



Navigating the road to BIMS-GPT adoption: Perceptions of construction professionals on drivers and barriers

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Abstract

The construction industry is at a critical juncture, facing both unprecedented opportunities and challenges driven by emerging technologies like BIMS-GPT, which combines Building Information Models (BIMs) with Generative Pre-trained Transformer (GPT) language models. This study investigates the drivers and barriers to the adoption of BIMS-GPT in the construction industry through empirical research using questionnaires and expert interviews. The results indicate that the most significant drivers are BIMS-GPT's ability to automate tasks, enhance decision-making, improve safety, and optimize processes across the entire building lifecycle. The main barriers include high development and training costs, lack of legal frameworks, data security concerns, and resistance to change among employees. Furthermore, the study analyzes differences in perceptions among respondents based on their years of experience and departmental roles. Those with 6-10 years of experience show the highest interest in adopting BIMS-GPT, while management and technical departments prioritize different aspects of the technology. The findings provide valuable insights for construction companies looking to implement BIMS-GPT and establish a solid foundation for its promotion and implementation. By understanding stakeholders' attitudes and addressing the identified drivers and barriers, the industry can fully leverage the potential of this transformative technology, paving the way for a smarter, more efficient, and sustainable future in construction.

Keywords: BIMS-GPT, construction industry, drivers and barriers, empirical study

1. Introduction

The construction industry is undergoing unprecedented changes due to the development of technology and the growth of the global economy. Construction projects typically have long project cycles and involve numerous stakeholders, necessitating the use of advanced information integration technologies by major construction companies to improve industry productivity. Building Information Modeling (BIM), a digital design and construction method, has gained significant attention for its importance and influence in construction projects^[1]. BIM is an architectural, engineering, and construction (AEC) method that can be used in the planning, design, construction, and operation of facilities^[2]. It enables architects, engineers, and constructors to visualize structures in a simulated environment, and identify potential design, construction, or operational issues^[3]. Over the past few decades, the construction industry has increasingly adopted BIM due to its numerous benefits and resource savings in the design, planning, and construction of new projects^[4]. The application of BIM technology has revolutionized the way buildings are designed, improving project efficiency, quality, and sustainability.

In the rapidly developing age of digitalization, Artificial Intelligence (AI) has become a major driver across various industries^[5]. Saka *et al.*^[6] defined AI as the ability of machines to fulfill tasks that typically require human intelligence, such as learning, reasoning, perception, and decision-making. AI systematically processes and analyzes large datasets to recognize patterns, relationships, inferences, recommendations, and actions. Generative Pre-trained Models (GPT), a prominent representative of the natural language processing field, are at the forefront of AI technology, demonstrating excellent performance in language understanding, conversational processing tasks, and automated text generation. GPT exhibits strong capabilities in text generation and language



understanding and shows tremendous potential for cross-application with other industries. Currently, GPT models have been applied in various fields, such as finance, business, medicine, education, and gaming. However, its cross-application with the construction industry has not been thoroughly researched and explored. The construction industry, one of the largest economic sectors worldwide, is characterized by its specificity and complexity, making the application of GPT modeling in this field highly significant. The large scale of construction projects and the involvement of numerous stakeholders necessitate extensive information processing, decision support, and communication at each period, areas where GPT modeling can play a critical role in assisting decision-making. Zheng and Fischer^[7] proposed a new technology that combines BIM and GPT, called BIMS-GPT technology, which not only includes all the functions of knowledge retrieval, language generation, data processing, and analytical reasoning that GPT can realize but also automatically creates and modifies BIM models and retrieves functions in the form of conversation. As a cutting-edge AI technology fully applicable to the construction industry, BIMS-GPT holds significant promise. It is expected to enhance the efficiency of architectural design and play an important role in project management, information processing, and decision support.

However, despite the great convenience and potential that BIMS-GPT technology offers to the construction industry, its promotion and application in the construction field still face a series of challenges and obstacles. Since the proposal of BIMS-GPT, few scholars have focused on the acceptance of this technology in construction companies. Therefore, an intensive study of the drivers and obstacles of BIMS-GPT in construction enterprises can offer valuable insights into its practical enterprises and stakeholders' attitudes, providing important theoretical and practical support for its further promotion and application. Based on this, this study will focus on the following questions:

(a) What are the drivers and barriers to the adoption of BIMS-GPT technology in the construction industry?

(b) How do experts in the construction industry rank the importance of BIMS-GPT as a technology?

(c) What are the attitudes of different groups of people towards BIMS-GPT technology?

To address these questions, this study summarizes the literature to refine the functions and weaknesses of BIMS-GPT, identifies the driving factors and barriers to BIMS-GPT technology in the construction field, and conducts empirical investigations based on questionnaires and expert interviews. This approach enables the determination of the significance of various types of factors and the analysis of the functions and challenges that experts are generally concerned about. Consequently, useful references and insights can be obtained to support the promotion and application of the technology in the construction industry. The remainder of this paper is organized as follows: [Section 2](#) provides a comprehensive review of the literature on BIM and GPT technologies, as well as their integration and adoption in various industries. [Section 3](#) describes the research methodology, including the empirical data collection process and the analysis of the empirical data. [Section 4](#) presents the results and discussion, focusing on the ranking of drivers and barriers, the differences between different groups of respondents, and the implications of the findings. Finally, [Section 5](#) concludes the paper by summarizing the key contributions, limitations, and future research directions. The framework of the research in this paper is shown in [Figure 1](#).

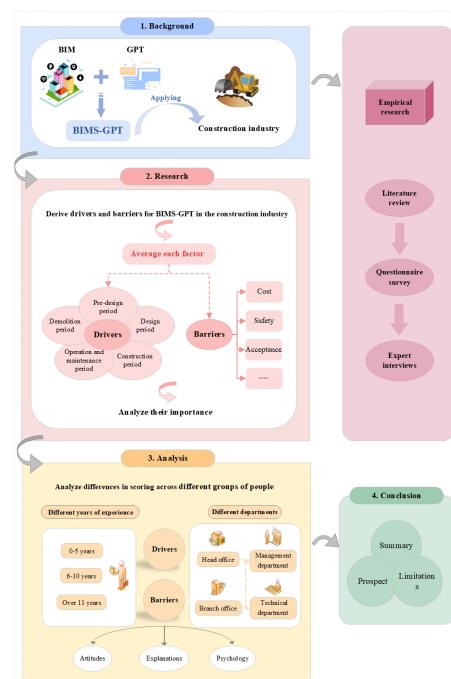


Figure 1. The research framework of this paper. BIM: Building Information Modeling; GPT: Generative Pre-trained Transformer.

2. Literature Review

The main research theme is BIMS-GPT, a technology that incorporates the conversational features of GPT into BIM design, enabling it to address various issues throughout the construction project lifecycle. This section reviews the development of BIM and GPT technologies, focusing on the integration of BIM with other emerging technologies and the adoption of GPT in various industries. While exploring the potential and advantages of BIMS-GPT technology, the review also considers the new opportunities and challenges it presents for innovation and development in the construction industry. The examination of BIM and GPT technology in this section aims to provide insightful background knowledge and references for the current study.

