



Challenges and Strategies for the Application of New Industrialized Construction technologies

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SUMMARY: *Although the new industrialised technology can improve the performance of the construction industry by optimising workflows and creating a better working environment, it is still in its infancy in application in the construction industry. The aim of this paper is to explore the problems in the application of new industrialised technologies, put forward effective countermeasures for promoting the application of new industrialised technologies, and investigate whether there are any differences in the opinions of different enterprises on these problems and countermeasures. First, I will conduct a review of related studies and interview some people in the industry. Based on the above analysis, the main problems are a lack of norms and reference systems, high investment in technology construction and deficiencies in high-end industrial personnel, and the most feasible countermeasures are to bolster organizational leadership, enhance policy support, and improve the top-level design. Enterprises of different types will have various business natures, industries and qualification levels, and thus may be at different stages of learning about the problems and responses to these issues. The research results can help us better understand the problems faced by different parts of the industry and the strategies that have been used successfully so far to build data-driven industrial policies to promote the spread of new industrialised technologies and drive digital transformation in the construction sector.*

KEYWORDS: *new industrialized construction technologies; challenges; strategies*

1 Introduction

With the continuous change in China's population structure, the old way of artificial and fragmented construction is no longer suitable for the demand for high-quality development in the construction industry [1]. At the same time, as the demand for good construction quality in society increases, so too does market competition, and construction enterprises are facing more and more problems related to safety, quality, speed and economy. Since the 18th National Congress of the Communist Party of China, with the deepening of the national green development strategy, the concept of sustainable development has become more widely spread, and energy saving, material saving, water saving, land saving, environmental protection and other urgent demands for reform and improvement in the construction industry have been put forward [2]. As a national strategy, new construction industrialisation has promoted the transformation and upgrading of the construction industry, and promoted green development and high-quality development in urban and rural construction. Although the construction industry has always been an old industry with relatively late application of new technologies,

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there are currently few scholars studying the problems in applying new construction industrialisation technologies, as well as countermeasures to promote the application of new technologies in the construction industry and thus start the digital transformation of the entire city. In order to promote the application of the new building industrialization technology system, the challenges and obstacles in its development need to be identified, and corresponding countermeasures should be taken to enhance the application of the new building industrialization technology system, including optimizing the organization and management mode, setting skill standards for personnel, and building an information management platform. The purpose of this paper is to explore the problems in applying the new building industrialisation technology, propose effective countermeasures and suggestions to promote the application of this technology, and determine whether there are significant differences in the perception of the importance of these problems and the effectiveness of countermeasures among different types of organisations. The results of this study provide better insights into the problems that industry practitioners face and effective countermeasures adopted, offering a reference for governments and the industry to identify specific areas for emphasis in the construction of data-driven roadmaps to promote the application of smart technologies in the construction industry. Promote the digital construction of the construction industry and, at the same time, promote the development of smart cities.

Briefly introduce the research in a large-scale environment and explain why it is necessary. Establish the objectives and reasons for this study. Study the present circumstances of the research field and list some outstanding works that have been cited. Mark any controversial or divergent hypotheses here. Finally, briefly state the goal of this paper and present the main results. At the same time, to the extent possible, keep the introduction understandable for scientists in other fields of research. References should be numbered in the order they appear and indicated by a number or numbers in square brackets, such as [1] or [2, 3], or [4-6]. See the end of the document for the list of references.

2 Literature Review

2.1 New industrialized construction technologies

The new type of building industrialization is driven by the new generation of information technology, employs systematic integrated design and lean production-construction of the whole life cycle of the project as its main means, links the entire industry chain, value chain and innovation chain of the project, and achieves high-efficiency, high-quality, low-consumption and low-emission construction industrialization. The new building industrialisation will be based on information technology, intelligence and green technology. The supporting technologies of the new building industrialisation technology include Cyber-Physical Systems (CPS), Internet of Things (IoT), Big Data (Big Data), etc. BD) Additive Manufacturing (AM), Augmented Reality (AR), Virtual Reality (VR), Construction Robotics (CR)[3], Autonomous Vehicles (AV) and Distributed Ledger Technology (DLT)[4]. CPS is now one of the representative technologies for the industrialisation of new buildings. CPS includes hardware and software components, and through sensors, actuators and real-time networks is connected to the system environment. It can collect data on changes in the physical environment in real time and provide this data in an information paradigm. Optimise the Process based on the physical environment [5]. Digitisation of the value chain promotes horizontal, vertical and end-to-end integration of the value chain, as well as automation and optimisation of processes.

