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RESEARCH ARTICLE

The Effect of Intelligent Construction Technology and Enterprise Green Management on Transformation of Construction Enterprises. Based on the perspective of dual carbon

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ABSTRACT

This study examines the collaboration between intelligent construction technology and enterprise green management within construction enterprises' "dual carbon" transformation framework. By integrating insights from previous literature and empirical data, we identify key indicators such as promotion strength, relevant codes and standards, application of intelligent platforms, and introduction of high-end design teams as pivotal in advancing green management practices. The descriptive analysis reveals a highly educated and experienced workforce predominantly from state-owned enterprises, emphasising the role of human capital in sustainable construction. Correlation analysis highlights the interconnectedness of various indicators, reinforcing the synergistic effects of comprehensive promotion, advanced technological applications, and stringent regulatory standards. Reliability and robustness analyses confirm the internal consistency and stability of the measurement indices, validating the findings. The willingness model indicates a strong inclination among enterprises to adopt intelligent technologies driven by competitive pressure, policy environment, technical advantages, and organizational culture. Aligning with previous research, this study underscores the critical role of cohesive strategies in achieving sustainable construction practices. The findings contribute to the growing literature on intelligent construction technology and green management, offering valuable insights for policymakers and industry stakeholders aiming to achieve dual carbon transformation goals.

Keywords: Intelligent construction technology, green management, Dual carbon transformation; sustainable construction, Promotion strength, regulatory standards

INTRODUCTION

In recent years, the strategic positioning of green management within construction enterprises has been profoundly influenced by the "dual-carbon" policy, a global initiative to achieve carbon neutrality and reduce carbon emissions. As the world shifts towards an economy dominated by the information industry, the construction sector is at the forefront of this digital and intelligent transformation. Similarly, China has launched the "Strategy on Promoting Intelligent Construction" and issued guidance to synergies intelligent construction with industrialization, setting an ambitious goal to be a world leader in intelligent construction by 2035 (Li et al., 2022).

However, despite these advancements, China's construction industry still needs to catch up in adopting new information technologies, ranking just above agriculture in digitization. The transition towards low-carbon, green construction practices and exploring new operational models, such as platformization, customization, networking, scaling, and globalization, are pivotal for the industry's contribution to the "dual-carbon" goals (Lai & Yan, 2019).

The importance of green management has been underscored by the ecological damage and resource depletion resulting from traditional industrial practices. The global consensus on sustainable development necessitates the adoption of green technological innovations and green economies (Wen, 2022; Eid Hamood & Thiruchelvam, 2023). For China, a developing nation with a population of 1.4 billion, the challenge lies in balancing economic development with environmental sustainability. Green innovation has become a critical driver for the green development of the construction industry, essential for building a socialist ecological civilization, promoting enterprise transformation and upgrading, and ensuring high-quality development (Chen et al., 2019). Digital transformation has the potential to revolutionize urban governance, enabling energy conservation and emission reductions across the entire industry chain and life cycle. It aligns with the objectives of achieving carbon peak and carbon neutrality (Ma, 2023).

Theoretical research and practical discussions have increasingly focused on the synergy between intelligent construction technology and green management within the context of "dual-carbon" transformation. Integrating these technologies with green management practices can enhance enterprises' core competitiveness, promote sustainable development, and align with national strategies for economic reform and development (Zheng, 2022).

The research draws on theories of core competitiveness, eco-economics, industrial innovation, green competition, and green construction management to comprehensively understand the field. The methodology combines questionnaires, interviews, and case studies to quantify the synergistic development of intelligent construction technology and green management, enriching the theoretical framework and offering practical insights (Lai, 2022). By focusing on the practical elements of questionnaire data collection, model construction, and case application, this research aims to create actionable strategies for the synergistic development of intelligent construction and green management (Ma, 2023; Ahmad et al., 2019).

Research Objectives

This research intends to focus on three primary aspects:

1. To clarify the research scope of intelligent construction, enterprise green management, and core competitiveness enhancement.
2. To explore the influence of domestic intelligent construction application levels and experiences on constructing enterprise green management systems.
3. To provide suggestions for enhancing technological innovation and efficiency in intelligent construction and deepening the synergy between intelligent construction and green management within the context of the "dual-carbon" strategy

Research Questions

1. What is the importance and necessity of building a synergistic mechanism for integrating intelligent construction technology and green management in construction enterprises?
2. What factors influence the ability level of the synergistic mechanism of green management of intelligent construction technology integration in enterprises?
3. How can the sustainable development of the synergy between intelligent construction technology and green management be achieved in line with the "dual-carbon" context?

By emphasising the strategic development and green management of enterprises through intelligent construction technology, this research aims to integrate green management, intelligent technology application, and sustainable development at both theoretical and applied levels (Wang, 2023).

LITERATURE REVIEW

The literature on integrating intelligent construction technology and enterprise green management within the context of the "dual-carbon" strategy is rich and multi-faceted, exploring various dimensions of this transformative approach. A primary focus has been on the strategic positioning of green management in response to the "dual-carbon" policy, emphasizing the necessity for construction enterprises to adopt sustainable practices. Integrating intelligent construction technology into green management has been seen as a pivotal strategy for overcoming these challenges. The use of intelligent technology, such as big data, artificial intelligence, and blockchain, has been recognized for its potential to enhance transparency and efficiency in green management practices (Wang, 2023). Another significant aspect of this literature is the exploration of the internal and external factors influencing enterprises' willingness to adopt intelligent construction technologies for green management. Organizational culture, technological advantages, and resource conditions are identified as critical internal factors (Yang, 2022; Wang, 2022).

External factors such as competitive pressure and policy support also play a crucial role. Competitive pressure drives enterprises to adopt intelligent construction technologies to gain a competitive edge (Li, 2022). However, the literature also highlights the challenges posed by these external factors. For instance, excessive reliance on government subsidies can lead to inefficiencies and even crowd out private investments in green technologies (Ma, 2023). The use of intelligent systems for real-time monitoring and data analysis allows for better decision-making and more effective management of resources (Wang, 2022). Case studies within the literature provide practical insights into implementing these technologies. These case studies illustrate the practical benefits of integrating intelligent construction technologies with green management practices and provide valuable lessons for other enterprises looking to undertake similar transformations (Guan & Liu, 2021).

Despite the comprehensive insights the existing literature provides, several research gaps still need to be addressed to fully understand the integration of intelligent construction technology and green management. Additionally, the literature primarily focuses on large enterprises and government-led initiatives, often overlooking the challenges and opportunities small and medium-sized enterprises (SMEs) face in adopting intelligent construction technologies. Another notable gap is the limited exploration of the long-term sustainability and scalability of integrated intelligent construction and green management systems.

METHODOLOGY

Main Perspectives

This study centers on the "Synergy between Intelligent Construction Technology and Green Management of Enterprises - Based on the Perspective of 'Dual-Carbon' Transformation of Construction Enterprises." The primary focus is on how the policy background and market conditions related to the "dual-carbon" strategy influence the transformation of critical industries, particularly the construction sector. Given the nascent stage of these transformations, the study evaluates enterprises' willingness and ability to adopt these changes, aiming to improve the effectiveness of strategies for synergizing intelligent construction and green management.

Quantitative Analysis Method

The quantitative analysis in this study is divided into two main parts: analysing the level of enterprise application of intelligent technology to build green management cooperative mechanisms and assessing the willingness of enterprises to apply intelligent technology for this purpose. This

evaluation is based on three hypotheses. The first hypothesis is that enterprises have already established green management systems and actively seek intelligent construction and transformation within the "dual-carbon" strategy. The second hypothesis suggests that enterprises adopt a standardised production and operation mode, where decision-making, design, production, construction, and operation. The third hypothesis, based on the significant number theorem and high-quality sample selection, the questionnaire survey data will represent and effectively study the synergy between intelligent construction and green management in construction enterprises.