2.1 BIM

BIM is a digital method of building design and management, realized by creating and maintaining virtual models throughout the building life cycle. Such models contain not only the geometry of the building, but also the information about the attributes of the building components, construction progress, cost data, and so on. BIM technology can integrate a diverse range of information during building design, construction, and operations, and facilitate collaboration and communication among all project stakeholders, thereby improving the efficiency, quality, and sustainability of the project. Such comprehensive data facilitates integrating constructability knowledge into architectural design and helps boost project efficiency and reduce rework risks^[8]. In the current construction industry, BIM has become a widely recognized and adopted digital solution that provides robust for the design, management and operation of construction projects^[9].

BIM was first introduced in the 1970s by Eastman^[10], who believed that designing by traditional architectural drawings was excessively costly. To address this, he proposed a computerized system for storing and managing detailed information related on design, construction, and analysis, which was an early prototype of BIM concept. Since then, BIM technology had not only continued to develop and spread rapidly in the U.S., but had also been widely accepted and adopted by construction organizations from all over the world^[11]. Simultaneously, an increasing number of scholars had conducted more profound researches on BIM. Nederveen and Tolman^[12] specifically discussed the data sharing and collaboration of BIM. Latiffi *et al.*^[13] summarized the definition and development of BIM concepts since 1975 and provided a more comprehensive explanation of the development of building information simulation. Rokooei^[14] believed that BIM can create a common language among all departments and in projects, functioning as a project manager to facilitate coordination and systematically analyze the constructability of projects' systems. BIM is developing rapidly in the construction industry and shows enormous potential; therefore, it is gradually being widely used by construction enterprises. Vignoli *et al.*^[15] applied an infrastructure BIM approach to upgrade a section of the SS 245 road in northern Italy, demonstrating its effectiveness in the renovation existing road infrastructure.

The application of BIM in the construction industry is expanding and is becoming an indispensable tool and approach for modern construction companies. Zhang^[16] analyzed the main applications of BIM technology in the whole project life cycle, introduced the role of BIM in various stages and nodes of the project life cycle construction and explained its capability. Bryde *et al.*^[17] focused on the extent to which BIM is being used in construction projects and explored the benefits of BIM in construction projects through the analysis of 35 case studies. Azhar *et al.*^[3] discussed the application, current trends, benefits, possible risks, and future challenges of BIM in the architecture, engineering, and construction industry, providing valuable information for AEC industry workers implementing BIM technology in their projects. Barlish and Sullivan^[18] developed and presented a framework computational model for determining the value of BIM to quantify the benefits that BIM delivers to the construction industry, and validated the effectiveness of the methodology through a real case study.

Over the past fifteen years, there has been an increasing diversity of research on BIM, and the integration of BIM with the emerging technologies of artificial intelligence will become a new trend for the future development. Abioye *et al.*^[19] proposed a method of combining BIM with computer vision for real-time monitoring of workforce safety risks at construction sites. Lin^[20] developed a web-based architectural BIM interface management system that integrated 3D interface maps into BIM to enhance the sharing of interface information and efficiency tracking in construction projects. Wetzel and Thabet^[21] developed a BIM-based framework to support safe maintenance and repair practices during the facility management period. Sobhkhiz and El-Diraby^[22] employed concept networks to represent the IFC data model and trained classifiers to assign text documents to their associated IFC classes based on concept network distance.

Through VOSviewer, we extracted the articles about BIM in Web of Science and cluster their keywords to get Figure 2, which is the co-occurrence network map of keywords about BIM. The figure illustrates that current research hotspots about BIM mainly revolve around modeling, implementation, construction and design. The strong interconnections among these areas indicate that the research on BIM has reached a relatively mature stage. Moreover, the main content of the research concentrates on BIM's functions and references, underscoring its significant and irreplaceable role in the construction industry.

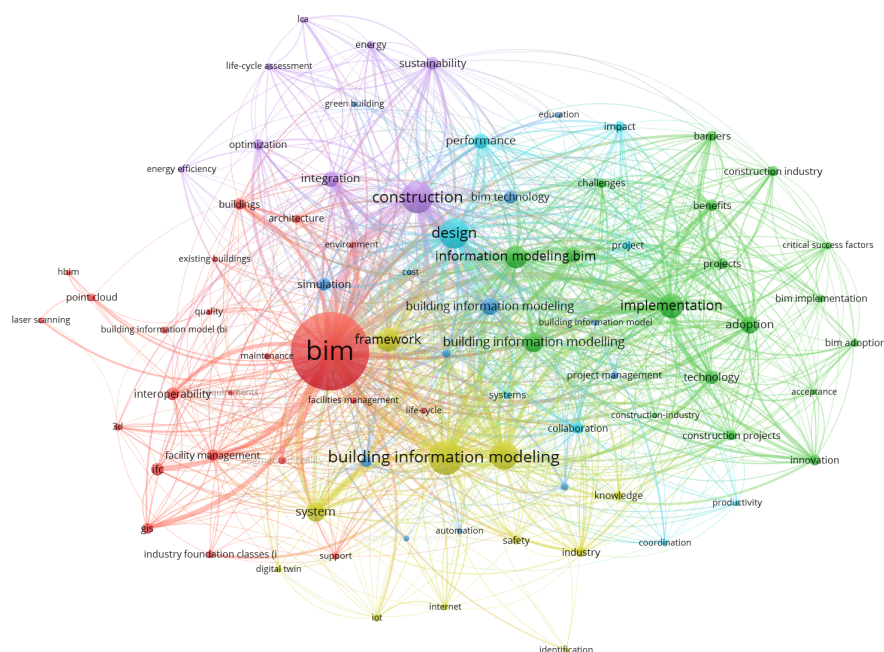


Figure 2. For BIM keyword co-occurrence network map. BIM: Building Information Modeling.

Construction companies are gradually recognizing the value of BIM and applying it to a wide range of aspects such as design, construction, facility management and sustainability. With the increasing development of the technology and the promotion of its application, BIM will continually play an outstanding role in construction organizations and promote the innovation and advancement of the industry. Construction organizations are encouraged to actively explore and apply BIM technology to improve competitiveness, reduce risk, and satisfy customer demand for high-quality buildings.

2.2 GPT

GPT is an important technology in the field of Natural Language Processing. In 2018, OpenAI released the first GPT model, GPT-1, which was based on the Transformer encoder and was pre-trained from large-scale text data through self-supervised learning, showing its great potential for natural language generation tasks. Later, OpenAI continuously released new models, which attracted widespread attention and discussion as these models continued to improve in scale^[23], pre-training data size^[24], and generative capacity^[25]. After 2020, the size of GPT models dramatically increased again, reaching the scale of billions and making them one of the largest pre-training models to date. The GPT models have not only made remarkable achievements in generative and language comprehension capability, but have also demonstrated exceptional generality and versatility in performing various natural language processing tasks from text generation to Q&A systems and conversational interactions.

The GPT model, due to its versatility, convenience and strong functionality, can perform an essential role in various industries and provide vigorous support for the digital transformation and intelligent development of these industries. Currently, there is a great potential for the application of GPT model in many industries. In medicine, GPT is commonly used for data analysis, automated abstract generation, disease diagnosis, patient interaction, and other related tasks. Haim *et al.*^[26] applied GPT models in healthcare to calculate five commonly used medical scores. Leclerc *et al.*^[27] mentioned that the applications and benefits of GPT in medical radiology include report generation, educational support, clinical decision support, patient communication and data analysis. Wu and Bibault^[28] explained the application of GPT model in radiation therapy toxicity monitoring in detail, mentioning that GPT not only automatically generated a summary of the reported results, but also directly interacted with the patient and categorized the symptoms. Chintagunta *et al.*^[29] applied the GPT model to medical dialogue summarization, which saved labor costs and improved accuracy of medical information. Waisberg *et al.*^[30] mentioned that GPT models can already accomplish numerous complicated tasks in the medical field, including literature search, report writing, and image analysis. Lee *et al.*^[31] highlighted the application of GPT as a real-time interactive AI chatbot in healthcare scenarios and provided cases to validate its convenience, high accuracy and efficiency.