The new building industrialization technologies considered in this study include: digital-aided design, review and management platforms based on BIM technology, such as: building

information model (BIM) collaborative design, construction drawing digitization, intelligent review, and digital collaborative management platform; the prefabricated construction system based on the Internet of Things information system, such as: intelligent production such as information automation parts production line, green mixing plant management, intelligent logistics such as intelligent positioning, transportation, warehousing, identification and labeling (RFID), Internet of Things equipment management, etc.; intelligent project management, including: personnel and vehicle access management, equipment safety and energy consumption environmental monitoring, mechanical visualization, AI video surveillance, automatic hazard monitoring and early warning, lift manned monitoring, intelligent management of on-site materials, digitization of internal industry data, construction impact log, data integration and interaction platform; and construction robots and intelligent assembly, including: general robot, intelligent fabric machine, wall panel installation robot, floor painting robot, opening robot, actual measurement robot, underground engineering intelligent construction assembly, automatic integrated building platform, remote control machinery and equipment.

2.2 Common challenges facing the industrialization of new buildings

With new technologies, combined with process optimisation, it is hoped that their full potential will be realised and the general level of development in the construction industry promoted [1]. However, due to the temporality, multi-subjectivity and fragmented value chain of the construction industry, the application of new technologies has been relatively slow [5]. Therefore, the reasons for not using the new technology in the construction industry have always been subjects of study by scholars. As the core supporting technology for the intelligent construction technology system of the construction industry, BIM can address the limitations of the two-dimensional nature of CAD by providing a three-dimensional visualization model of building components, and has received increasing attention in the construction industry [6]. Scholars have recently been conducting research on the problems in the application of BIM technology. The high cost of BIM technology application and the lack of unified national and international standards for BIM technology are the main problems in its application [7]. Therefore, a method for measuring the benefits of BIM implementation needs to be developed to address the owner's hesitation due to the uncertainty of the return on investment (ROI) of BIM adoption [6]. The above problems help to understand the obstacles in the application process of BIM, but smart construction technology will change the focus from manual labour to a work process supported by technology, and thus a different set of challenges may arise in the application process of BIM technology. Therefore, some research has focused on the problems that the industry faces in applying certain intelligent technologies. The Cost of RFID systems, a lack of knowledge and skills, and no approved standards are the main enabling technologies for CPS and IoT. Are the top three barriers to the application of RFID technology in construction [8]. Although CPS can improve the performance of project management, first of all, there are obstacles such as hardware limitations and implementation costs [5]. As shown by the authors in [9], some of the primary problems of using the Internet of Things in construction include security and privacy issues, difficulties in data collection, processing and storage, lack of value chain cooperation, and interoperability issues. The problems in deploying IoT technology in construction are network connectivity and hardware limitations; at the same time, the use of CPS and IoT generates a large volume of diverse and rapid data that requires big data applications [10]. The main problems in the application of BD technology include a lack of skilled professionals, complex data integration, security and privacy risks of data, data ownership, issues with data and information sharing, and high application costs [11-13]. In

addition to CPS, IoT and BD are also relatively common technologies, as are AR and VR, robotics, AV, AM and DLT. A framework for mobile-based information management at construction sites has been proposed to overcome hardware limitations, fragmentation of the value chain, high implementation costs and interoperability problems [14]. Lack of knowledge and skills, hardware limitations, interoperability problems, etc., have inhibited the application of AR and VR technology in construction at present [15]. Implementation costs affect the attitude of stakeholders towards adopting robotic systems to some extent [16]. Network connectivity, interoperability, implementation costs, hardware constraints and the need to redesign workflows are all major deficiencies in the use of unmanned aircraft systems for construction project management that inhibit their application [17]. The hardware limitations and design problems of robotic on-site manufacturing in construction, as well as the cost of implementation and changes in work processes, are all constraints that have yet to be solved [18]. The reasons for not widely using additive manufacturing in the building industry are: A shortage of knowledge and skills, hardware limitations, and problems in system design [19]. Implementation costs, lack of skills and knowledge, interoperability issues, absence of regulations, network connectivity, and hesitation to adopt DLT in the built environment industry are the main problems that have arisen in [20]. Rather than studying the problems that particular technologies face, Oesterreich et al used a case study approach to identify common issues in the adoption of intelligent technologies in the construction industry and classified the identified problems according to a political-economic-sociotechnology-environment-law (PESTEL) framework. The authors have proposed that the main reasons for the application of intelligent technology in the construction industry are problems with the sharing of data and information, compliance issues, and data ownership. Similar analysis systems have been applied by other scholars in their research [1, 9, 20].