The questionnaire will be distributed in two stages. The first stage involves testing with three enterprises in a specific city to refine the questionnaire. The second stage involves a broader survey targeting executives, project managers, and employees of ten significant enterprises nationwide, aiming to collect at least 500 valid responses. Additionally, an interview outline will gather qualitative data on the importance of green management, the application of intelligent construction technologies, and factors influencing collaboration willingness.

Case Analysis Method

The case analysis focuses on two iconic intelligent construction technology application scenarios: the assembly building green management supply chain construction and the intelligent site green management application. The study evaluates the benefits of integrating intelligent construction technology with green management by mapping, researching, and analysing these cases. It discusses feasible mechanisms for achieving green management under the "dual-carbon" strategy. This comprehensive methodology ensures that the study addresses the theoretical underpinnings and provides actionable insights for practical implementation in the construction industry.

Ethical Considerations

Ethical considerations are paramount in this study to ensure the integrity of the research process and the protection of participants. Participants will be informed about the purpose of the study, the nature of their involvement, and their right to withdraw from the study at any point without any repercussions. Participants ' confidentiality and anonymity will be strictly maintained. Data collected will be stored securely and only accessible to the research team. Additionally, the study will adhere to ethical guidelines for conducting research involving human subjects, as outlined by relevant institutional review boards and ethical committees.

RESEARCH RESULTS

Research Questions and Progress

Main Research Questions

This research centres on the theme of "Synergy between Intelligent Construction Technology and Green Management of Enterprises - Based on the Perspective of 'Dual-Carbon' Transformation of Construction Enterprises", and the main points are as follows: It closely matches the "dual-carbon" transformation of construction enterprises in recent years. Based on the consideration of enhancing the core competitiveness of enterprises and adapting to the market development trend, building and deepening the application of green management mechanisms by relying on the initiatives of ESG, equity investment in new industries and intelligent transformation of production and construction have become the key strategic transformation direction of relevant enterprises. However, considering that the relevant mechanism is not perfect enough at the starting stage, analysing the aspects of transformation willingness and ability evaluation will help improve the effectiveness of the enterprise's intelligent construction synergistic green management strategy.

Research Progress of Quantitative Analysis

In the "analysis of the level of enterprise application of intelligent technology to build green management synergistic mechanism", this study uses the questionnaire survey method to collect information and data. The study is subdivided into three phases: (1) the first phase of the questionnaire test is selected from any of the S city's major (more than three) enterprises that have been applying intelligent building technology. (2) In the second stage, on the optimised questionnaire, selecting the enterprise executives (≥30%), project management (≥30%) and relevant position workers of 10 significant enterprises that have applied intelligent building technology and proposed the concept of integration of green management. (3) The third stage is the construction stage of the cloud object model. According to the requirements of the topic and the research schedule, the preliminary work of (1) and (2) in "Analysis of the Level of Green Management Collaboration Mechanisms Built by Enterprises Using Intelligent Technology" has been completed by the beginning of March 2024, in which the questionnaire survey of the two has been combined into a preliminary questionnaire survey (220 valid questionnaires were recovered) for the sake of convenience. In the next stage, the author plans to complete the formal research in (2) and the expert interviews in (3) with the advantages of the supervisor and work resources and construct a cloud of the level of enterprises applying intelligent technology to build green management collaborative mechanisms that can be used for practical evaluation based on the perfect indicator system.

The study is subdivided into two phases: (1) adopting the mature scale for evaluating the willingness to apply green management in the construction industry and constructing a structural equation model for "Analysis of Enterprises' Willingness to Apply Intelligent Technology to Build Green Management Collaboration Mechanisms". (2) Based on all the research results mentioned above, we selected Enterprise Z and its subordinate Project A, which is a leading enterprise in intelligent construction and green management. The following section will briefly introduce descriptive statistics, correlation analysis, hypothesis testing and robustness testing for the corresponding results.

Acquisition of Important Indicators Based on Literature

This paper combines the research of previous scholars on the development level of new building industrialization and its evaluation system in related fields. It analyses and extracts the related indexes through literature reading. In order to make an objective and accurate evaluation of the development level of new building industrialization, it is necessary to establish a corresponding evaluation system, and the construction principle of the evaluation index system is the most crucial part of the evaluation system as shown in Table 1.

Table 1 Preliminary Indicator Extraction for Analyzing the Level of Green Management Synergy Mechanism Based on Literature Review

Description	Literature Citation	Indicator Extraction
The greater the degree of promotion and publicity for new building industrialization, the more favourable it is for its development.	Hou et al., (2021)	P1 Strength of promotion
Having specific institutions and relevant supporting policy documents can guide the development direction of new building industrialization; in the pre-decision period, using remote sensing intelligent platform to quickly extract the elemental information of the corresponding location from massive images, generating A.I. maps for	Wang et al., (2021)	P2 Relevant Specifications and Standards P3 Application of Remote Sensing Big Data Intelligence Platform

visualization and display, and carrying out online analysis can provide a basis for decision-making for subsequent design.		
The analysis should find problems in decision-making and use this as a starting point to build an intelligent macro decision support system. This system would provide government departments with policy formulation and enterprises with cutting-edge information on industry development.	Wu, Jing (2018)	P4 Application of Intelligent Macro Decision Support System
The existing industry design level, as well as the design quality, has not been able to meet people's needs, and it is necessary to continuously improve the overall quality and business level of the personnel engaged in the design industry and to organise more professional skills training and seminars; the Ministry of Housing and Construction has pointed out in the relevant documents that the degree of application of autonomous and controllable digital design software has not yet been paid attention to, and that the BIM-related software, the intelligent review of the design drawings, collaborative design of various professions.	Mao Chao (2021)	P5 Introduction of high-end design team P6 Application of independently controllable digital design software P7 Degree of integrated design P15 Integration of decoration
Optimisation of production and processing technology and automation of processes can significantly improve production efficiency and precision; the degree of greenhouse gas emissions during the building production stage can reflect the degree of energy saving and green environmental protection from the side.	Mao Chao (2021)	P18 Adoption of advanced operation and maintenance methods P11 Degree of carbon emission
In the process of project construction, new technologies should be fully used to realise the collection, storage, analysis and transmission of information to realise the all-round monitoring of the entire construction site and, at the same time, assembly construction, 3D printing and other technologies also provide support for the improvement of the entire construction environment; the Ministry of Housing and Construction has pointed out that in the process of project construction, the machinery and equipment should be energy-saving and environmentally friendly, and should be as energy-saving and environmentally friendly as possible, in addition to conforming to the basic requirements of the state and the industry.	Mao Chao (2021)	P10 Use of Intelligent Production Equipment P13 Application of Intelligent Site Service Platform
Transforming the existing management style, changing the human-oriented into a combination of monitoring with information technology and intelligence can not only provide users with a safer living environment but also increase the service life of the building to a certain extent; the application of the property management service platform is not	Mao Chao (2020)	P19 Application of Intelligent Property Service Platform P17 The use of intelligent operation and maintenance equipment

only a fusion of various information technologies but also reflects the care for the occupants.		P18 Adoption of Advanced Operation and Maintenance Methods P19 Application of Intelligent Property Service Platform P21 Resident Satisfaction
In the design stage, the focus should be on environmental adaptability, site selection and coordination of the transportation system to ensure its sustainable development; the impact of the degree of integrated design on the design stage should be considered critically, and the application of CAD technology can realise the effective transmission and storage of data between different design stages and different design disciplines of the whole project, making the information communication efficiency of the whole design stage substantially improved.	Li, Xiaoting (2019)	P8 Coordination between site selection and transportation system P7 Degree of integrated design P24 Environmental adaptability
Water resource utilisation has a significant impact on the production stage.	Xu Yumeng (2015)	P12 Degree of water resource utilization
Decoration integration not only makes users more comfortable but also more environmentally friendly, safe, and energy efficient; at the same time, it should also reasonably use renewable energy sources such as solar energy to provide part of the project's energy according to the natural location of the project itself and the local climatic conditions, to improve the overall efficiency of energy utilisation.	Ziqi Zhang (2019)	P15 Integration of renovation P16 Application of clean energy
Recognising the green building market in engineering and construction affects green construction management.	Edwin et al. (2009)	P25 Public evaluation of the situation
New methods and technologies can affect the efficiency of green construction management if they create organisational and procedural difficulties.	Häkkinen Tet al. (2011)	P14 Use of energy efficient specialized equipment
The main reason for hindering green construction management is the need for more awareness of green construction among the responsible parties at different stages of engineering and construction projects.	S Anyango（2014）	P1 promotion efforts
The responsible subject in the design stage needs more professional ability to plan the overall situation in the design stage. The long-term effects on the design need to be considered, thus affecting green operation management.	Mohammad（2014）	Introduction of P5 high-end design team
Because stakeholders are unaware of green construction, the corresponding investment will be limited, hindering its management.	Asif & Mansoor, (2024)	P1 promotion efforts P23 supervision and enforcement mechanism