In the field of education, there are also potential uses for GPT. Hendy *et al.*^[32] conducted a comprehensive evaluation of GPT models for machine translation and demonstrated that they can deliver very competitive translation quality in high-resource languages through 18 different translation directions. Ausat *et al.*^[33] explored the application of GPT technology in classroom teaching and its broader potential within the field of education. Zong and Krishnamachari^[34] applied GPT models in the field of mathematics education to accomplish classification, extraction, and generation tasks related to mathematical words through GPT. Markel *et al.*^[35] utilized GPT to simulate student responses for teacher training, allowing teachers to respond to actual teaching situations in an immersive

manner.

In the field of finance and society, there is still a formidable function that GPT model can play. Chen *et al.*^[36] tried to make decisions on risk, time, and society and measure the rationality of the decisions by using the GPT model. Ullah *et al.*^[37] used a questionnaire to get a deeper understanding of the applications of GPT in finance, such as managing risk, optimizing portfolios, predicting market trends, and explored the impact of GPT models on the decision-making processes of financial investors. Niszczota and Abbas^[38] validated the strong potential of the GPT model as a robo-advisor through a financial literacy test.

GPT has also been widely used in other fields. Ding *et al.*^[39] used GPT models as a data annotation tool for training machine learning models. Värtinen *et al.*^[40] attempted to automatically generate high-quality quests for role-playing games using GPT models, enhancing storytelling, logic coherence, and overall player experience. It is evident that GPT can play a formidable role in a variety of industries.

In the keyword co-occurrence network map of GPT articles ([Figure 3](#)), it is obvious that the current articles about GPT are more about the application of GPT in medicine, except for the explanation of the origin, theory and basic model of GPT. The current research on GPT still stays in the explanation and investigation of the technology itself, and there are relatively few studies on the application of GPT, and it lacks a particularly wide range of applications in more fields other than medicine.

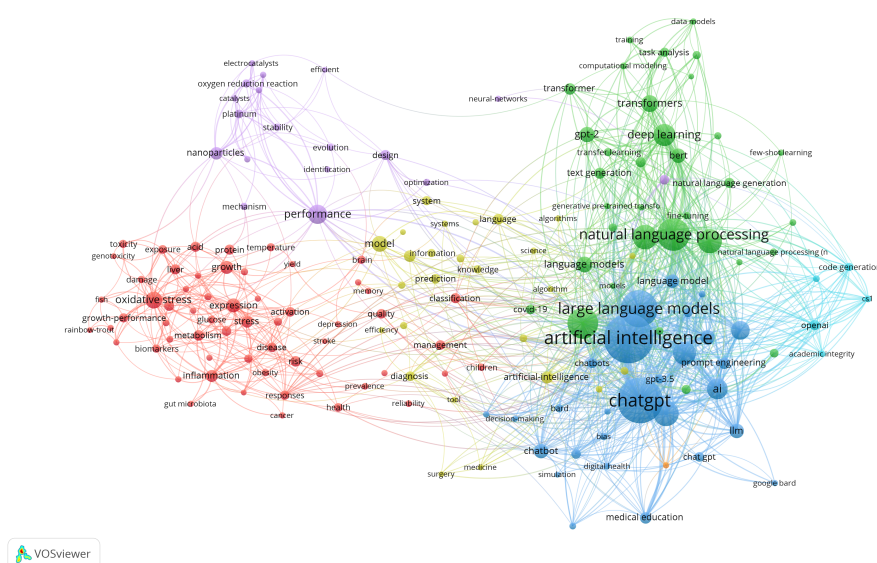


Figure 3. For GPT keyword co-occurrence network map. GPT: Generative Pre-trained Transformer.

In recent years, scholars have linked GPT to the construction and engineering industry. Saka *et al.*^[6] presented the opportunities, challenges of using GPT in the construction industry and verified the use cases of GPT and BIM in material selection and optimization. Wang and Issa^[41] used GPT to create an intelligent building safety chatbot and applied it to retrieve information from safety codes to reduce fall risk in the construction industry. Zheng and Fischer^[7] applied the session form of GPT to BIM software to form a virtual assistant framework based on dynamic prompts to automate the search of BIM operations. Prieto *et al.*^[42] attempted to automate the generation of construction schedules for construction projects by using the GPT model and pointed out the great potential that such language models have in automating the engineering type of tasks. Ghimire *et al.*^[43] analyzed industry perceptions with programming-based word cloud and frequency analysis and summarized the potential opportunities and challenges of implementing generative AI in the construction industry. Lee *et al.*^[44] also examined the technical specifications of complex construction projects by training GPT modeling. Panahi *et al.*^[45] proposed a new framework for assisting design review through GPT modeling of a large number of historical information requests.

Although GPT modeling is undergoing rapid development, there remains a limited number of existing studies that explore its applications in the construction industry, and even fewer studies that integrate it with BIM. This research gap constitutes the primary focus of this study. This study not only examines the acceptance of BIMS-GPT in the construction industry after the technology has been proposed, but also conducts empirical research by means of literature review, questionnaire survey and expert interviews to explore the drivers and barriers of BIMS-GPT in the construction industry from the perspective of experts in construction enterprises. It also explores the scoring preferences and key concerns of different groups of people, fills in the gaps in the reality of acceptance and drivers of this technology, emphasizes the advantages of using large language modeling technology combined with BIM in the construction industry and the necessity of further research on this technology, and establishes a solid foundation for the advancement and introduction of the new technology.

3. Method

This paper employs a multi-method research approach, including literature review, questionnaires, and interviews, to conduct an empirical study investigating the drivers and barriers for construction organizations in adopting the BIMS-GPT technology.

3.1 Empirical data collection

To explore the drivers and barriers, the empirical study adopted the following steps. The functions and key barriers of BIMS-GPT in various lifecycle phases, such as automatic model generation in the design phase and real-time risk identification in the construction phase, are mainly extracted and refined from existing literature in the fields of BIM applications, large language model (LLM) integration, and construction lifecycle management. Subsequently, a questionnaire was employed to collect data, aiming to analyze the specific drivers and barriers more comprehensively, as well as the magnitude of their respective influence.

For empirical data collection, we collaborated with the Third Bureau of China State Construction Engineering Corporation (CSCEC) to conduct empirical research. As one of CSCEC's crucial subsidiaries, the Third Bureau holds significant influence and status in China's construction industry. Its primary operations encompass the construction and management of large-scale projects, including public buildings, commercial complexes, residential communities, industrial plants, and infrastructure projects. With its abundant experience, technological prowess in construction, robust financial resources, and skilled workforce, the Third Bureau plays a vital role in the large-scale infrastructure and construction project domain, having participated in numerous landmark projects and garnered an excellent reputation within the industry. Therefore, the subsidiary was selected as the subject of empirical analysis in this study, as its prominent position and expertise in the construction industry can ensure the credibility and relevance of the findings.