Most domestic research has focused on the problems and challenges of new-type building industrialisation at a high level and has been relatively sparse in terms of empirical studies. The primary issues and difficulties are as follows: The system of policy support is not ideal; the design technology system is defective; the key technology and integration technology lack maturity; the cost problem that hinders the development of new-building industrialisation has not been solved effectively; public opinion is neither comprehensive nor accurate enough; and the level of industry team expertise needs to be raised [1, 21]. An Increase in the cost of off-site construction limits the development of prefabricated buildings. Some scholars have examined the four causes of the increase in cost for precast concrete components: design, production, transportation and installation [21, 22]. Some scholars have applied the improved ISM-MICMAC model to build a 5-level hierarchical structure model of obstacle factors and classified them, and summarized 18 influencing factor index systems that hinder the development of new-type building industrialisation across these five levels: policy, technology, personnel, management and market. Principal Component Analysis was used to find the five major reasons for the industrialisation of new buildings [1, 22]. Based on the actual situation in Fujian Province, the identified problems will be classified into the five categories of technical, economic, organisational, managerial and social deficiencies.

2.3 Promote the development of new building industrialization countermeasures

In addition to studying the problems in the application of new technologies in the industry, this paper will also offer some countermeasures to promote their application in the construction sector. First, there will be the use of specific technologies in the construction industry. In terms of BIM technology adoption, sustained government support and leadership have been provided,

and through the establishment of regulations and standards, training and sharing of successful cases that have shown positive results in promoting BIM application around the world have been carried out; at the same time, communication and change management efforts, as well as the creation of standards and partnerships, have also been undertaken to encourage the spread of BIM technology [7]. In terms of the application of green building technology, the ultimate countermeasure to promote the adoption of green building technology in the construction industry is the combination of financial and market incentives for adopters, the availability of information on the costs and benefits of green building technology, mandatory government policies and regulations, and green rating and labeling [2]. Training, dissemination of good cases, establishment of standards, provision of resources and formation of partnerships can all help SMEs introduce Big Data technology [23].

Some scholars have generally studied effective methods for the application of new technologies in the construction industry, and the countermeasures identified in the literature review are classified according to the level at which the strategies can be implemented [22, 24]. Good communication and change management facilitators are needed to promote the smooth implementation of changes, and leaders have promised to lead the organisation through these changes in the future [25]. To promote the spread of construction innovation, financial incentives and strengthened legislation and reasonable procurement methods are needed [26]. Financial incentives, government policies, the formation of standards, funding for industry and research projects, cooperation, training and knowledge management and dissemination, change management, etc., can all address the main problems that enterprises face in the adoption of fourth industrial revolution technologies [4]. Leverage government support to build a collaborative model and foster partnerships to promote the application of construction robots [16]. At the industry, enterprise and project levels, the following will be implemented as measures to promote the use of new technologies in the Australian construction industry: incentives, benefit sharing, partnerships, staff training, communication and change management [27].

Some scholars at home have put forward countermeasures to speed up the development of new building industrialisation in eight aspects: accelerating the strengthening of policy support mechanisms, accelerating the research of design key technologies, accelerating the research of integrated technology systems, accelerating the innovation of management modes, accelerating the construction of industrial alliances, accelerating the research and development of BIM information technology, accelerating the integration of green technology, and accelerating the capacity building of industry teams [1, 21]. Some scholars have put forward countermeasure proposals for promoting the development of new building industrialisation, covering aspects such as promoting industrialisation and the integrated development of industrialisation, optimising the government-guided and market-led cooperation mechanism, breaking through common technologies, and improving the industrialisation organisation model [1, 22]. The five contents of the countermeasures in this paper are: policy guidance, technical support, capacity building, supervision and management, and innovation and development.

3 Research methods and data presentation

3.1 Research procedures

The five steps of this study are:

3.1.1 Literature search and review

Retrieval of Chinese literature used the CNKI database, and "title" was used as the search field, with "building industrialisation" as the search term. Journal sources include EI+SCI+ Overview of Chinese core journal contents + CSSCI+CSCD, and the time range is 2013-2023. A total of 65 relevant papers were found, and many other papers did not fit the criteria for exclusion. Finally, 59 valid papers were collected by the retrieval time of January 13, 2024. Use the FULink document-providing system to find foreign literature. Keywords for searching include "challenges", "strategies", "construction industry", and "technology adoption", and foreign literature published between 2013 and 2023 has been retrieved. Screen and review the papers to identify the problems and obstacles in the development process of new-type building industrialisation, as well as countermeasures to promote the popularisation and application of technology systems for new-type building industrialisation. The five types of problems in this study are technology, economy, organisation, management and society, and the five countermeasures are policy guidance, technical support, capacity building, supervision and management, and innovation and development.

3.1.2 Scale design and optimization

Based on the results of the literature review, a five-point Likert scale will be used. In order to verify the all-encompassing nature and scientific basis of the scale, three senior experts from construction units, design institutes and supervision units in the expert database of the Zhangzhou Construction Industry Association were selected for interviews. According to the above analysis, experts believe that the constructed scale can cover the problems in the application of new technology in the industry to some extent, is reasonably distributed, and the suggestions provided are simple in expression. In addition, the author went to the Construction Department of the Zhangzhou City Housing and Urban-Rural Development Bureau and offered suggestions on the feasibility and accuracy of the scale countermeasures. Based on the feedback, adjust the scale and finally compile the list of problems and corresponding countermeasures, as shown in Table 1 and Table 2.