Green awareness of employees, their technical level, managers' management ability, green culture, relevant laws, regulations and policies, industry technical specifications, technological innovation, management system and mechanism, and recognition of other participants will affect green construction management.	Wang Xiangyun et al. (2017)	P1 promotion efforts P2 related specifications and standards P23 supervision and enforcement mechanism P25 Public evaluation
Relevant government policies, personnel's green consciousness, personnel's technical level and technical standard system will affect green construction management.	Shi Jian (2018)	P2 related specifications and standards P24 environmental adaptability
Government policies, corporate social responsibility and industry technical standards can drive enterprises to build green.	Liu Xuezhi (2019)	P2 related specifications and standards P25 Public evaluation
The social responsibility of enterprises, the professional ability of employees and the support of technology development will affect the development of green construction.	Halou et al., (2019)	P1 promotion efforts P25 Public evaluation
Establishing a green strategy and culture, employees' green consciousness, social responsibility, professional ability, application and development of information technology, industry technical standards, laws and regulations issued by the government, and market recognition will all affect green construction.	Chen Qiu (2020)	P1 promotion efforts P2 related specifications and standards P25 Public evaluation
The development of green construction will be affected by industry technical specifications, government laws and regulations, market acceptance, personnel technical and management levels, and cultural factors.	Xie Qiang et al. (2020)	P2 related specifications and standards P25 Public evaluation
The policies issued by the government, the technical level of employees, the ability to develop technology, industry technical standards, the application of information technology, and other factors will affect the development of green construction.	Zhao Weishu et al. (2021)	P2 related specifications and standards
The professional level of enterprise employees, the ability to update technology, and the setting of technical specifications of supervision mechanism will affect the productivity of construction enterprises.	Sun Guoshuai et al. (2021)	P2 related specifications and standards P23 supervision and enforcement mechanism
The enterprise's green strategy, management system, and support for scientific and technological innovation will affect the quality of green building products.	Zhang et al. (2019)	P1 promotion efforts
Management mechanisms, the professional technical level of employees, employees' green awareness, recognition of other participants, BIM	Liet al. (2022)	Application of P6 Self-Controllable Digital Design Software

technology application, and other factors will affect the quality of green buildings.		P25 Public evaluation
Intelligent construction technology in the construction stage mainly includes building safety, disaster early warning, building resource management, building site management and building monitoring.	Matej et al. (2019)	Application of P13 Smart Site Service Platform
This paper studies the BIM+ intelligent construction technology in Tibet railway, based on BIM, the Internet of Things, big data, and other technologies. This technology mainly includes the timely collection, transmission, and analysis of primary, environmental, and process data, the management and regulation of construction progress and material elements, and the management of construction quality and safety.	Wang Fei et al. (2020)	Application of P6 Self-Controllable Digital Design Software Application of P9 New Building Materials P22 recycling degree of construction waste
This paper analyses and summarises the supporting technologies involved in the intelligent construction of railway tunnels, such as the identification and processing technology of surrounding rock parameters through signal acquisition, processing and transmission, the three-dimensional space and positioning technology of tunnels based on BIM, three-dimensional scanning and robot technology, the big data processing and sharing technology and the intelligent decision control technology of tunnel construction related equipment based on artificial intelligence.	Liu Feixiang (2019)	Application of P6 Self-controllable Digital Design Software Application of P20 Intelligent Operation and Maintenance Management System Platform

Based on the literature mentioned above refining and the systematic analysis conducted by the author through public information, practice and training, expert consultation and professional learning, the index system of "Analysis on the Level of Enterprises Applying Intelligent Technology to Build Green Management Collaboration Mechanism" is preliminarily mentioned in Table 2.

Table 2 Preliminary Index System for Level Analysis of Green Management Collaboration Mechanism

Serial number	Index content
1	Promotion strength
2	Relevant codes and standards
3	Application of Remote Sensing Big Data Intelligent Platform
4	Application of Intelligent Macro Decision Support System
5	Introduction of high-end design team
6	The Application of Self-controllable Digital Design Software
7	Degree of integrated design

Serial number	Index content
8	Coordination between site selection and transportation system
9	Application of new building materials
10	Use of intelligent production equipment
11	Carbon emission degree
12	Utilization degree of water resources
13	Application of Smart Site Service Platform
14	Use of high-efficiency and energy-saving special equipment
15	Decoration integration
16	Application of clean energy
17	Use of intelligent operation and maintenance equipment
18	Adopt advanced operation and maintenance mode
19	Application of Intelligent Property Service Platform
20	Application of Intelligent Operation and Maintenance Management System Platform
21	Resident satisfaction
22	Degree of recycling of construction waste

Optimization of index system based on expert opinions

In order to further improve and correct the preliminary identified influencing factors, this paper invited eight people who have participated in green building management or scholars who have participated in green building-related research for face-to-face or online interviews. The main content of the interview is to let experts judge the rationality of influencing factors according to their own experience and ask experts whether they need to and other influencing factors. The summary data is shown in the Table 3.

Table 3 Expert Evaluation Results of Preliminary Index System for Level Analysis of Green Management Collaboration Mechanism

Serial number	Index content	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Recognition
1	Promotion strength	√	√	√	√	√	√	√	√	100%
2	Relevant codes and standards	√	√	√	√	√	√	√	√	100%

Serial number	Index content	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Recognition
3	Application of Remote Sensing Big Data Intelligent Platform	√	×	√	√	×	√	√	√	75%
4	Application of Intelligent Macro Decision Support System	√	√	√	√	√	×	√	×	75%
5	Introduction of high-end design team	√	√	√	√	√	√	√	√	100%
6	The Application of Self-controllable Digital Design Software	√	√	√	×	√	√	√	√	88%
7	Degree of integrated design	×	√	√	√	√	√	√	√	88%
8	Coordination between site selection and transportation system	√	√	×	√	√	√	√	×	75%
9	Application of new building materials	√	√	√	√	√	√	√	√	100%
10	Use of intelligent production equipment	√	√	√	√	√	√	√	√	100%
11	Carbon emission degree	√	√	√	√	√	√	√	√	100%
12	Utilization degree of water resources	×	√	√	√	√	√	√	×	88%
13	Application of Smart Site Service Platform	√	√	√	√	√	√	√	√	100%
14	Use of high-efficiency and energy-saving special equipment	√	×	√	√	√	√	×	√	75%
15	Decoration integration	√	√	√	√	√	√	√	√	100%

Serial number	Index content	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Recognition
16	Application of clean energy	√	√	×	√	√	√	√	×	75%
17	Use of intelligent operation and maintenance equipment	√	√	√	√	√	√	√	√	100%
18	Adopt advanced operation and maintenance mode	√	√	√	√	√	√	√	√	100%
19	Application of Intelligent Property Service Platform	√	√	√	√	√	×	√	√	88%
20	Application of Intelligent Operation and Maintenance Management System Platform	√	√	√	√	√	√	√	√	100%
21	Resident satisfaction	√	√	√	√	√	√	√	√	100%
22	Degree of recycling of construction waste	√	√	√	√	√	√	√	√	100%

From the results, the expert recognition of the 22 influencing factors is 75% or above, which shows that the rationality of these 22 influencing factors meets the requirements. In addition, for the following analysis, each index is coded. Update the "Preliminary Index System for Level Analysis of Green Management Collaboration Mechanism" as shown in the Table 4.

