitations of cost and to assist firms that may have ambition but may not have resources. Government support is conveyed in a variety of formats through direct financial assistance (grants loans and subsidies) and non-financial assistance (training consulting infrastructure) or indirectly through mechanisms such as regulations, tax relief and ecosystem. In the case of SMEs and startups, support will be offered through financial, education or consulting, and approaches will be recommended that best meet their needs (Prasannath et al., 2024).

3. Research framework

The research framework, as presented in Figure 1, integrates the Technology–Organisation–Environment (TOE) framework to explore the determinants of digital transformation success among construction SMEs. In this research, digital transformation success

serves as the dependent variable, while technological readiness, data management capability, and government support are specified as the independent variables.

Based on the content of literature review and discussion, the following hypothesis can be stated.

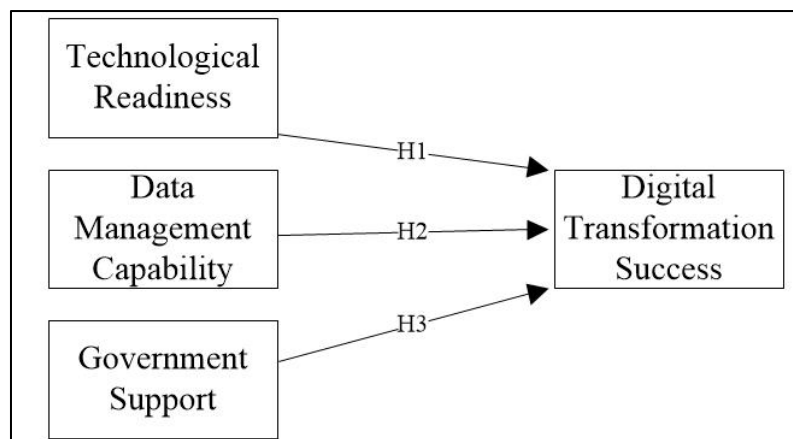
H1: Technological readiness positively influences digital transformation success in construction SMEs.

H2: Data management capability positively influences digital transformation success in construction SMEs.

H3: Government support positively influences digital transformation success in construction SMEs.

Figure 1

Theoretical framework



4. Methods

This research utilises a quantitative methodology to investigate the factors contributing to digital transformation success within small and medium-sized construction firms (SMEs) in Beijing, China. Using the Technology–Organisation–Environment (TOE) framework, this research focus on three independent variables: technology readiness, data management capability and government support, to examine their effects on digital transformation success as the dependent variable. This research uses a survey questionnaire as the primary research tool to gather primary data from participants who represented management-level employees in construction SMEs. This method was selected because it enables systematic data collection from a relatively large sample size, and it also enables statistical analysis of the hypothesised relationships among the variables in the research (Sekaran & Bougie, 2016). The structured questionnaire is developed from previously validated instruments, and some items are modified according to the context of the Chinese construction SMEs.

The research process follows a path of three major phases. First, the literature is reviewed to locate trustworthy measurement items and provide construct validity. Second, a pilot test is conducted

to develop the questionnaire and to verify clarity and comprehension. Third, data is collected from the target group of construction SMEs through an online survey and distribution by direct email. The data collected will be analysed through Partial Least Squares Structural Equation Modeling (PLS-SEM), which is appropriate for investigating complicated models that have several constructs and smaller sample sizes (Hair et al., 2021). In conclusion, this methodological approach is theoretically sound while being practically relevant and provides a thorough understanding of how lightweight AI tools and related digital technologies are contributing to the digital transformation of SMEs in the construction industry in Beijing.

4.1. Research instrument

This research utilises a structured questionnaire as the primary data collection tool for quantitative data from small and medium-sized construction SMEs in Beijing, China. All the items in the questionnaire are adopted and adapted from existing validated measurement scales from previous studies and culturally and contextualized for construction SMEs. Participants are asked to rate each statement using a five-point Likert scaled ranging from 1 = strongly disagree to 5 = strongly agree. Typically, five-point scales are reliable and valid to use with most populations and have better reliability and data richness than shorter scales. Likert scale data are ordinal in nature, meaning that the research cannot assume the distance between points is equal. However, means are commonly reported, and some researchers argue that it is more appropriate to report medians or modes unless the data has been transformed into interval data. Odd-numbered scales (such as five-point) can result in central tendency bias, where participants frequently select the neutral option, while even-numbered scales (four-point) may compel a choice and lead to increased bias (Kusmaryono & Wijayanti, 2022).