Table 1: Common Problems in the Application of New Building Industrialisation Technologies.

Categories	Code	Challenges
Technology	C1	Network stability and bandwidth constraints: To monitor project site activities in real time, support instant data transmission and centralized big data storage between project sites, put higher requirements on the stability and bandwidth of broadband connections, and improve remote collaboration.
	C2	High requirements for technical equipment: The outdoor operation on the construction site is affected by temperature, humidity, dust and surrounding environment, as well as the problem of dispersed project organization and low risk tolerance, which requires high assembly complexity, processing performance, integration, wireless and mobility of new technologies.
	C3	Lack of Standards and Reference Architectures: The construction of common standards and research and development for digital technology has not been carried out, the coupling between digitalisation and standardisation is weak, and a personalised technology system based on standards cannot be built. The integrated modular system in each link has not been constructed, and there is a lack of a standardised interface among the modules for design, production, installation, operation and maintenance.
Economy	C4	High investment in technology implementation: The high cost of new technology and equipment purchase, training and education, consulting fees and operation costs are in sharp contradiction with the low overall profit rate of construction projects.
	C5	High cost of construction organisation: The combination of new and old technologies results in the construction of two separate modes at the construction site. For example, prefabricated buildings are based on cast-in-place design and achieve "equivalent cast-in-place" prefabricated buildings by dividing components, which increases the cost of construction organisation.
	C6	Unclear expected benefits: However, it is difficult to quantify the cost savings, speed up the schedule and safety improvement brought by new technologies, lack of uniform financial evaluation standards, and enterprises are not willing to invest in them.
Organization	C7	Low acceptance among managers: internal managers of enterprises are conservative and resistant to changes and new technologies such as technical equipment, computers and construction robots, and are unable to adapt to new technological innovations.
	C8	Lack of skilled industrial talents: The knowledge level and integration ability of skilled industrial talents in new technologies are increasingly required, while the technical ability of workers on construction sites is relatively low.
Management	C9	Poor quality of data and knowledge management [24]: Construction projects are temporary, multi-subjective and fragmented across the construction value chain, with low-quality data and difficulty sharing all data and information among various parties; there is a lack of systematization and sharing for project knowledge, weak standards for knowledge management, it is difficult to establish and implement standards of knowledge management at the organizational level, and new technologies and management experiences cannot be continuously learned and improved for the project.
	C10	Lack of a refined management concept and experience: The production mode of industrial development has higher demands for management, and its management needs to be based on an information platform, cover the entire life cycle of project development, scrap information from the whole industrial chain process, take lean construction as the concept, and the current extensive management mode is not suitable for the industrial fine management mode.
	C11	Lack of integrated planning and professional cooperation: The old management model of segmentation and cutting has led to separation in the links of design, production, construction, operation and maintenance; information flow is hindered, the integrated general contracting mode such as EPC is not well-developed, and an organisation for integration and professional cooperation has not been established.
Society	C12	Compliance and ethical Risk: The use of RFID technology for security management and employee management requires the automatic acquisition and recording of personal data, and there are ethical and legal risks in the tracking and monitoring of employees and the processing of recorded information.
	C13	Data security, data protection and management: As the volume of data increases, so does the need for data mobility, collaboration between project organizations, and information sharing, leading to data security, data ownership, and management issues, such as access control, intrusion prevention, denial of service (DoS) defense.

Table 2: Strategies for the Development of New Building Industrialization.

Categories	Code	Strategies
Policy guidance	S1	Strengthen organizational leadership, accelerate the implementation of local management responsibilities, and establish a mechanism for departmental coordination.
	S2	Improve the top-level design, build legislative guarantee for the development of prefabricated buildings, and strengthen government promotion.
	S3	Strengthen policy incentives, land security, fiscal incentives and financial support.
Technical support	S4	Clear technical path, promote the "first horizontal" to "post vertical" lifting, promote assembly decoration.
	S5	Conquer key technologies, promote mature and applicable technological products, and establish a collaborative platform for "industry-university-research and application".
	S6	Enhance the level of digitalization, promote the development of digital design, and build an intelligent production platform for prefabricated components.
Capacity enhancement	S7	Cultivate professional and technical personnel to transform migrant workers into industrial workers and upgrade their vocational skills.
	S8	Carry out management personnel training, improve management ability, and add professional and technical titles for prefabricated construction.
	S9	Build a comprehensive training base and carry out training for operators in key positions.
Supervision and Administration	S10	Strengthen the control of design quality, strengthen the quality supervision of the production of prefabricated components and the quality supervision of the construction link.
	S11	Strengthen supervision and assessment, and establish a hierarchical supervision and assessment mechanism.
	S12	Strengthen the quality control of all links, and strengthen the control of the completion acceptance link.
Innovative development	S13	Innovate and optimize the organizational management model.
	S14	Build an integrated green development model and integrate development with green building materials and green buildings.
	S15	Innovative digital supervision of engineering quality and safety.