Table 4 Second Edition Index System for Level Analysis of Green Management Collaboration Mechanism

S.N	Index content	Index interpretation	Index coding
1	Promotion strength	Publicity and attention to new building industrialization.	P_1
2	Relevant codes and standards	Including clear modulus standards and acceptance specifications.	P_2
3	Application of Remote Sensing Big Data Intelligent Platform	Using the remote sensing intelligent platform, the specific feature information can be extracted from massive images quickly, timely and at low cost,	P_3

S.N	Index content	Index interpretation	Index coding
		and the AI map can be generated for visual display and online analysis.	
4	Application of Intelligent Macro Decision Support System	Provide government departments with the formulation of development policies and provide enterprises with insight into the frontier of industry development.	P_4
5	Introduction of high-end design team	Conduct skills training for designers of related majors to improve the design level and quality of the whole industry.	P_5
6	The Application of Self-controllable Digital Design Software	Including BIM software, collaborative design platform of various design majors, integrated decoration design, etc.	P_6
7	Degree of integrated design	CAD technology is applied in different design stages of the whole project to complete the complete transmission of data of various design majors.	P_7
8	Coordination between site selection and transportation system	Coordination between the selected address and local traffic.	P_8
9	Application of new building materials	Including the use of new glass materials, glass fiber composites and other materials.	P_9
10	Use of intelligent production equipment	The integration of the whole production process can improve the efficiency and accuracy.	P_{10}
11	Carbon emission degree	Greenhouse gas emissions in the construction production stage.	P_{11}
12	Utilization degree of water resources	Utilization of water resources in production stage.	P_{12}
13	Application of Smart Site Service Platform	Through information technology, information collection, storage, analysis and transmission are realized, so as to monitor the whole project in all directions.	P_{13}
14	Use of high-efficiency and energy-saving special equipment	The mechanical equipment used in the project construction process should be as energy-saving and environmentally friendly as possible besides meeting the basic requirements of the country and industry.	P_{14}
15	Decoration integration	Industrial construction integrating decoration and main structure.	P_{15}

S.N	Index content	Index interpretation	Index coding
16	Application of clean energy	According to the natural location of the project itself and the local climate conditions, the rational use of renewable energy can provide some energy for the project.	P_{16}
17	Use of intelligent operation and maintenance equipment	Including construction robots, intelligent transportation robots and intelligent concrete pumping equipment.	P_{17}
18	Adopt advanced operation and maintenance mode	Assembled construction, 3D printing and other technologies have improved the construction environment, and the safety and quality of construction have also improved.	P_{18}
19	Application of Intelligent Property Service Platform	Property management companies should integrate information technologies such as the Internet of Things and big data into the platform to reduce costs and improve the owner experience.	P_{19}
20	Application of Intelligent Operation and Maintenance Management System Platform	Automatic operation and maintenance management is used instead of manual inspection, and intelligent technology is integrated into the platform to realize information and all-weather intelligent monitoring.	P_{20}
21	Resident satisfaction	User satisfaction with new building products.	P_{21}
22	Degree of recycling of construction waste	The dismantled building components are classified and recycled, and some components can be reused after corresponding testing.	P_{22}
23	Supervision and enforcement mechanism	Specialized institutions conduct unified management and are equipped with relevant operational documents.	P_{23}
24	Acclimatization	The performance of a piece of equipment in its own state under extreme conditions during its life cycle, thus realizing the desired capability.	P_{24}
25	Public Evaluation	Public evaluation of the new industrialization of construction.	P_{25}

Analysis on the level of enterprises' application of intelligent technology to build green management synergy mechanism

Descriptive analysis of questionnaires

The descriptive analysis of the questionnaire is to analyze the basic information of the respondents, and the basic information of the respondents of 220 valid questionnaires is shown in the Table 5.

Table 5 Preliminary questionnaire research for the analysis of the level of green management synergy mechanism - basic information of respondents

No.	Question	Options	Number of people (person)	Percentage (%)
1	Gender	Male	183	83.18%
		Female	37	16.82% of the total
2	Educational attainment	Specialized and below	23	10.45
		Bachelor's Degree	86	39.09% Graduate and above
		Graduate and above	111	50.45% of the total
3	Years of working experience	1-3 years	119	54.09
		4-6 years	67	30.45% 7-9 years
		7-9 years	31	14.09% 10 years and above
		10 years and above	3	1.36 percent
4	Position in the enterprise	General Employee	98	44.55
		Grassroots managers	86	39.09
		Middle management	29	13.18
		Top Management	7	3.18%
5	Enterprise Size	Small business (total assets less than 50 million)	11	5.00%
		Medium-sized enterprises (total assets of 50 million to 80 million)	31	14.09 percent
		Large Enterprises (total assets greater than $80,000,000)	178	80.91% of the total assets of medium-sized enterprises
6	Nature of the enterprise	State-owned enterprise	182	82.73% Private enterprises
		Private enterprise	38	17.27% Other
		Other	0	0.00%

Regarding education level, more than half of the respondents have postgraduate education or above, accounting for 50.45%, 39.09% have bachelor's degrees, and only a few respondents have specialised education or below. Hence, the overall education level is high. Most of them are researchers who have participated in green construction management-related research, so their questionnaires are representative.

Regarding the type of work unit, 82.73% of the respondents are from state-owned enterprises, and the rest are from private enterprises. First of all, state-owned enterprises are the leading enterprises in the construction industry, with more extensive scale and more muscular strength, and relatively have the resources, ability and ability to systematically carry out the research and application of green construction and intelligent construction, which indicates that the questionnaire data have a certain degree of reliability. The results of correlation analysis show in Table 6, a small number of weakly correlated variables in the overall model, and its model validity needs to be further demonstrated by combining the reliability analysis, convergent validity, and discriminant validity in the later section.

Correlation Analysis

Table 6 Preliminary questionnaire survey for analyzing the level of green management synergistic mechanism-indicator correlation analysis

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18	P19	P20	P21	P22	P23	P24	P25
P1	1.000	0.37	0.555	0.688	0.588	0.05	0.112	0.110	0.09	0.04	-0.06	0.03	0.03	0.04-0.07	-0.03	-0.03	0.03-0.03	0.05-0.03	0.03-0.05-0.03	-0.02	0.002-0.002	0.009-0.009	0.009-0.009	0.009-0.009	-0.09
P2	0.37	1.000	0.666	0.555	0.511	0.04	0.08	0.05	0.06	0.06	-0.06	0.09	0.09	0.01-0.04	0.04-0.006	-0.06	0.06-0.006	0.12-0.100	-0.07	0.07-0.100	0.10-0.007	0.07-0.006	0.006-0.009	0.09-0.009	-0.08
P3	0.555	0.66	1.000	0.441	0.333	0.10	0.115	0.111	0.116	0.10	-0.113	0.04	0.07	0.00	0.000-0.006	-0.06	0.06-0.006	0.05-0.03	-0.03	0.03-0.03	0.003	0.003	0.002	0.002	0.03
P4	0.688	0.55	0.441	1.000	0.888	0.02	0.07	0.07	0.05-0.02	0.05-0.06	0.04-0.07	0.02	0.12	-0.05	-0.06	-0.06	0.06-0.06	-0.03	0.03-0.03	-0.04	0.004-0.004	0.12-0.12	0.12-0.12	0.13-0.14	-0.14
P5	0.558	0.51	0.333	0.888	1.000	0.02	0.006	0.006	0.05-	-0.06	-0.05	-0.02	0.12	0.12-	0.07-	-0.	0.09-	-0.06	0.06-	0.01-	0.002-	-0.11	0.111-	0.111-	-0.