In alignment with the BIMS-GPT technology concept, we conducted a detailed exploration of its potential functionalities and summarized the main functions into four questions (Figure 4), enabling respondents to rapidly comprehend the capabilities of the new BIMS-GPT technology while completing the questionnaires, thus facilitating a better understanding of the technology.

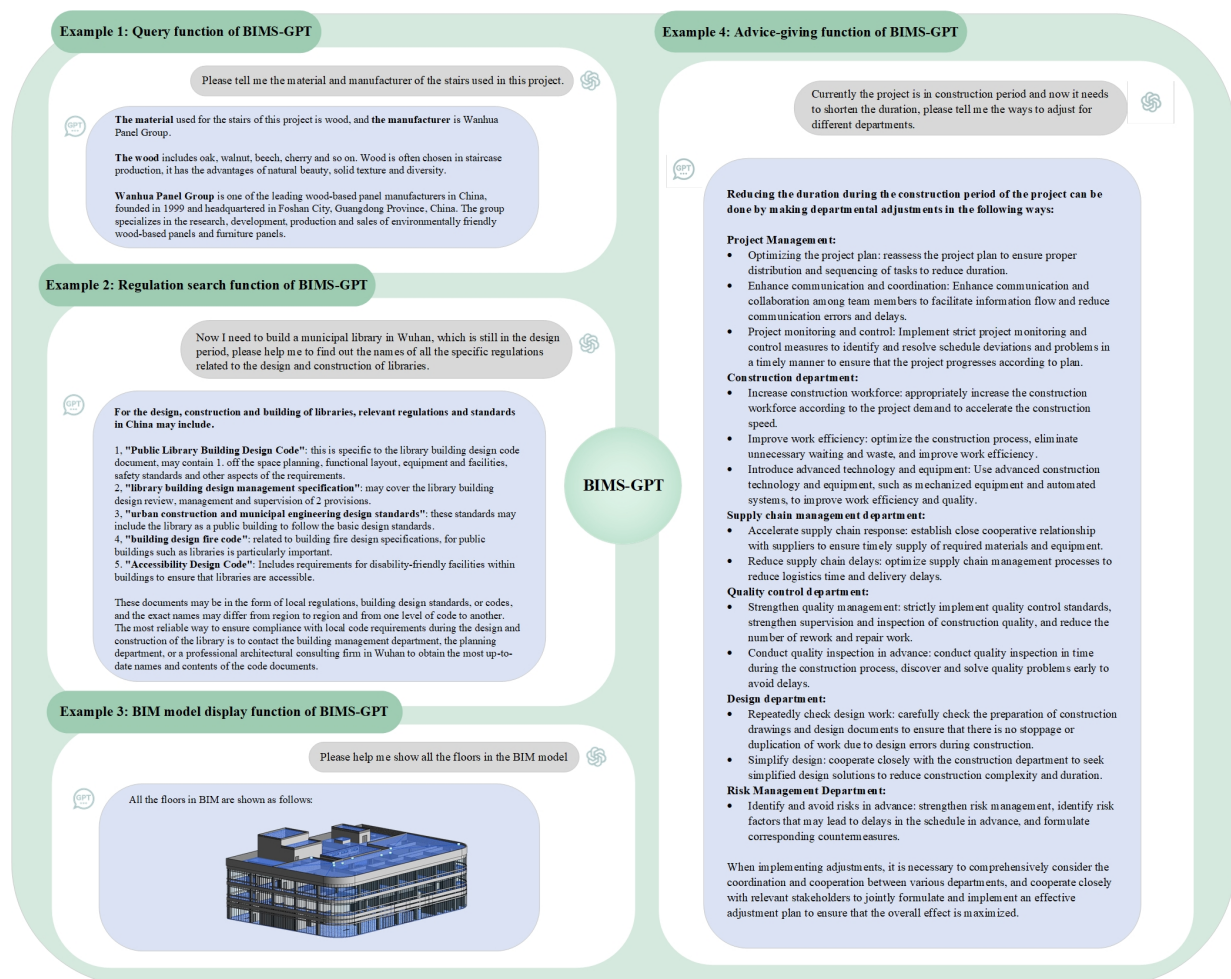


Figure 4. Schematic diagram of BIMS-GPT. BIM: Building Information Modeling; GPT: Generative Pre-trained Transformer.

We categorized the functions of BIMS-GPT according to the entire building life cycle: pre-design, design, construction, operation and maintenance, and demolition periods. To identify the functions and barriers of BIMS-GPT throughout lifecycle phases, we conducted a systematic literature review aligned with the technical characteristics of BIM, LLMs and project needs, covering three areas: 1) BIM application scenarios across project lifecycles, such as BIM’s applications and implementation barriers in various phases^[46,47]; 2) LLMs’ capabilities in engineering tasks, including data processing and scheme generation^[48,49]; 3) construction lifecycle management, such as full-process collaboration and intelligent management^[50-52]. Each period is further refined with specific functions to facilitate the investigation of the driving factors for BIMS-GPT adoption in the construction industry. For the barriers, we identified eight potential obstacles through literature review and combined them with the drivers into a comprehensive questionnaire, which was distributed to personnel across various departments within the Third Bureau of CSCEC.

The questionnaire employed a five-point Likert scale, ranging from “1 - not a driver” to “5 - major driver” for the drivers, and from “1 - not a barrier” to “5 - major barrier” for the barriers. A total of 128 questionnaires were distributed, with 43 responses retrieved, resulting in an overall response rate of approximately 33.6%. After rigorous validity checks, which included the exclusion of incomplete submissions and those with logical inconsistencies, 19 responses were confirmed valid, with a valid response rate of 14.8% relative to the total number of distributed questionnaires. The questionnaires were distributed to technical and management staff of the third bureau of CSCEC, who are typically engaged in high-intensity on-site coordination or project management work. Many respondents could only complete the questionnaires during fragmented time, leading to incomplete answers that were subsequently excluded during validity screening. Additionally, to ensure the comprehensiveness and completeness of the empirical study, we conducted open invitations for expert interviews and ultimately obtained responses from six professionals. Since no fixed pool of invitees was predefined, the number of experts interviewed is clear, but the response rate cannot be calculated. These interviews served to complement and support the questionnaire results. Table 1 presents the basic information of six interviewed experts in the construction industry.

Table 1. Basic information about the six interviewed experts in the construction industry.

No.	Department	Years in the industry	Position	Job Description
1	Design Institute Cost	5 years	Cost Engineer	Investment Estimation, Design Estimates, Construction Drawing Budget, Program Selection
2	Intelligent City Research Institute	10 years	BIM Engineer	BIM engineer, BIM training, BIM awards, with other production departments BIM bidding, BIM implementation
3	Construction Center Audit and Settlement Section	6 years	Audit and Settlement Section	Clerk Engineering Pre-settlement, Project Costing
4	Construction Progress Management Department	8 years	Deputy Project Manager	Project Site Construction Management
5	Technology Management Department	5 years	Department Manager	Daily basic technology management, introduction and application of new technology
6	Technology Information Department of Technology Plant Construction Company	8 years	Department Manager	Maintaining technology system operation, technology research and development, bidding, informationization management

BIM: Building Information Modeling.