3.1.3 Questionnaire distribution and recovery

The three parts of the questionnaire are as follows: The first is the general information of the respondents and their enterprises; The second is a scale for obstacles and difficulties in the development of new-building industrialization; and the third is a scale of countermeasures for the development of new-building industrialization. There are 596 construction enterprises (including construction, design, supervision, consulting and owners, etc.) from the leading member units, executive director units and governing units of the Fujian Construction Industry Association. The priority of the survey objects is: experts, technical leaders, business leaders and project managers of the above enterprises selected in the expert database of the construction industry association. The respondents needed to have an intermediate professional title or higher, more than five years of work experience, and had participated in at least one project that used new construction industrialisation technology. A questionnaire star was distributed to the

respondents via a WeChat link for online completion.

3.1.4 Data processing and analysis

The Social Science Statistical Package (SPSS V26.0) was used to analyze the sample data. Statistics were used to conduct Shapiro-Wilk tests, mean rank analyses, single-sample Wilcoxon signed-rank tests and Mann-Whitney U tests.

3.1.5 Post-survey interview

Answer the questions in this stage, and then we will present the survey results in Step (2); some senior scholars will also offer their opinions on whether this information can help address the current problems of the industry and whether the proposed countermeasures can genuinely promote the application of new technologies.

3.2 Data analysis methods

To determine whether a parametric test or a non-parametric test would be used in the following analysis, the Shapiro-Wilk test was performed to check the normality of the sample data at a significance level of $\alpha = 0.05$ [21]. Based on the above results, the data do not meet the requirement for normality and are therefore not suitable for parametric statistical tests. Mean rank analysis was conducted to determine the significance of the impact degree of the challenges faced by survey subjects in adopting the new building industrialization technology on the promotion of the new building industrialization technology, and the challenges and countermeasures were ranked according to the average values of the identified challenges and countermeasures. A single-sample Wilcoxon signed-rank test was used to examine the strength of the impact of challenges and the degree of recognition for countermeasures. As the five levels of the Likert scale were used for both the degree of challenge impact and the extent of agreement with the proposed countermeasures in the questionnaire, it was assumed that the median was 3. A Mann-Whitney U test was employed to determine whether there were significant differences in challenges and expected countermeasures among survey subjects with different working years and different organisation sizes, and the significance level was set at $\alpha = 0.05$.

3.3 Data presentation

A total of 188 valid answers were collected in this survey; the recovery rate was 31.5%, and the sample size exceeded 30. The Central Limit Theorem has been proven, and the data from a sample can be analyzed statistically to some extent [21]. The response rate was relatively high compared to the general statistical level of social science research (10%-15%) [28], and the construction industry association was utilized as the work platform for the research and cooperation improvement activities of the enterprises. The type of enterprise in the survey object is shown in Figure 1, the nature of the enterprise in the survey object is shown in Figure 2, the industry type of the enterprise in the survey object is shown in Figure 3, and the qualification level of the enterprise in the survey object is shown in Figure 4. It shows that the survey objects are generally representative, and this survey provides a diverse sample of data from all parties involved in the construction project. 74.47% of the survey subjects have been working for 20 years or more, 78.72% hold titles such as associate senior manager or higher, 100% have participated in projects using new building industrialization-related technologies, and 68.09% have taken part in three or more such projects; thus, the survey subjects have accumulated extensive experience in new building industrialization. Whether they can identify the problems and countermeasures effectively. Based on the above content, a relatively accurate and meaningful statistical analysis of the sample data will be conducted.



Figure 2: Nature of the Investigating Object.

4 Data analysis and discussion

4.1 Data analysis

4.1.1 Challenges faced by the industrialization of new buildings

Table 3 shows the problems that the survey subjects have encountered in the application of new building industrialisation technology. The middle value of 3 is set as the threshold for the extent of challenge impact. Based on the results of the single-sample Wilcoxon signed-rank test, all subjects' degrees of perceived impact were statistically significant. The above results are consistent with the results of mean rank analysis; that is to say, the degrees of influence of all challenge factors exceed the threshold value of 3. Based on the mean rank analysis results, the three main problems in the industrialisation process of new buildings are a lack of standard and reference architecture (C3), high investment in technology implementation (C4), and a shortage of skilled industrial talents (C8). Independent samples Mann-Whitney U tests were carried out on enterprises with different types of business, types of enterprises, industries, qualifications,