										0.01					0.07	0.09	9	0.09		0.06	0.02	0.11		0.04	0.11	0.11	1	1
P6	0.05	0.04	0.10	0.02	0.02	1.00	0.88	0.86	0.62	0.60	-0.03	0.05	0.14	0.04	0.04	0.04	0.01	0.00	0.01	0.03	-0.03	-0.05	-0.03	0.05	-0.03	-0.03	-0.03	-0.03
P7	0.12	0.08	0.15	0.07	0.06	0.88	1.00	0.95	0.54	0.67	-0.01	0.05	0.19	0.06	0.01	0.01	-0.03	0.03	-0.03	-0.05	-0.03	-0.05	-0.03	0.05	-0.03	-0.03	-0.03	-0.03
P8	0.10	0.05	0.11	0.05	0.05	0.86	0.95	1.00	0.54	0.69	-0.02	0.06	0.18	0.06	-0.06	-0.01	-0.05	0.01	0.03	-0.03	-0.05	-0.05	-0.03	0.05	-0.03	-0.03	-0.03	-0.03
P9	0.09	0.06	0.16	-0.02	-0.01	0.62	0.54	0.54	1.00	0.63	0.03	0.03-0.02	0.10	0.10-0.02	0.02-0.02	-0.04	0.03-0.02	0.01	0.05	0.05-0.11	0.11-0.11	-0.11	-0.09	-0.08					
P10	0.04	0.02	0.10	-0.04	-0.06	0.60	0.67	0.69	0.63	1.00	-0.08	0.02	0.06	0.02	-0.02	-0.07	0.07-0.07	0.02	0.04	0.04-0.03	0.03-0.03	-0.03	-0.02	-0.02					
P11	-0.06	-0.06	0.06-0.06	-0.07	-0.05	-0.03	0.03-0.01	-0.02	0.03	0.03-0.08	1.00	-0.07	0.01	0.01-0.05	0.00	0.00	-0.05	-0.11	-0.10	0.03	0.02	0.00	0.03	0.01					
P12	0.03	0.09	0.04	0.02	-0.02	0.05	0.05	0.06	0.06-0.02	0.02	0.02-0.02	1.00	0.23	0.31	-0.05	-0.05	0.05-0.05	0.00	0.03	0.03	-0.03	-0.06	0.06-0.06	0.07-0.08	-0.08					
P13	0.04	0.01	0.07	0.12	0.12	0.14	0.19	0.18	0.10	0.06	0.01	0.23	1.00	0.44	-0.02	-0.02	0.11	0.10	0.10-0.07	0.07-0.08	0.08-0.01	0.00	0.00-0.04	-0.04	-0.05					

P14	-0.07	-0.04	0.00	0.000-0.005	0.005-0.005	0.04	0.006	0.006	-0.006	0.02	0.002-0.002	0.31	0.444	1.00	-0.006	-0.06	0.007	0.005	0.09	0.10	-0.003	-0.003	-0.003	-0.001	-0.01
P15	-0.03	-0.06	-0.006	-0.006	-0.009	0.04	0.001	-0.001	0.001-0.010	-0.07	0.000	0.000-0.005	-0.002	-0.06	1.100	1.00	0.666	0.664	-0.23	-0.118	0.118	0.117	0.117	0.117	0.117
P16	-0.03	-0.06	-0.006	-0.006	-0.009	0.04	0.001	-0.001	0.001-0.010	-0.07	0.000	0.000-0.005	-0.002	-0.06	1.100	1.00	0.666	0.664	-0.23	-0.118	0.118	0.117	0.117	0.117	0.117
P17	-0.05	-0.12	0.05-0.12	-0.003	-0.006	0.01	0.001-0.003	-0.05	0.005-0.003	0.03-0.08	0.008-0.005	0.005-0.005	0.111	0.07	0.666	0.66	1.100	0.996	-0.20	-0.115	0.005	0.004	0.006	0.111	0.06
P18	-0.03	-0.10	-0.003	-0.003	-0.006	0.00	0.000-0.003	-0.05	-0.002	-0.07	-0.005	0.000	0.110	0.05	0.664	0.64	0.996	1.100	-0.19	-0.114	0.002	0.001	0.003	0.008	0.03
P19	-0.02	-0.07	0.007-0.003	-0.004	-0.001	0.01	0.001	0.001	0.001	0.01	0.002-0.111	0.003	0.003-0.007	0.09	0.009-0.233	-0.23	0.233-0.233	0.220-0.195	1.00	0.955	0.442	0.442	0.542	0.399	0.52
P20	-0.02	-0.10	-0.006	-0.004	-0.002	0.03	0.003	0.003	0.005	0.05	-0.110	0.003	0.003-0.008	0.10	0.100-0.188	-0.18	0.188-0.188	0.150-0.144	0.95	1.000	0.311	0.300	0.466	0.333	0.44
P21	-0.09	-0.07	0.003	0.003-0.112	-0.111	0.11-0.11-0.04	-0.04	0.004-0.004	0.004-0.004	-0.03	0.003	0.003-0.006	0.006-0.001	0.01-0.01-0.03	0.188	0.18	0.005	0.005	0.42	0.311	1.000	1.000	0.997	0.996	0.95
P22	-0.	-0.	0.003	0.003-	-0.111	0.11-	0.005-	0.005-	0.005-	0.005-0.005-	0.002	0.002-	0.000	0.000-	0.177	0.17	0.004	0.001	0.42	0.300	1.000	1.000	0.996	0.995	0.94

	09	06		0.12		0.05	0.005	0.005	0.005	0.05-0.11		0.006		0.03											
P23	-0.09	-0.09	0.002	-0.13	-0.111	-0.03	-0.003	-0.003	0.003-0.003	-0.002	0.000	0.000-0.007	-0.004	-0.01	0.117	0.17	0.006	0.003	0.54	0.446	0.97	0.96	1.00	0.98	0.999
P24	-0.10	-0.09	0.002	0.002-0.13	-0.13	0.13-0.13	0.003-0.003	0.003-0.003	0.003-0.003	0.09-0.02	0.003	0.003-0.008	0.008-0.004	-0.03	0.25	0.25	0.11	0.08	0.39	0.333	0.96	0.95	0.98	1.00	0.998
P25	-0.09	-0.08	0.03	0.003-0.14	-0.111	-0.03	-0.003	0.003-0.003	0.003-0.003	0.08-0.02	0.001	0.001-0.008	0.008-0.005	0.01-0.08-0.02	0.117	0.17	0.006	0.003	0.52	0.444	0.95	0.94	0.99	0.98	1.000

Robustness Analysis

The reliability analysis of the questionnaire mainly looks at the Cronbach Alpha coefficient of the questionnaire in the analysis process, and the larger the Cronbach Alpha coefficient is, the higher the credibility of the measurement index is shown in Table 7. Measuring the indicators on the developmental level of new building industrialization under the perspective of intelligent construction.

Table 7 Preliminary questionnaire research for the analysis of the level of green management synergy mechanisms - Reliability test

Cronbach Alpha	Cronbach Alpha based on standardized items	Number of items
0.794	0.737	25

After the reliability test is passed, the entire data is tested for validity. In the actual research process, the questionnaire is generally analysed in terms of content and data. In the design process of the questionnaire, firstly through the literature reading combined with other scholars' research, and secondly with the tutor and fellow students for discussion and modification, to finally get the questionnaire, the above steps can be considered that the questionnaire in the content validity of the effect of the questionnaire in the better. Referring to the research of related papers, the validity analysis of multivariate questionnaires can be replaced by expert validity evaluation; we will not carry out the validity test here; in the formal questionnaire research, the author will pay attention to the results of the validity analysis and calibrate the model concerning the validity and other essential indexes.