This study collected 19 valid questionnaires. Although the sample size is limited, all responses were obtained from actual industry practitioners, ensuring the authenticity and reliability of the data. In addition, six in-depth expert interviews were conducted as a supplementary source of evidence. We acknowledge that the relatively small number of experts may restrict the comprehensiveness of perspectives to some extent. Nevertheless, since the questionnaire data serve as the core empirical basis, demonstrating validity and reliability, and the expert interviews function only as a complementary qualitative source, the combined dataset still provides representative and valuable support for the research findings. Future studies may further broaden the scope of empirical investigation by incorporating more enterprises and regions, extending the data collection period, and increasing the sample size, thereby enhancing the robustness and generalizability of the conclusions.

According to the ethical review guidelines of this institution, this study was exempted from formal ethical approval. The interviews focused solely on collecting professional opinions regarding the adoption of BIMS-GPT technology, and did not involve any sensitive information, such as personal health data, privacy-related details, or confidential individual or organizational information. Prior to each interview, all six experts were verbally informed of the study’s purpose, data collection methods, intended use of interview

content, and measures for privacy protection. Participants were explicitly notified that their participation was voluntary, and they could refuse to answer any questions or terminate the interview at any time without penalty. Their identities would be anonymized in all study outputs. No personal identifying information, like full names, contact details, or specific organizational affiliations, was collected during the interviews. Instead, participants were referred to by pseudonyms (e.g., “Respondent 1”) throughout the analysis and manuscript to ensure confidentiality.

3.2 Analysis of empirical data

To conduct a thorough analysis of the empirical findings, we calculated the mean values of each factor and ranked the drivers and barriers influencing the adoption of the new BIMS-GPT technology within the construction industry according to the building lifecycle stages. This approach facilitates an assessment of the relative importance of the factors. In total, 46 drivers and 8 barriers are analyzed and interpreted in this study. Prior to this, the questionnaire underwent reliability and validity testing, ensuring that the results can be considered valid and persuasive.

3.2.1 Drivers for the pre-design period

The pre-design period is a preparatory phase preceding the design period. This period supports the design period and encompasses tasks such as site studies, planning, building cost analysis, and value assessment. As this period involves fewer tasks, the drivers for adopting BIMS-GPT technology during the pre-design period consist of four main components. The expert scores for the pre-design period are shown in Table 2.

Table 2. Functions and scores that can be realized by BIMS-GPT (Pre-Design Period).

No.	Functions	Average score	Max	Min
Pre-Design Period	Automatically give project quote references and make purchasing decisions	3.8947	5	1
	Automatically develop initial project summary	3.3684	5	1
	Develop project management plans on a personalized basis	3.5790	5	2
	Easier for novices to learn the shape of various components of the BIM model	3.8947	5	2

BIM: Building Information Modeling; GPT: generative pre-trained.

The BIMS-GPT technology is characterized by its robust database functionality and automatic document generation capabilities. As evident from the respondents’ scores, during the pre-design period, the functions prioritized by experts include the automatic generation of estimated quotations, material cost pricing for construction projects, and the creation of related purchasing plans through the aggregation and analysis of historical data in conjunction with the current project situation. Respondent 1 highlights the value of BIMS-GPT technology in simplifying pricing processes that traditionally relied on human experience and judgment. Its extensive historical database can provide more accurate and reasonable quotes and pricing, serving as a valuable reference for construction companies during procurement and project bidding. This data-driven advantage aligns with Safar and Ghandeharian^[53], who emphasized the critical role of data availability and quality in enhancing BIM-based lifecycle assessments.

Simultaneously, as BIMS-GPT is a new artificial intelligence technology specifically designed for the construction industry, its ability to incorporate BIM simulation modeling allows novices to learn the shape, corresponding parameters, and functions of each building component through dialogue boxes while working with a BIM model. This capability enables new staff members in the construction industry to more easily learn and design using BIM, making it a key driver during the pre-design period. Such facilitation of novice learning via BIM integration also resonates with Wang and Chen^[50], who proposed a BIM capabilities framework to enhance project management across the lifecycle. Our study complements their work by illustrating how AI-integrated BIMS-GPT specifically bolsters pre-design training and knowledge transfer, a vital yet under-explored dimension of BIM capabilities.

3.2.2 Drivers for the design period

The design period is one of the most critical periods in the entire building life cycle, where BIMS-GPT technology will play a significant role. This period typically falls within the project inception stage, encompassing planning, conceptualization, and preliminary design of the overall building project. Generally, the work carried out during the design period directly determines the direction, quality, cost, time schedule, and feasibility of the subsequent phases. The quality of the design period lays the foundation and establishes the overall framework for the construction project, which is crucial for the success of the entire endeavor. As the design period requires numerous intricate and complex tasks, the quality and efficiency of these tasks directly impact the subsequent development of the construction project, making the use of advanced BIMS-GPT technology during this period extremely significant. The expert scores for the design period are shown in Table 3.

Table 3. Functions and scores that can be realized by BIMS-GPT (Design Period).

No.	Functions	Average score	Max	Min
Design period	Automatically budget the cost of construction projects	4.2105	5	2
	Automatic generate relevant BIM base models	4.2105	5	3
	Identify potential problems in the design period as early as possible	4.1579	5	2
	Automatically check design solutions for regulation compliance	4.1579	5	2
	Automatically analyze the energy efficiency of the building and propose solutions to save energy costs	4.1579	5	2
	Query and display all information related to BIM components at any time	4.1053	5	3
	Automatically prepare bills of quantities	4.0526	5	2
	Automatically evaluate materials for building components and select the optimal material	3.8947	5	3
	Automatically generate targeted design ideas	3.6316	5	2

BIM: Building Information Modeling; GPT: Generative Pre-trained Transformer.

From the research results, construction companies generally exhibit greater interest in automated cost budgeting, automatic risk identification and prevention monitoring, and the simplicity of BIM modeling. For construction companies, cost estimation and budgeting are among the most pivotal aspects of a project, and only accurate and reasonable cost budgeting can lead to a successful venture. In the expert evaluation, this function also received the highest score of 4.2105 during the design period. This emphasis on BIMS-GPT’s automated cost budgeting aligns with Sepasgozar *et al.*^[54], who highlighted that BIM, when integrated with digital tools, significantly enhances cost estimation and monitoring in construction projects. Through BIMS-GPT technology, construction companies can leverage historical project information, material data, labor costs, and other data, as well as current market conditions and trends, to conduct accurate cost budgeting and price estimation, while providing a reasonable floating space. This enables construction companies to establish budgets and resource planning at the project’s outset, thereby improving project control. This automatic cost budgeting function assists companies in better grasping the project’s economic cost and structure, facilitating the implementation of corresponding measures to reduce expenses. Additionally, it can rationalize resource allocation, improve resource utilization, and enable timely budget adjustments, all of which hold great significance to construction companies. Respondent 3 discusses that cost prediction is the core of project implementation, and BIMS-GPT can more reasonably provide reference intervals, thereby enhancing the accuracy and reliability of cost predictions. Respondent 6 highlights show BIMS-GPT is very useful when faced with profound challenges, such as resource allocation and scheduling, which are features that BIMS-GPT can excel at compared to other AIs.