etc. Based on the above analysis, it can be concluded that: At the 0.05 level of significance, the cognition of the impact degree of technology, economy, organisation and management challenge factors differs significantly among owner units and other participating units (design institutes, construction units, consulting units, etc.), but not among them; Cognition of social factors was not significantly different. There were no significant differences in the cognition of the impact degree of technology, organisation, management and social challenge factors between state-owned enterprises and private enterprises, but a significant difference existed in the cognition of economic factors. There was no significant difference in the cognition of the impact degree of organisational, management and social challenge factors between housing construction engineering and other types of engineering (municipal engineering, highway engineering, railway engineering, etc.), but a significant difference existed in the cognition of technical and economic factors. There were no significant differences in the cognition of the impact degree of organisational and management challenge factors between large enterprises with special qualifications and other qualified enterprises (level 1 qualification and below), but significant differences existed in the cognition of technical, economic and social factors.

Table 3: Results of Challenges in Applying New Industrialized Construction Technologies.

Challenges Code	Mean	Rank	Standard deviation	MW1	MW2	MW3	MW4
C1	3.98	7	1.123	0.711	0.746	0.556	0.056
C2	3.87	10	0.892	0.014*	0.629	0.043*	0.034*
C3	4.15	1	0.877	0.000*	0.112	0.464	0.350
C4	4.06	2	0.934	0.000*	0.000*	0.019*	0.654
C5	4.02	4	0.936	0.000*	0.743	0.463	0.014*
C6	3.74	12	0.759	0.000*	0.024*	0.495	0.538
C7	4.00	6	1.055	0.003*	0.204	0.377	0.949
C8	4.04	3	0.969	0.041*	0.817	0.468	0.264
C9	3.98	7	0.787	0.002*	0.870	0.401	0.318
C10	3.98	9	0.981	0.001*	0.817	0.611	0.192
C11	4.02	5	0.959	0.003*	0.193	0.374	0.481
C12	3.49	13	0.989	0.677	0.662	0.128	0.049*
C13	3.74	11	1.002	0.680	0.338	0.161	0.116

Note: 1. "MW1" refers to the Mann-Whitney U test of independent samples for different types of business; "MW2" is the Mann-Whitney U test of independent samples of different types of business; "MW3" is the Mann-Whitney U test of independent samples of different industries; "MW4" is the Mann-Whitney U test of independent samples of different qualification levels; 2. "*" indicates that $p < 0.05$.

4.1.2 Development countermeasures of new building industrialization

Table 4 is a summary of the countermeasures for the industrialisation of new buildings. The median of 3 is taken as the threshold for countermeasure recognition. The result of the single-sample Wilcoxon signed-rank test is that the perceived countermeasure recognition of the respondents is statistically different. The above results are consistent with the results of mean rank analysis, and all the degrees of strategy recognition exceed the threshold of 3. Based on the results of mean rank analysis, strengthening organizational leadership (S1), strengthening policy incentives (S3) and optimizing top-level design (S2) are the three essential countermeasures for the industrialisation of new buildings.

The results of the Mann-Whitney U test are as follows: at the significance level $\alpha=0.05$, there are significant differences between owner units and other participating

units (design institute, construction unit, consulting unit, etc.) in the recognition of technology policy guidance, technical support, capability improvement and innovation development, but no significant differences in the recognition of supervision and management; there are significant differences between state-owned enterprises and private enterprises in the recognition of technology support, supervision and management, but no significant difference in the recognition of policy guidance, ability improvement and innovation and development; and there are significant differences in the recognition of housing construction engineering and other engineering types (municipal engineering, highway engineering, railway engineering, etc.) in terms of policy guidance, technical support, ability improvement, supervision and management, innovation and development. There is a relatively large difference in the recognition degree of improvement for large enterprises with special qualifications and other qualified enterprises (level 1 qualification and below), but no significant differences in the other four factors.

Table 4: Results of Strategies for Application of New Industrialized Construction Technologies.

Challenges Code	Mean	Rank	Standard deviation	MW1	MW2	MW3	MW4
S1	4.38	1	0.891	0.052	0.842	0.795	0.945
S2	4.26	3	0.980	0.022*	0.029	0.613	0.125
S3	4.34	2	0.860	0.464	0.961	0.003*	0.065
S4	3.94	14	0.838	0.007*	0.446	0.042*	0.726
S5	4.11	10	0.930	0.000*	0.017*	0.004*	0.404
S6	4.00	12	0.902	0.095	0.355	0.520	0.873
S7	4.17	7	0.955	0.422	0.109	0.007*	0.001*
S8	4.21	6	0.900	0.026*	0.436	0.071	0.012*
S9	4.26	4	0.889	0.006*	0.583	0.023*	0.002*
S10	4.15	8	1.013	0.186	0.151	0.000*	0.604
S11	4.13	9	0.916	0.482	0.093	0.935	0.062
S12	4.21	5	0.924	0.537	0.031*	0.004*	0.769
S13	3.98	13	0.959	0.042*	0.580	0.149	0.409
S14	3.87	15	1.067	0.019*	0.890	0.024*	0.183
S15	4.02	11	1.024	0.003*	0.627	0.021*	0.322

4.2 Discussion

4.2.1 The main challenges faced by the industrialization of new buildings

Research has found that the bottlenecks and serious problems at the core of the issues in technology maturity, technical standards, economic benefits, project management, talent reserve, and supporting policies and regulations can be summarized into three main problems: a lack of standards and reference structures, high investment in technology implementation, and a shortage of skilled industrial talents.