Technological readiness refers to items relating to an organisation's technological infrastructure, networking literacy, and all necessary systems being compatible. Technology readiness is conceived under the concepts of technology maturity and implementation capability proposed by researchers (Jones, 2024; Salvador-Carulla et al., 2024). Data management capability includes data integration, access, quality assurance, and data-driven decision-making. The measurement of data management capability is based on the data management capabilities (Pörtner et al., 2025; Hafner & Mira da Silva., 2024). Government support refers to items regarding policy assistance, financial incentives, and any scheme or program that promotes technical training for digital transformation among SMEs. The construct is drawn from the research (Prasannath et al., 2024), who examine the effects of policy-driven support to SME performance. The dependent variable for success in digital transformation is represented by items that evaluate the effectiveness of digital initiatives and operational efficiency, which contribute to the success of overall business improvement, which is consistent with previous researches (Weritz et al., 2024; Martínez-Peláez et al., 2023).

To provide evidence of content validity and conceptual relevance, the questionnaire is reviewed by academic experts on digital transformation and construction industry practitioners. A planned pilot test should be implemented with 30-50 respondents for the purpose of providing assessments on item clarity and reliability. When it is well-designed and performed, pilot test is deemed as a valuable tool that can provide important information for the development and potential success of possible larger research. In fact, these kinds of tests are frequently utilised to evaluate feasibility for initiating larger research (Saunders et al., 2019). The reliability value of this research will be assessed through Cronbach's alpha, a level of 0.70 or higher will be considered acceptable (Hair et al., 2021). The measurement items for each variable are presented in Table 1 as below.

Table 1

Measurement items

Construct	Code	Measurement items
Technological Readiness (TR)	TR1	Our company has sufficient IT infrastructure in support of light-weight AI applications.
	TR2	Employees in our firm have sufficient digital skills to operate AI-enabled tools.
	TR3	The administration supports exploration and learning consistently with electronic technologies.
	TR4	There are specific procedures for appraising and implementation of new technologies.
	TR5	Digital transformation is included in our corporation's long-term plan.
Data Management Capability (DMC)	DMC1	The firm puts together project information from different sources into one digital system.
	DMC2	Project information is readily shared among teams and departments.
	DMC3	Data analytical tools are widely used in helping decision-making.
	DMC4	Procedures for ensuring the quality, accuracy, and timeliness of the data, is established
	DMC5	Employees are trained in processing and interpreting data effectively.
Government Support (GS)	GS1	The government grants tax breaks and budget incentives for SMEs' digitalisation.
	GS2	Capacity-building and training in the use of computers are provided.
	GS3	The government's digital strategy provides clear directions for the SMEs' transformation.
	GS4	Collaborations with the public institutions facilitate SME innovation and AI implementation.
	GS5	Government policies remain stable and consistent to sustain

digital initiatives.

Digital Transformation Success (DTS)	DTS1	Digital transformation aided in accelerating project delivery and reducing the cycle time.
	DTS2	Communication and collaboration have improved through digital platforms.
	DTS3	Data-driven decision-making ensured better project-wide results.
	DTS4	Artificial Intelligence based tools have improved project quality and reduced human errors.
	DTS5	The process of digitisation rendered our business more competitive in the market.

4.2. Data collection method

The research adopts a quantitative survey research design in the collection of data from small and medium construction entities (SMEs) in Beijing, China. The possible respondents are the decision-makers, engineers, and managers directly involved in the execution or direction of digital transformation projects in the entities. The questionnaires are distributed through electronic means using survey websites such as Wenjuanxing for easier accessibility and fast response accumulation. In China, Wenjuanxing is a very common online survey platform that enables researchers to easily collect large-scale, diverse, and geographically dispersed data. It is widely used in many fields of research-transferable knowledge beyond public health to education or consumer behavior or technology--demonstrating its versatility and trustworthiness for academic research (Su et al., 2024). This research applies a convenience sampling research methodology where the data is collected from participants easily accessible and willing to respond. It is a very suitable methodology when the research must have elementary insights from a provided population target under time and resource constraints (Sekaran & Bougie, 2019). It is a popular methodology for research in information systems and management because it is easily implementable, quick, and affordable, particularly when it is impossible to conduct probability sampling due to the limitation of the resources or the access constraints (Baltes & Ralph, 2022).