Simultaneously, the convenience of using BIMS-GPT in BIM is also a major driving factor for architectural firms to adopt this technology. When designing with BIM models, planners can automatically generate BIM base models through GPT-powered dialogue boxes based on specific requirements, replacing a significant amount of repetitive work, greatly reducing the simulation load on planners, improving design efficiency, and shortening project duration and cost. Moreover, due to its advanced BIM model processing capabilities, BIMS-GPT enables real-time querying of comprehensive information related to various components, such as manufacturers and materials, via an interactive dialogue box. These queries can be filtered according to specific criteria and are dynamically reflected within the BIM simulation model. The functions perfectly combine BIM and GPT, simplifying the design process for construction companies and making the BIM simulation model more targeted and intelligent. Respondent 1 mentioned that the most attractive aspect of BIMS-GPT is its ability to extract desired project components at random, which can greatly improve the productivity of BIM modeling. Respondent 2 discussed the crucial importance of drawing and modeling in the design period, and if BIMS-GPT can be properly applied to this aspect, it can greatly improve the frequency and quality of the design period.

Additionally, it is one of the most important functions for construction companies to conduct risk management as early as possible. This proactive risk identification and compliance checking during the design phase aligns with Salzano *et al.*^[55], who demonstrated that integrating BIM into risk management and project execution enables dynamic risk assessment and mitigation, thereby enhancing workplace safety and project efficiency. BIMS-GPT technology can automatically identify potential problems during the design period, enabling designers to correct them in a timely manner before construction begins. This capability reduces the time required for corrective actions and specification reviews, allowing the design team to implement immediate solutions, minimize design modifications, and prevent cost escalation and schedule delays in subsequent phases. BIMS-GPT technology can also

automatically check the compliance of design solutions with relevant regulations, standards, and specifications. This not only ensures regulatory adherence, thereby reducing risks associated with non-compliance, but also significantly reduces the time and costs associated with manual review and consultation of regulatory documents, enabling designers to complete their design work more efficiently. Both features reached a score of 4.1579 in the expert evaluation, indicating that they are vital drivers for the application of BIMS-GPT technology in construction companies.

Moreover, energy efficiency and emission reduction of building projects are receiving increasing attention, as evident from the expert scoring, which reached 4.1579 points. The strong database function of BIMS-GPT technology provides crucial support for realizing the goal of energy saving and emission reduction. When developing efficiency analyses, it can offer relevant standards, regulations, design principles, and energy information, enabling designers to utilize these resources to conduct energy efficiency analyses and refer to industry standards and best practices to develop more energy-saving and environmentally friendly design solutions. Additionally, BIMS-GPT technology can perform customized energy efficiency analyses according to the specific requirements and characteristics of the project. Designers can choose appropriate analysis methods and tools to tailor the energy efficiency analysis according to the project's needs. Meanwhile, BIMS-GPT technology can assist designers in conducting a comprehensive assessment and analysis of a building project's energy consumption and emissions.

BIMS-GPT can also identify and extract repetitive items in the bill of quantities, automatically complete the corresponding calculation of quantities and list preparation, automatically prepare the bill of quantities for existing projects by analyzing historical bills of quantities, and complete more repetitive or prescriptive document writing, thus reducing redundant efforts by designers and minimizing inaccuracies in quantity calculations caused by human error. Automated bill of quantities generation greatly accelerates the workflow, enabling designers to complete the preparation of project-related documents more quickly and greatly saving time and labor costs. Respondent 3 discussed that the automated preparation of project-related documents is a very attractive driver for BIMS-GPT technology, and the introduction of this technology can drastically reduce the repetitive work of in-house staff, not only increasing work efficiency and reducing human errors but also freeing up related human resources, which will enhance the overall work efficiency and productivity of the team.

3.2.3 Drivers for the construction period

The construction period typically refers to the actual construction phase of a building project, which includes activities such as building construction, material procurement and installation, as well as work supervision and management. This period is intrinsically linked to the control and management of project quality, safety, schedule, and cost, making it critical to the success of the entire construction project. Therefore, efficient management during the construction period is essential to ensure successful project completion and the achievement of desired goals, and BIMS-GPT will play a vital technological role throughout this period. The expert scores for the construction period are shown in Table 4.

Table 4. Functions and scores that can be realized by BIMS-GPT (Construction Period).

No.	Functions	Average score	Max	Min
Construction period	Automatically identify high-risk and unnoticed areas of a construction site	4.2105	5	1
	Predict the possibility of encountering conflicts or claims in the project	4.1579	5	2
	Enable more intuitive interactive safety training for workers in conjunction with BIM	4.1053	5	3
	Monitor construction sites in real time and automatically generate project progress reports and monitor progress	4.0000	5	2
	Automate risk assessment, explore potential dangers and visualize them in BIM	4.0000	5	2
	Automatically categorize incidents, identify risk causes and make recommendations	4.0000	5	2
	Automatically revise supervisory guidelines for effective risk avoidance	4.0000	5	2
	Allow reallocation and optimization of site resources	4.0000	5	2

Automatically generate financial and cost forecasts	4.0000	5	2
Update and replace the data of BIM-related components at any time	3.8421	5	3
Automatically generate quality control tests according to project requirements and safety rules	3.7895	5	3
Resolve conflicts formed by current stakeholders and provide solutions	3.7895	5	2
Automatically check current construction processes for regulatory compliance	3.6316	5	2

BIM: Building Information Modeling; GPT: Generative Pre-trained Transformer.

The highest-scoring driver is BIMS-GPT's ability to automatically identify high-risk areas and unattended areas of a construction site, receiving a high score of 4.2105. This reflects the great significance of safety issues for construction companies during the construction period, as safety is always the primary concern on construction sites. As Manzoor *et al.*^[56] highlighted, BIM has transformative potential in enhancing construction safety, particularly via early hazard identification and improved danger detection. Our findings extend this perspective by demonstrating how BIMS-GPT, leveraging its robust database and intelligent algorithms, automates real-time high-risk area identification and visualization in BIM models. With its strong database function and case invocation capability, BIMS-GPT can rapidly learn from historical safety incidents and corresponding mitigation measures driven by intelligent algorithms. Simultaneously, it can capture the characteristics of related accidents in the early stage. Additionally, BIMS-GPT can display high-risk areas of the current project in the BIM model through conversational interfaces, enabling relevant personnel to directly view specific high-risk locations and adjust the construction schedule accordingly. The question-and-answer format can be continued through progressive BIM operations, switching viewpoints at any time to provide a more intuitive representation of high-risk and potentially hazardous areas in the BIM model. This ability to identify potential safety threats and risks in a timely manner based on the current project situation allows companies to promptly respond to potential safety challenges through appropriate preventive and mitigative measures, thereby safeguarding the safety of construction personnel and those around the site while improving the safety and controllability of the construction process. Respondent 4 commented that dynamic project risk identification enables continuous monitoring and management of project risks throughout the project lifecycle, allowing for flexibility in responding to new risks and changing circumstances as they occur, which is critical for on-site construction management.