First, the development of new building industrialisation should form a standardised module interface based on the construction of a modular proprietary technology system at the enterprise level to achieve standardisation and personalised unity. Standardisation for the Digitalisation Project. At present, the application cases for digitalisation and standardisation are dispersed, and standardisation alone cannot provide a foundation for digitalisation. An integrated modular system for design, production, construction, operation and maintenance in the industrial chain of building industrialisation has not yet been formed, and there is a lack of standardised

interfaces among modules. In the case of a small standardization constraint, many enterprises are independent, and their personalised and digital technology systems are not standardised; thus, supporting enterprises and related industrial auxiliary chains cannot be standardised. The most typical case is that the current industry chain for the design, production, construction, operation and maintenance of various stages of BIM repeated modeling phenomena is very serious; the standardization of each stage has not been achieved, integration and modularization are difficult to promote, and a new building industrialization system cannot be established.

Second, there are some problems in promoting the industrialisation of new buildings by prefabricated buildings. The main reason is that the low degree of standardisation of prefabricated components leads to high costs in the production, stacking and transportation of components, construction management, etc., and a unified component system has not been established yet; as a result, the unilateral cost of prefabricated buildings is high. The unilateral cost of the prefabricated project is more than 10% higher than that of a cast-in-place concrete structure; at the same time, the application of new technology requires investment in the entire industry chain for equipment acquisition, training and education, consulting and operation costs, thus increasing the overall investment for the adoption of new building industrialization technology, and the general low profit rate of construction projects has been prominent. In addition, the construction period of prefabricated construction projects has not been significantly reduced, and the single-storey construction period of projects with PC vertical stress components is more time-consuming than traditional concrete projects; thus, the advantages of new building industrialization technology have not been realized.

Third, a team of highly skilled talents suitable for the new building industrialisation has not been formed yet. Talent is the most dynamic driving force in the development of the new construction industrialisation. Whether it is the application of new technology or the implementation of a project organisation and management model, one must be proficient in the technical and management talents who have the relevant knowledge of new construction industrialisation, and training specifications and standards for high-skilled talents in new construction industrialisation need to be established. The training of talents has a certain regularity, and due to the lack of prefabricated professional technology and management talents, it has been difficult to form good support for the industrial chain system.

In addition, based on investigations of typical construction enterprises, assembly and manufacturing enterprises, and typical construction projects in Fujian Province, an integrated organization and management model for design, procurement, construction and operation and maintenance that is suitable for the application of new technologies has not yet been established, and the flow of construction information across all stages of life of construction projects has not been realised. Building industrialisation is a socialised mass production that aims to achieve the final formation of building products, and the application of new technology should not be carried out unilaterally. Building industrialization is the way forward, and prefabricated buildings are to be the driving force and means to promote the deep integration of technical factors and non-technical factors in the process of new building industrialization.

4.2.2 Development countermeasures of new building industrialization

According to the results of this study, regardless of the type of business or enterprise, industry, level of qualification, etc., effective countermeasures need to be implemented to address the problems caused by the introduction of new technology, and all respondents agreed with this assessment. The three strategies with the highest levels of agreement are: strengthening organizational leadership, speeding up the implementation of local management responsibilities, and establishing a mechanism for coordinated promotion among departments; Strengthening policy incentives, land security, financial incentives and financial support; Improving the top-

level design, establishing a legislative guarantee for the development of prefabricated buildings, and strengthening government promotion. Therefore, the main reason is that the enterprise wishes for more industrial policy support from the government and other levels. The basic reason is that new-type construction industrialisation is an externality, and thus it cannot compel enterprises to consciously break away from the existing technology system and adopt a new technology system through reform and innovation at the level of economic decision-making. The government's particular follow-up and executive role in promoting the development of new-type building industrialisation is more appealing to enterprises than that in other countries, and this is self-evident. At the same time, enterprises also hope to offset or compensate for the increase in investment brought about by the adoption of new technologies through the government's economic incentive and subsidy policies to improve the economic feasibility of the project.

4.2.3 Differences in companies' responses to challenges and solutions

According to the research results, enterprises of all sizes and types have different business scales, characteristics, industry structures and qualifications; therefore, their consciousness of the seriousness of the problem and awareness of the need for countermeasures varies accordingly.