The data collection procedure places great importance on the voluntary basis of participation, anonymity, and adherence to ethical practices. Participants are informed about the purpose of the research, that their feedback will remain anonymous, and that they can withdraw from the research at any time with no consequence. The online survey has a short introduction that states these ethical concerns. Following the measurement of the data, the feedback will be analysed using Partial Least Squares Structural Equation Modeling (PLS-SEM). This analysis technique is selected because it is appropriate for predictive and exploratory models when the research comprises a number of constructs and the sample size is moderate (Hair et al., 2021). Application of PLS-SEM will allow for the testing

of the measurement model's reliability and validity and for the hypothesised connections between the constructs of the TOE framework.

4.3. Population and sample

The population for the research is the small and medium construction organisations (SMEs) of China in the city of Beijing. SMEs are the significant segment of the Chinese construction market and a key driver of the nation's overall digital transformation initiative (National Bureau of Statistics of China, 2024). It is the construction SMEs that are selected because they are susceptible to the specific operational challenges that include access to scarce finances, data silos, and a poor level of technology preparedness that offer a perfect target for exploring the digital transformation success factors.

The sampling frame is selected from the open databases of the National Bureau of Statistics of China and the local construction industry associations whose directories contain all the construction SMEs that are licensed in Beijing. It is however not possible to access a complete list of all SMEs in the target population. Therefore, this research adopts a convenience sampling technique. This non-probability approach entails the selection of the respondents that are easily accessible and willing to complete the questionnaires, particularly in exploratory research where the conceptual relationship between the variables is the focal point.

The sample participants are owners, project managers, engineers, and digital or IT officers themselves having corresponding knowledge about their organisations' digital transformation efforts. For the purpose of representativeness, the research will cover SMEs of various size and years of operation in the construction industry. According to the recommendations by Hair et al. (2021), a sample size of 150 to 200 has been deemed sufficient for the PLS-SEM analysis where the model has a number of constructs and relationships. Table 2 provides an overview of the demographic profile that the respondents are intended to have, including important background characteristics, such as organisational size and years in operations, and respondent's position.

Table 2

Proposed respondents' demographic profile

Items	Category	Description
Firm size	Small / Medium	Based on annual turnover or total assets
Years of operation	< 5 years / 5–10 years / > 10 years	Organisational maturity level
Position	Owner / Project Manager / Engineer / IT Officer	Decision-making role in digital initiatives
Type of construction work	Commercial / Infrastructure / Residential	Primary business activity

5. Expected outcome

The proposed conceptual research will seek to conclude the creation and validation of a model that adopts the Technology–Organisation–Environment (TOE) framework to explore how small and medium-sized enterprises in Beijing can apply lightweight artificial intelligence (AI) to overcome both data fragmentation and financial constraints during digital transformation. The expected result that can be anticipated from the completion of the proposed research will provide insight into how technology readiness, data management, and government support are factors and elements that can contribute to digital transformation happening in the construction industry, especially for small and medium-sized enterprises.

The technological readiness construct is particularly expected to affect the readiness and ability of the SMEs to adopt AI-based technology. This is because organisations that are technologically well-equipped, both in terms of human resources and a futuristic mindset towards technology innovation, will tend to experiment and successfully implement lightweight AI applications. The lightweight nature and affordability of such AI applications will enable the SMEs to digitise key operational activities, such as project view and defect detection, without having to spend much. The expected result will prove that technological readiness is an important factor that helps overcome adoption difficulties and improve ease-of-use for the SMEs.

Regarding the organisational context, the ability to manage data is expected to act as a key factor that affects the relationship between technological readiness and digital transformation success. Organisations that exhibit advanced levels of data management maturity, characterised by their competence to harvest, process, evaluate, and safely store their data, can better expect valuable insights from their AI deployment. This will enable them to accomplish the conversion of scattered information to valuable knowledge, thereby aiding them in coordinating various operations through different departments. Subsequently, their efforts in enhancing effective data management will enable them to provide better project delivery quality, thereby enhancing their digital maturity.