With BIMS-GPT's strong ability to predict site conflicts and claims, the importance of the construction period is well demonstrated. The score of 4.1579 for this feature, ranking second in the construction period, highlights the extreme importance of identifying and resolving conflicts and claims during the construction process from the architectural firm's perspective, and that of the dynamic assistance BIMS-GPT can provide in resolving this issue. In construction projects, conflicts and claims can lead to schedule delays, additional costs, contractual disputes, and degradation of building quality. Therefore, the ability to predict the possibility of on-site conflicts and claims can help construction companies take timely measures to reduce risks, minimize losses, and ensure smooth project progress. BIMS-GPT technology can identify potential points of conflict and claim risks and provide predictive results through the analysis and modeling of a large amount of data, including construction plans, design documents, contract terms and conditions, and real-time data from the construction site. Based on the analysis of these data, BIMS-GPT technology can provide predictive insights to help construction companies identify potential risk areas and possible conflicts at an early stage of the project, take prompt measures to avoid or resolve them, formulate targeted risk management strategies and countermeasures, and ensure successful project implementation and delivery.

In the construction period, interactive safety training ranked third with a score of 4.1053, indicating that construction companies attach importance to interactive training in safety management. This also emphasizes a major feature of BIMS-GPT technology in safety management. Since BIMS-GPT has the capability of real-time feedback output through GPT dialogue boxes, it enables construction workers to ask questions to the system at any time and receive instant answers, serving as a real-time learning and training tool. The interactive nature of the training, with its diverse forms and personalized adjustments, can improve the attractiveness and effectiveness of the training. Through the simulation of actual work scenarios and situational exercises, the training content becomes more specific and vivid, helping staff thoroughly understand safety regulations and operating procedures.

Following that, there are six features with the same score of 4.0000, indicating that these functions have a closer importance for construction companies. Firstly, since BIMS-GPT is integrated with BIM, it can monitor the real-time status and progress of the construction site by collecting information such as sensor data and surveillance camera videos. Based on the real-time monitoring data and information from the BIM model, BIMS-GPT can automatically generate project progress reports which include construction

progress, material usage, personnel allocation, and more, thereby providing managers with timely and accurate insights into project progress. Additionally, BIMS-GPT can produce detailed construction progress reports by comparing planned versus actual progress, offering a clear visual representation of discrepancies. This helps managers immediately identify deviations and take appropriate corrective actions. The automated generation of project reporting and construction progress tracking can greatly improve managerial efficiency, while also allowing decision-makers to maintain real-time awareness of on-site conditions.

While monitoring the construction site, BIMS-GPT can also synchronize the automated assessment of potential risks for the current project based on the site situation, such as potential risk factors related to safety issues, project delays, or quality issues, and provide corresponding suggestions and countermeasures^[57]. It can automatically classify conflicting or contradictory opinions arising on the construction site, identify their underlying causes, and provide targeted suggestions and solutions to help management personnel effectively solve on-site problems, ensuring successful project execution. Meanwhile, different types of conflicting views may emerge during the construction period, and then BIMS-GPT technology incorporates information about the conflict resolution process, causes, and resolution methods into its knowledge database. Upon completion of the construction phase, it can retrospectively analyze the problems that occurred throughout the construction process, map these onto the BIM model to highlight areas prone to conflict or risk, and cross-reference them against relevant regulatory standard. Based on these analyses, BIMS-GPT can suggest revisions to the regulatory guidelines to continuously improve them and reduce the occurrence of similar problems in future construction projects.

3.2.4 Drivers for the operation and maintenance period

The operation and maintenance (O&M) period refers to the post-construction period focused on maintaining a completed building. It typically encompasses routine maintenance, equipment upkeep, energy management, safety protocols, emergency preparedness, and other operational aspects^[58]. Construction companies place a high priority on this period as it directly impacts the building’s long-term performance, value retention, and user satisfaction. During this period, companies must execute various management and maintenance tasks to ensure the building’s normal operation and sustainable long-term development. The expert scores for the operation and maintenance period are shown in Table 5.

Table 5. Functions and scores that can be realized by BIMS-GPT (Operation and Maintenance Period).

No.	Functions	Average score	Max	Min
Operation and maintenance period	Automatically customize recommendations for energy-saving measures	4.2105	5	2
	Automatically generate safety reports and solutions in case of equipment breakdown	4.1053	5	2
	Automatically assess the severity of natural disasters and identify potential dangers	4.1053	5	3
	Analyze optimal inspection and maintenance times in order to reduce expenses	4.0000	5	2
	Accurately predict the remaining useful life of assets	3.9474	5	2
	Automatically generate preventive measures for targeted accidents	3.8421	5	3
	Automatically alert building equipment to the need for upgrades	3.8421	5	1
	Analyze waste materials and automatically generate step-by-step procedures and disposal methods for waste	3.7895	5	2
	Act as a chatbot to communicate with users at any time	3.3684	5	2

BIM: Building Information Modeling; GPT: Generative Pre-trained Transformer.

BIMS-GPT technology harnesses advanced database functions to collect, analyze, and explore a vast amount of historical data, including a building’s energy consumption and environmental data. By analyzing this information, the main sources of energy consumption and potential energy-saving improvements can be identified. Based on these analyses, BIMS-GPT can customize personalized energy-saving solutions for building projects, such as adjusting heating, ventilation, air conditioning, and other system settings to optimize the building’s energy use efficiency. This allows projects to obtain personalized and continuously improved green energy-saving solutions during the O&M period. Such solutions not only reduce energy consumption and operating costs but also lower carbon emissions and environmental impact, enhancing the building’s sustainability and competitiveness. With BIMS-GPT’s personalized green energy-saving solutions, construction companies can achieve more intelligent and sustainable energy management, improving buildings’ environmental performance and competitiveness. This feature scored 4.2105 points, the highest in the O&M period, indicating that construction companies greatly emphasize green energy-saving and emission reduction which reflects their environmental and social responsibility, compliance with regulatory requirements, and alignment with broader

industry trends toward sustainable development. As social awareness of environmental protection and technological progress increase, green energy-saving and emission reduction will become a pivotal strategic priorities for the future development of construction enterprises.

The O&M period involves the daily maintenance and management of building facilities and equipment. After prolonged operation, equipment may fail due to various reasons, such as daily wear and aging, improper use and operation, and lack of regular maintenance. This focus on enhancing O&M efficiency aligns with Corlander and Thollander^[59], who identified “more knowledge within the building industry” and “long-term perspective at the client” as critical drivers for technology implementation in building projects. BIMS-GPT can automatically generate safety reports and solution measures when equipment fails during this period, helping O&M personnel quickly understand the failure nature, its impact, and the best way to cope with it. It can generate personalized reports based on specific equipment failures and building characteristics, meeting the needs of different construction companies and equipment. This not only improves the building company's O&M management level but also enhances the project's reliability and sustainability. The high score of 4.1053 reflects the interest and importance that construction companies attach to technological tools and instruments for improving O&M management, and demonstrates the recognition and expectation of BIMS-GPT technology in solving practical problems. This interest and recognition will promote the further application and promotion of BIMS-GPT technology in the construction industry, providing more possibilities and opportunities for the industry's development and progress.