Willingness of Enterprises to Apply Intelligent Technology to Build Green Management Collaboration Mechanisms Analysis

Descriptive analysis of the questionnaire

This pre-survey questionnaire adopts the same "basic information" item setting as the part mentioned above in the 4.2 questionnaire. Also, it uses a Likert five-level scale to analyse specific indicators, but the sampling object, research time, research objectives, and data processing methods are different. Table 8 shows preliminary questionnaire survey of green management collaborative willingness analysis-basic information of respondents.

Table 8 Preliminary Questionnaire Survey of Green Management Collaborative Willingness Analysis-Basic Information of Respondents

Question	Option	Number of people (persons)	Proportion (%)
Gender	Man	79	77.45%
	Woman	23	22.55%
Degree of education	College degree or below	3	2.94%
	undergraduate course	43	42.16%
	Graduate students and above	fifty-six	54.90%
working life	1-3 years	62	60.78%
	4-6 years	35	34.31%
	7-9 years	4	3.92%
	10 years and above	1	0.98%
The position of the enterprise	Ordinary employee	61	59.80%
	first line managers	33	32.35%
	Middle manager	7	6.86%
	Top management	1	0.98%
The scale of the enterprise	Small enterprises (total assets less than 50 million)	4	3.92%
	Medium-sized enterprises (total assets of 50 million-800 million)	47	46.08%
	Large enterprises (total assets greater than 800 million)	51	50.00%
Nature of the enterprise	state-owned enterprise	90	88.24%
	private enterprise	12	11.76%
	Other	0	0.00%

Judging from the education level, this survey mainly aims at the scientific research staff, enterprises, and institutions who have participated in the research on intelligent technology and green construction. Therefore, more than 50% of the staff have reached a graduate degree or above. However, at the same time, they also cover the grassroots employees of some construction

enterprises, and the proportion of respondents with junior college degrees or below is about 3%. The questionnaire results can represent the wishes of the whole three-dimensional system of the construction industry. Judging from the nature and scale of the enterprises, the leading enterprises in the construction industry are large state-owned enterprises, so in this survey, the proportion of state-owned enterprises reached 88.24%, and the proportion from large enterprises with assets exceeding 800 million yuan reached 50%.

Table 9 Willingness Model of Green Management Collaboration Mechanism-Index Importance Evaluation

index	Importance analysis	average value	standard deviation	Dispersion coefficient
F22	1.7647	0.6321	1.7647	0.3582
F27	1.7549	0.6204	1.7549	0.3535
F25	3.0588	1.0608	3.0588	0.3468
F26	1.6765	0.5479	1.6765	0.3268
F28	2.4118	0.7224	2.4118	0.2995
F24	3.6863	1.0898	3.6863	0.2956
F23	3.8333	1.0253	3.8333	0.2675
F19	3.6471	0.9507	3.6471	0.2607
F33	3.6373	0.9205	3.6373	0.2531
F29	2.7843	0.6983	2.7843	0.2508
F21	3.8725	0.9613	3.8725	0.2482
F18	4	0.9228	4	0.2307
F13	3.3627	0.7283	3.3627	0.2166
F31	3.8922	0.8072	3.8922	0.2074
F20	4.2157	0.8516	4.2157	0.202
F30	4.1667	0.8215	4.1667	0.1972
F32	4.1569	0.8052	4.1569	0.1937
F11	3.8922	0.7434	3.8922	0.191
F10	4.1373	0.7583	4.1373	0.1833
F12	3.7255	0.6772	3.7255	0.1818
F9	4.1863	0.7543	4.1863	0.1802
F8	3.7549	0.5705	3.7549	0.1519
F7	4.5	0.6254	4.5	0.139
F17	3.9804	0.5446	3.9804	0.1368
F16	4.2745	0.5829	4.2745	0.1364
F5	4.6471	0.5198	4.6471	0.1119
F2	4.6765	0.4907	4.6765	0.1049
F15	4.7451	0.438	4.7451	0.0923
F3	4.7941	0.43	4.7941	0.0897

F14	4.7843	0.4133	4.7843	0.0864
F6	4.8039	0.399	4.8039	0.0831
F4	4.8431	0.3916	4.8431	0.0809
F1	4.8627	0.3458	4.8627	0.0711

From the information in the questionnaire, the results as shown in above table, Table 9, "F22 The enterprise has people related to the implementation of smart construction technology" and "F25 The enterprise has sufficient funds to cope with changes in the processing system adopted by smart construction technology" are relatively discrete, which may be due to the significant differences in the fundamentals of the enterprises in which the sample was interviewed.

Correlation Analysis

Table 10 Willingness Model of Green Management Synergy Mechanism - Correlation Analysis of 33 Indicators

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	F32
F1	1.000	0.055	0.477	0.355	0.111	0.116	0.223	0.118	0.211	0.334	0.225	0.222	0.228	0.000	0.003	0.039	0.200	0.222	0.211	0.210	0.255	0.121	0.124	0.117	0.217	0.018	0.120	0.027	0.225	0.222	0.112	0.19
F2	0.555	1.000	0.433	0.255	0.113	0.088	0.244	0.033	0.088	0.233	0.218	0.115	0.114	0.004	0.112	0.107	0.216	0.152	0.224	0.155	0.241	0.120	0.072	0.121	0.215	0.015	-0.040	0.013	0.266	0.118	0.124	0.16
F3	0.470	0.430	1.000	0.571	0.200	0.466	0.466	0.280	0.460	0.540	0.460	0.450	0.430	0.191	0.190	0.310	0.320	0.520	0.550	0.530	0.460	0.370	0.570	0.525	0.480	0.300	0.250	0.440	0.486	0.580	0.480	0.52
F4	0.350	0.250	0.570	1.000	0.461	0.755	0.577	0.490	0.500	0.472	0.520	0.470	0.480	0.222	0.170	0.190	0.130	0.580	0.490	0.610	0.550	0.410	0.530	0.461	0.450	0.455	0.370	0.510	0.560	0.510	0.420	0.52
F5	0.110	0.130	0.200	0.460	1.000	0.388	0.611	0.310	0.270	0.350	0.390	0.430	0.240	0.024	0.250	0.260	0.010	0.370	0.370	0.380	0.370	0.320	0.390	0.238	0.380	0.430	0.410	0.470	0.470	0.440	0.380	0.39
F6	0.160	0.080	0.460	0.750	0.380	1.000	0.522	0.530	0.480	0.450	0.400	0.422	0.320	0.028	0.220	0.190	0.120	0.570	0.490	0.590	0.550	0.440	0.500	0.450	0.500	0.520	0.440	0.490	0.490	0.430	0.430	0.47
F7	0.223	0.244	0.465	0.570	0.611	0.522	1.000	0.511	0.391	0.383	0.333	0.377	0.291	0.023	0.218	0.166	0.103	0.577	0.584	0.547	0.477	0.433	0.494	0.449	0.439	0.320	0.322	0.488	0.573	0.533	0.488	0.49
F8	0.180	0.033	0.280	0.280.49	0.311	0.531	0.511	1.000	0.451	0.383	0.263	0.291	0.263	0.241	0.183	0.032	0.022	0.402	0.392	0.422	0.455	0.392	0.377	0.353	0.383	0.311	0.222	0.392	0.313	0.363	0.292	0.34