Concerning the environmental factors, government support is anticipated to play another key role, ensuring that the positive relationship that can exist between organisational and technological capabilities and digital transformation outcomes is strengthened by overcoming resource constraints that tend to inhibit the growth of firms, particularly in the SME segment. Considering that digital transformation in Beijing aligns with country strategies for satisfying quality, government support measures are expected to act both as enablers and accelerators for AI adoption.

In general, it is anticipated that the proposed research will generate both theoretical and practical contributions. Theoretically, it will enhance the TOE framework by incorporating the adoption of lightweight AI as an appropriate mechanism for digital transformation for SMEs in the emerging

economy context. The research will demonstrate the importance of the interactions existing between the internal structures and the support structures that guarantee digital success. The practical contributions will enable the proposed research to provide direction for the adoption of an effective lightweight AI implementation process for SMEs, construction, and other related industries by offering cost-efficient digital strategies that improve productivity, project quality assurance, and sustainable construction practices for China's construction sector. Therefore, the expected outcome of this research will prove that lightweight AI tools can provide a viable and effective path for digital transformation in construction SMEs, by turning traditional constraints into opportunities for innovation and growth.

6. Significance of research

This research seeks to investigate the extent to which technological readiness, information management capability, and government support shape digital transformation success in small and medium-sized building businesses (SMEs) in Beijing, China, under the Technology–Organisation–Environment (TOE) framework. The rationale behind the research interprets the anticipated outcomes conceptually, with the focus on the theoretical and practical significance in the context of the adoption of light-weight AI tools.

From a theoretical point of view, this research develops the TOE framework by investigating the notion of 'lightweight' AI adoption, and contributes to the knowledge of how SMEs achieve digital transformation utilising limited resources. It positions the lightweight AI, not simply as a technological innovation, but as a strategic enabler that connects low-end digital tools and technologies with advanced automation systems. The research contributes to the academic literature on digitalisation in emerging economies and resource-constrained environments.

From a practice perspective, the research also provides ideas for practice for industry practitioners and policy makers. SME managers are encouraged, to invest in basic (low-end) digital infrastructures and employee digital literacy training programs to improve technological readiness, to implement structured and iterative data management systems, and support the practice of data-driven decision making to achieve efficient operationalisation, and to be actively engaged with public initiatives and take advantages of government subsidy program or training on digital technologies to enhance their innovation capacity.

Furthermore, for policy makers, the research suggests to expand their financial and technical training support arrangements to diffuse artificial intelligence across the construction industry. Schemes such as subsidised AI tools, arrange demonstration projects and digital transformation grants may further enhance engagement of SME's with the larger innovation led economy of China.

7. Limitation, recommendation and conclusion

Since it is conceptual research, the current research does not involve empirical facts in verifying the relationships proposed. Therefore, the predictive precision and generalisability of the model remain theoretical and must be verified with actual-world facts. Geographically, the research also converges only on Beijing, thus limiting possible applicability in other parts in China with varied industrial structure or policy conditions. Furthermore, the model also focuses only on three determinants, no other possible determinants such as organisational culture, leadership, or digital ecosystem maturity are studied in the current research.

Future researches should empirically examine this conceptual model with the aid of data from construction SMEs in varying parts of China or other emerging economies. Utilising PLS-SEM or multi-group analysis can be used to confirm the relations and also examine differences across size, age, or type of project. Future researches are also invited to examine the mediating or moderating role of organisational culture, innovation orientation, or ease of access to funds. To investigate longitudinal data so that the progress in the maturity of digital transformation in the long run can be gauged in SMEs, and to investigate the effect of the application in specific instances of lightweight AI (e.g., predictive maintenance, image recognition, safety monitoring) in project performance and sustainability outcomes. In developing this conceptual model further towards empirical examination, future researches can provide more substantial understandings of the ways in which construction SMEs can efficiently exploit the voluntary AI technologies towards sustainable transformation and competitiveness.

In summary, this research aims to examine the determinants of successful digital transformation in small and medium-sized construction enterprises (SMEs) in Beijing, China, based on the theory of Technology–Organisation–Environment (TOE). The proposed conceptual model suggests three key determinants (i.e., technological readiness, data management capability, and government support), which together influence the success of digital transformation. The research also highlights the capabilities of light-weighted AI tools as facilitators which can help SMEs overcome structural barriers such as data silos, limited finances, and disintegrated procedures.

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Data availability

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The authors declare that there is no conflict of interest.

Ethics approval

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Consent to participate

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Consent for publication

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