In terms of challenges, since the owner unit is the main investor and decision-maker for adopting the new building industrialisation technology, its attention to the application of new technology in technical feasibility, economic benefits, organisational management mode, etc., is relatively higher than that of other participating units; therefore, it tends to be more hesitant and conservative. The expected economic benefits of adding new technologies to private enterprises are generally higher than those for state-owned enterprises, and thus, private enterprises are more likely to be motivated by economic factors in their investment decisions; state-owned enterprises consider a broader range of reasons, such as social benefits and technological progress. Housing construction engineering is a different kind of project, and the technical difficulty and economic benefits of new technology application are not required. Practically speaking, the housing construction industry may not be the most suitable for applying the new building industrialisation system. Research and formulation of industrial policies for the application of industrialisation technology in municipal engineering, highway engineering and other industries can be carried out to obtain better results. The above results will provide support for the government's planning of industrial policies in the coming years. The results show that the large enterprise has good basic support for technical reserve, economy, and society, and is more optimistic about technical and economic and social problems. They should be regarded as all-encompassing promoters of new building industrialisation, and small and medium-sized enterprises are considered special promoters.

There are differences in countermeasures among the owner units and other participating units at most levels; thus, the owner units have more pressing demands for policy guidance, technological innovation, personnel training and changes in the mode of organisation and management for new-technology application, and their integration of technology and management is less complete. State-owned enterprises are paying more attention to the role of technical support and supervision and management; thus, it can be concluded that the current situation of state-owned enterprises is that they are more focused on improving the success rate of new technology application and reducing risks through technological progress and a perfect management mechanism in the process of new technology application. In terms of countermeasures, the policy guidance, technical support, capacity building, supervision and management, and innovative development of housing construction engineering are applicable to other types of engineering, such as municipal engineering, highway engineering, railway engineering, etc., and the government and enterprises can strengthen mutual reference in their

countermeasures. In addition, large enterprises have given more attention to the training of technical and management personnel, strengthened their professional technology and management abilities, promoted the transformation of migrant workers into industrial workers and enhanced vocational skills, built a comprehensive training base, conducted training for key positions, and reflected that large enterprises in technological innovation pay more attention to the role of people.

4.3 Management inspirations

The results of this study have the following management applications. First of all, at the level of the government, it is necessary to formulate corresponding industrial policies to promote the development of new-type building industrialisation. The government should strengthen top-down organisation, set up a coordinated mechanism for the industrialisation of new-type buildings, and enhance the incentive system for land, finance and finance. Second, stronger policy coordination among housing, transportation, water conservancy and other departments in the new construction industrialization at a higher level needs to be established, and relatively more attention should be paid to the different types of industries rather than focusing only on the housing system; Third, the government should strengthen its leadership in standard-setting, common-technology research, industrial-chain cultivation, personnel training and other work with externalities, and formulate industrial policies around the above key issues. First, at the enterprise level, set the direction for the development of new construction industrialisation and actively participate in new construction industrialisation. Second, enterprises should follow the mode of collaborative innovation and form innovation alliances with upstream and downstream enterprises in the industrial chain based on engineering projects to solve engineering problems in the process of new construction industrialisation through innovation. Thirdly, the same focus should be given to technological innovation and management innovation, and the reconstruction of enterprise resources, information and organisation should be promoted through management mode innovation to build a foundation for the application of new technologies.

5 Conclusions and suggestions

New-type construction industrialisation has promoted the digitalisation, integration and automation of work processes in the value chain of the construction industry, and shows promise for enhancing the competitiveness of the industry. New technologies have been applied to construction by this time, but they face some issues. Taking the civil construction industry as the object of study, this paper will investigate the main problems in adopting new industrialisation technologies for this industry and propose countermeasures to promote the application of these new technologies. Different types of enterprises, their character and industry, as well as the level of qualifications, have all shown different levels of awareness and different levels of countermeasures for the challenges. Based on the above data, the main problems that practitioners face in the adoption of new industrialisation technology are a lack of standards and reference systems, high investment in technology deployment, and a shortage of skilled industry talent; these should be the first priorities addressed in building a roadmap for promoting the digital transformation of the construction industry. The following countermeasures are available to achieve this: strengthen leadership at the top of the organisation; enhance policy incentives and improve top-level design. A number of differences have been identified among enterprises in the critical degrees of perceived possibilities, impacts and challenges. The reasons for the perceived differences are mainly that the organisations are

of different types. This paper will help explore some problems in the application of new technologies, suggest ways to promote their widespread use, identify various reasons for the failure of the new technologies, and add new theoretical support to this field of research. The results of this study can offer some reference for specifying the content of industrial policies to promote the application of new industrialised technologies in the construction industry. This can promote the digital transformation of the construction industry and help build a smart city.

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