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	F32
F9	0.21	0.08	0.46	0.50	0.27	0.48	0.39	0.45	1.00	0.65	0.51	0.64	0.67	0.42	0.33	0.29	0.23	0.57	0.49	0.54	0.53	0.38	0.54	0.51	0.53	0.39	0.46	0.46	0.46	0.53	0.41	0.59
F10	0.34	0.23	0.54	0.47	0.35	0.45	0.38	0.38	0.65	1.00	0.64	0.61	0.57	0.38	0.35	0.43	0.32	0.51	0.44	0.46	0.46	0.34	0.53	0.46	0.52	0.42	0.37	0.47	0.57	0.40	0.40	0.53
F11	0.25	0.18	0.46	0.52	0.39	0.40	0.33	0.26	0.51	0.64	0.00	0.71	0.66	0.34	0.34	0.41	0.17	0.61	0.49	0.49	0.55	0.28	0.55	0.47	0.49	0.45	0.39	0.49	0.52	0.38	0.44	0.56
F12	0.22	0.15	0.45	0.47	0.43	0.42	0.37	0.29	0.64	0.61	0.71	0.00	0.69	0.42	0.40	0.34	0.17	0.52	0.46	0.50	0.51	0.36	0.49	0.43	0.44	0.45	0.45	0.42	0.44	0.44	0.44	0.53
F13	0.28	0.14	0.43	0.48	0.24	0.32	0.29	0.26	0.67	0.57	0.66	0.69	0.00	0.46	0.45	0.39	0.22	0.58	0.53	0.53	0.53	0.40	0.52	0.47	0.50	0.47	0.44	0.37	0.44	0.30	0.29	0.56
F14	0.00	0.04	0.19	0.22	0.24	0.28	0.23	0.24	0.42	0.38	0.34	0.42	0.46	1.00	0.90	0.45	0.47	0.36	0.38	0.42	0.28	0.30	0.34	0.27	0.41	0.39	0.33	0.32	0.31	0.29	0.25	0.29
F15	0.03	0.12	0.19	0.17	0.25	0.22	0.18	0.18	0.33	0.35	0.35	0.40	0.45	0.90	1.00	0.51	0.48	0.34	0.40	0.36	0.28	0.28	0.32	0.25	0.42	0.40	0.35	0.34	0.27	0.34	0.31	0.31 0.31 0.31 0.35 0.34 0.27 0.34 0.31
F16	0.09	0.07	0.31	0.19	0.26	0.19	0.16	0.03	0.29	0.43	0.41	0.34	0.39	0.45	0.51	0.10	0.55	0.24	0.30	0.24	0.22	0.29	0.26	0.25	0.31	0.31	0.27	0.27	0.29	0.46	0.44	0.33
F17	0.20	0.16	0.32	0.13	0.01	0.12	0.03	0.03	0.23	0.32	0.17	0.17	0.22	0.47	0.48	0.55	1.00	0.04	0.12	0.03	-0.02	0.02	0.05	-0.01	0.07	0.11	0.04	0.15	0.20	0.30	0.31	0.10
F18	0.22	0.15	0.52	0.58	0.37	0.57	0.57	0.40	0.57	0.51	0.61	0.52	0.58	0.36	0.34	0.24	0.40	0.00	0.84	0.81	0.80	0.59	0.79	0.76	0.77	0.61	0.54	0.49	0.52	0.61	0.47	0.76
F19	0.21	0.24	0.55	0.49	0.37	0.49	0.58	0.39	0.49	0.44	0.49	0.46	0.53	0.38	0.40	0.30	0.12	0.84	0.00	0.77	0.74	0.60	0.75	0.74	0.79	0.62	0.49	0.53	0.50	0.65	0.57	0.68
F20	0.20	0.15	0.53	0.61	0.38	0.59	0.54	0.42	0.54	0.46	0.49	0.50	0.53	0.42	0.36	0.24	0.03	0.81	0.77	0.00	0.83	0.65	0.82	0.81	0.78	0.60	0.53	0.50	0.56	0.64	0.54	0.70

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	F32
F21	0.25	0.16	0.46	0.55	0.37	0.55	0.47	0.45	0.53	0.46	0.55	0.51	0.53	0.28	0.28	0.22	-0.02	0.80	0.74	0.83	1.00	0.68	0.90	0.86	0.80	0.65	0.60	0.59	0.58	0.63	0.51	0.72
F22	0.120	0.070	0.370	0.410	0.320	0.44	0.43	0.390	0.380	0.340	0.280	0.360	0.400	0.30	0.280	0.290	0.200	0.590	0.600	0.650	0.680	1.000	0.641	0.65	0.670	0.660	0.580	0.560	0.49	0.610	0.570	0.66
F23	0.24	0.21	0.570	0.53	0.39	0.50	0.49	0.37	0.54	0.53	0.55	0.49	0.52	0.34	0.32	0.26	0.05	0.79	0.75	0.82	0.90	0.64	0.40	0.92	0.86	0.64	0.57	0.64	0.63	0.69	0.56	0.74
F24	0.17	0.12	0.52	0.46	0.38	0.50	0.49	0.35	0.51	0.46	0.47	0.43	0.47	0.27	0.25	0.25	-0.01	0.76	0.74	0.81	0.86	0.65	0.92	1.00	0.86	0.62	0.57	0.59	0.57	0.66	0.52	0.71
F25	0.21	0.15	0.48	0.45	0.38	0.50	0.49	0.38	0.53	0.52	0.49	0.44	0.50	0.41	0.42	0.31	0.07	0.77	0.79	0.78	0.80	0.67	0.86	0.86	1.00	0.70	0.61	0.63	0.54	0.66	0.55	0.65
F26	0.08	0.01	0.30	0.45	0.43	0.52	0.39	0.31	0.39	0.42	0.45	0.45	0.47	0.450.47	0.40	0.31	0.11	0.61	0.62	0.60	0.65	0.66	0.64	0.62	0.70	1.00	0.84	0.64	0.57	0.54	0.48	0.61
F27	0.12	-0.04	0.25	0.37	0.41	0.44	0.440.32	0.22	0.46	0.37	0.39	0.50	0.44	0.33	0.35	0.27	0.04	0.54	0.49	0.53	0.60	0.58	0.57	0.57	0.61	0.84	1.00	0.65	0.52	0.53	0.44	0.59
F28	0.270	0.130	0.440	0.510	0.470	0.49	0.48	0.390	0.460	0.420	0.400	0.420	0.370	0.33	0.340	0.290	0.200	0.490	0.530	0.500	0.590	0.560	0.640	0.59	0.630	0.640	0.650	1.000	0.71	0.650	0.550	0.55
F29	0.250	0.260	0.480	0.560	0.470	0.49	0.57	0.310	0.380	0.470	0.490	0.420	0.370	0.32	0.270	0.270	0.150	0.520	0.500	0.560	0.580	0.490	0.630	0.57	0.540	0.570	0.520	0.710	1.000	0.631	0.501	0.61
F30	0.22	0.18	0.58	0.51	0.44	0.43	0.53	0.36	0.53	0.57	0.52	0.44	0.44	0.31	0.34	0.46	0.30	0.61	0.65	0.64	0.63	0.61	0.69	0.66	0.66	0.54	0.53	0.65	0.63	0.00	0.83	0.83
F31	0.12	0.24	0.48	0.42	0.38	0.380.33	0.48	0.29	0.41	0.40	0.38	0.34	0.30	0.29	0.31	0.44	0.31	0.47	0.57	0.54	0.51	0.57	0.56	0.52	0.55	0.48	0.44	0.55	0.50	0.83	1.00	0.68
F32	0.19	0.16	0.52	0.52	0.39	0.47	0.49	0.34	0.59	0.53	0.56	0.53	0.56	0.25	0.26	0.33	0.10	0.76	0.68	0.70	0.72	0.66	0.74	0.71	0.65	0.61	0.59	0.61	0.61	0.83	0.68	1.00

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20	F21	F22	F23	F24	F25	F26	F27	F28	F29	F30	F31	F32
F33	0.115	0.120	0.446	0.339	0.339	0.337	0.447	0.332	0.444	0.551	0.448	0.441	0.443	0.224	0.226	0.335	0.220	0.661	0.666	0.554	0.661	0.660	0.665	0.663	0.664	0.555	0.445	0.554	0.559	0.881	0.773	0.880

The results of correlation analysis as shown in Table 10, a small number of weakly correlated variables in the overall model, and its model validity need to be further demonstrated by combining the reliability analysis, convergent validity and discriminant validity in the later part of the study.

Robustness Analysis

(1) Reliability Analysis

Based on the results of the following reliability analysis shown in Table 11, only F4 has a CITC lower than 0.5, but deleting this indicator will decrease Cronbach's value, so the indicator will not be deleted; the CITCs of the other items are higher than 0.5, and the standardised Cronbach's value of the eight latent variables exceeds the critical value of 0.7. The model passes the confidence test, and no corrections are made to the model framework.

Table 11 Green Management Synergy Mechanism Willingness Model - Reliability Analysis Results

Indicator grouping	Variable Name	Corrected Item Total Correlation (CITC)	Item Deleted Cronbach Values	Cronbach value based on normalization	Retention or not
Competitive pressure	F1	0.5980	0.6720	0.7570	Yes
	F2	0.5040	0.7250		F2 0.5040 0.7250
	F3	0.6380	0.6380 0.6360		Yes
	F4	0.4760	0.7250		Yes
Policy environment	F5	0.5360	0.7450	0.7840	Yes
	F6	0.5900	0.7330		F6 0.5900
	F7	0.7060	0.6510		F7 0.7060 0.6510
	F8	0.5400	0.7450		F8 0.5400 0.7450
Technical Advantage	F9	0.7210	0.8780	0.8970	Yes
	F10	0.7230	0.8780		F10 0.7230 0.8780
	F11	0.7350	0.8750		F11 0.7350 0.8750
	F12	0.7850	0.8650		Yes

Indicator grouping	Variable Name	Corrected Item Total Correlation (CITC)	Item Deleted Cronbach Values	Cronbach value based on normalization	Retention or not
Technology Costs	F13	0.7600	0.8690	0.8350	Yes
	F14	0.7060	0.7530		Yes
	F15	0.7370	0.7370 0.7350		Yes
	F16	0.5950	0.8040		F16 0.5950 0.8040
	F17	0.5870	0.8000		F17 0.5870 0.8000 Yes
Organizational culture	F18	0.8830	0.9120	0.9400	Yes
	F19	0.8340	0.9280		F19 0.8340 0.9280
	F20	0.8640	0.9200		Yes
Resource Condition	F21	0.8480	0.9240	0.9290	F21 0.8480 0.9240
	F22	0.6840	0.9050		Yes
	F23	0.9090	0.8730		Yes
	F24	0.9110	0.8740		F24 0.9110 0.8740
	F25	0.8810	0.8810 0.8840		Yes
Convenience perception	F26	0.7790	0.8330	0.8830	Yes
	F27	0.7490	0.8370		0.7490 0.8370 Yes
	F28	0.7690	0.8300		0.8300 Yes
	F29	0.6750	0.8680		F29 0.6750 0.8680 Yes
Willingness to collaborate on green management	F30	0.9070	0.8930	0.9350	Yes
	F31	0.8010	0.9270		F31 0.8010 0.9270
	F32	0.8310	0.9180		F32 0.8310 0.9180 Yes
	F33	0.8460	0.9150		F33 0.8460 0.9150 Yes

Overall, the "Cronbach value with items deleted" and "Cronbach value based on standardisation" of the above index system have exceeded the 70% critical value of the reliability test, and the CITIC is higher than 0.5.

DISCUSSION

The results of this study provide an accurate, comprehensive overview of ICT integration and enterprise green management in the process of the "dual carbon" transformation in construction enterprises. The findings from the first step of indicator extraction, expert assessments, and questionnaires provide an idea about the complex processes that create synergy between technological developments and sustainable resource management. These conclusions align with Guan (2021) and Lai and Yan (2019) studies, which focus on the need for powerful promotion and favourable regulation as critical in enhancing the industrialisation of new buildings. These are some recommendations on how site selection and transport systems should go hand in hand. Also, using new building materials agrees with the need for sustainable construction outcomes; therefore, more emphasis should be placed on planning issues and material optimisation.

The correlation analysis also stresses the interdependence of different factors, whereby highly significant 'r' coefficients were established between the strength of promotion and intelligent technologies and the effectiveness of green management practices. Such findings align with Li (2022) and Chen et al. (2019) studies, which pointed out the combination of comprehensive promotion, technological development, and strict regulatory measures towards green construction management. This goes a long way in enhancing the credibility of the findings in light of the conclusions made on data analysed from the study. It is noteworthy that the focus on high internal consistency corresponds to the methodological concerns outlined by Yang (2022) and Wang (2022) in their works on green construction management. The Willingness Model examination indicated the great readiness of enterprises to incorporate intelligent technologies for green management due to competitive pressure, policy environment, technical advantages, and organisational culture.

Policy Implications

This study contributes the following policy implications to enhancing intelligent construction technology and green management collaboration in the construction industry. Appropriate authorities should employ heavy promotion campaigns that draw the public's and stakeholders' attention to the idea of green construction and the use of smart technologies. It can be done by creating awareness and conducting relevant trade shows and seminars that assemble all the players in one venue to learn. Secondly, such works demonstrate that regulatory systems are one of the most crucial prerequisites for creating green buildings; thus, policymakers must adopt and facilitate strict sets of codes and requirements.

The results also stress the role of the government in encouraging the implementation of advanced technology. It is recommended that policymakers should employ sweeteners by offering enticements like tax exemption or subsidies to enterprises undertaking intelligent construction technologies. This process of transforming and optimising construction work should involve governments and industry associations systematically encouraging the creation of proper training courses that prepare the construction industry members to use smart technologies effectively. Finally, due to competitive pressure and organisational culture, enterprises are ready to implement intelligent technologies, which points to the fact that the enterprise's sustainability culture should be focused.

CONCLUSION

Consequently, it implies the feasibility of utilizing intelligent construction technology and enterprise green management while constructing the "dual-carbon" transformation in construction enterprises.

Analyzing the study's findings, we find essential implications for promoting sustainable construction practices: promotion strength, regulatory standards, application of intelligent platforms, and high-end design teams. The last two analyses of correlation and reliability support the idea that different indicators are interrelated and consistent in the study and prove that the proposed green management synergy mechanism is dominant.

As affirmed by prior studies, this research emphasizes the importance of working on consecutive strategies with sound promotional activities, effective legislation, relevant financial motivation and incentives, adequate training programs, and a proactive institutional culture to support sustainable construction goals. These findings generate pertinent recommendations for policies and practices to enhance the co-beneficial integration of intelligent construction technology and green management. This research will advance the knowledge of sustainable construction practices, production of guidelines and proceeding framework for policy and research studies in the important field of sustainable construction.

Limitations and Future Research

Despite the broad range of the analysis and the identified conclusions, this study has some limitations that must be discussed. Firstly, the number of respondents invited into the study was two hundred and twenty. While this might contain sufficient data analysis for preliminary purposes, understanding construction industry responses across regionality and operational ranges may need to be more comprehensive. Thus, future research should focus on the larger sample study since the generalizability of the findings is one of the study's limitations. Secondly, the current study mainly depends on quantitative questionnaires, which may expose the study to socially desirable and recall bias.

Further studies could use the information from self-completion questionnaires complemented with actual data concerning energy consumption, emissions levels and the descriptions of actual projects to confirm the results. However, for correlation analysis, as conducted in this paper, although highly informative in identifying the relationship between social media usage and student performance. Finally, due to the fast development of new technologies, when the readers of this paper use the findings of this study, some of the indicators and technologies may need to be of limited usefulness. More studies should be carried out to update the framework to contain the new technologies and new trends in green structures.

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