The function that shared the second-highest score is also safety-related, exemplifying the extraordinary importance that construction companies place on safety due to the potential risks and dangers on construction sites and in buildings. During the O&M period, projects are often prone to various natural disasters, such as fires, earthquakes, and tsunamis. BIMS-GPT technology has a significant impact on dealing with natural disasters during this period. By integrating BIM and real-time monitoring data, BIMS-GPT can conduct real-time monitoring and assessment of natural disasters. It can analyze the disaster's severity, the scope of its impact, and the possible damage it may cause, sending timely alerts and reminders to relevant individuals. Additionally, it can identify areas and facilities that may be affected by analyzing factors such as building structure, geographic location, and climatic conditions, providing building managers with appropriate action recommendations, including evacuation guidelines, emergency rescue plans, equipment shutdowns, and other measures to minimize damages and protect people's safety. After a disaster, BIMS-GPT can also assist building managers with post-disaster assessment and restoration work by analyzing losses and impacts, guiding the priority and direction of restoration work, and providing technical support and decision-making basis. BIMS-GPT enables construction companies to respond promptly to the threat of natural disasters through real-time monitoring, intelligent analysis, and early warning reminders, identify potential dangers, ensure the safety of buildings and people, reduce losses, and improve emergency response capability and management level.

Moreover, maintenance is a crucial aspect of the O&M period, involving regular inspection, maintenance, and repair of building facilities and equipment to ensure normal operation and prolong service life. BIMS-GPT can play an important role in maintenance management by analyzing historical maintenance data, equipment operation status, and maintenance records to identify failure patterns, predict potential future breakdowns, and forecast maintenance requirements. It can also analyze construction data to derive the optimal time for inspection and repair, helping O&M teams strategically schedule maintenance activities that minimize disruptions to building operations and reduce downtime-related losses. The application of BIMS-GPT technology makes maintenance management more intelligent and sophisticated, helping construction companies better guarantee the normal operation of building facilities and equipment, extend their service life, and improve the overall O&M level and competitiveness. Through reasonable planning and optimization of maintenance plans, construction companies can decrease maintenance costs, improve productivity, and enhance sustainable development. The feature's high rating, 4 out of 4 by construction companies, underscores its perceived critical importance in maintenance management.

BIMS-GPT can bring many other benefits to the O&M period. For example, it can predict the remaining service life of building facilities and equipment, helping enterprises formulate maintenance and renewal plans in a timely manner that optimize asset lifecycle management and improve asset utilization and value. Furthermore, BIMS-GPT can identify potential accident risks and hazards, provide early warnings and automatically generate targeted preventive measures. It further supports the analysis and evaluation of equipment performance, technical indicators, and renewal cycles, reminding managers whether upgrades or replacements are necessary. It can additionally detect waste materials generated on-site and during operation, subsequently producing detailed, stepwise protocols for waste treatment and disposal. Collectively, these functions can help construction enterprises improve management efficiency, reduce costs, enhance safety, and realize intelligent and refined O&M management, enhancing their competitiveness and promoting sustainable development.

3.2.5 Drivers of the demolition period

The demolition period is the stage when a building is slated for demolition and ultimately dismantled. During this period, the building's demolition undergoes a series of planning, preparation, execution, and clean-up phases. It is a critical stage in the building life cycle that requires meticulous planning and preparation to ensure that the demolition work is safe, efficient, and environmentally friendly. BIMS-GPT plays significant roles during the demolition period, making every effort to ensure safety and improve efficiency

by formulating plans, proposing measures, optimizing processes, and anticipating risks. The expert scores for the demolition period are shown in Table 6.

Table 6. Functions and scores that can be realized by BIMS-GPT (Demolition Period).

No.	Functions	Average Score	Max	Min
Demolition period	Identify potential risks, establish the optimal demolition sequence and propose appropriate safety measures	4.0000	5	2
	Develop better reconstruction plans through powerful data processing capabilities	3.9474	5	3
	Analyze various demolition risk factors and propose appropriate safety measures	3.9474	5	2
	Identify potential environmental dangers and propose appropriate measures	3.8421	5	3
	Enhance structural assessment by identifying hidden defects that may be overlooked by manual inspection	3.8421	4	2
	Simplify step-by-step procedures for disposal of harmful substances	3.7895	5	3
	Automatically recognize compliance with relevant regulatory laws and regulations	3.6842	5	2
	Predict and assess various risks in various fields	3.6316	5	2
	Identify materials through powerful image recognition capabilities to develop material recovery programs	3.6316	5	1
	Rapidly identify waste types and improve efficiency of waste sorting	3.5263	5	1
	Rapidly learn new waste recycling methods and update relevant datasets	3.4737	5	1

BIM: Building Information Modeling; GPT: Generative Pre-trained Transformer.

Safety is always the primary concern for experts. During the demolition period, BIMS-GPT can rapidly identify potential risks in the demolition process, establish the optimal demolition sequence in combination with the actual project conditions, and propose relevant safety precautions and targeted measures. This capability to integrate risk identification and process optimization in demolition aligns with Kaewunruen *et al.*^[60], who demonstrated that BIM-driven frameworks enhance demolition safety and efficiency by enabling real-time risk assessment and optimized workflow planning. This not only effectively avoids accidents but also improves work efficiency, helps staff pay more attention to potential safety hazards, and ensures the demolition work can be carried out successfully. As Respondent 1 mentioned, timely and fully automated safety warnings are the goal they are looking for in the future. It is clear that these safety features are the most important aspect of the demolition period for experts and are the main driving factors for BIMS-GPT in this period.

During the demolition process, whether the on-site demolition complies with relevant laws and regulations is also a major concern for construction companies. As Alotaibi *et al.*^[61] noted, BIM adoption significantly enhances legal and contractual management in construction, particularly through clearly defined BIM protocols in contracts and efficient dispute resolution mechanisms. Building on this, our findings show how BIMS-GPT uses a real-time updated regulation database and knowledge base to automatically monitor and flag non-compliant demolition activities. Furthermore, Mitera-Kleibasa and Zima^[62], who analyzed European BIM policy trends (indicating that 35% of European countries have or plan BIM mandates for regulatory compliance), help explain why firms prioritize tools such as BIMS-GPT: these tools directly address the industry’s need for legal practices. BIMS-GPT’s ability to automatically monitor site conditions and identify real-time operations during demolition enables it to cross-reference its extensive knowledge base with real-time regulatory data. It can identify irregularities in operations and retrieve specific regulatory violations, including relevant clauses, at any moment. This feature not only helps construction companies take timely corrective measures to ensure regulatory compliance but also helps them mitigate the risk of legal liabilities associated with non-compliance, thereby improving the demolition work’s legality and safety.

Furthermore, BIMS-GPT also allows for the development of material recovery plans, quick identification of waste types, and rapid learning of new waste recovery methods. These functions not only help construction companies complete the demolition task more efficiently but also help reduce the negative environmental impact and improve the level of sustainable development. By developing material recovery plans, BIMS-GPT can assist construction companies in rationally utilizing the waste and resources generated during the demolition process to achieve resource recycling and reuse. Meanwhile, by rapidly identifying waste types and learning new waste recycling methods, BIMS-GPT can help construction companies process waste more efficiently, reduce waste emissions,

minimize pollution and environmental damage, and raise the level of sustainable development of demolition work. These functions can not only improve construction companies’ economic benefits but also promote environmental protection and sustainable development, realizing the coordinated development of the economy, society, and environment.

3.3 Analysis of Driver Results for each Period

The average scores across different periods (Table 7) show that construction companies generally express their interests in the functions of BIMS-GPT during the design period, which is a positive response to BIMS-GPT’s strong ability in modeling and design. BIM is a digital architectural design and management software, which creates, manages and maintains digital models of construction projects. Digital model construction is an indispensable part of the design period. BIM can help designers create high-precision 3D building models, perform collision detection, analyze building energy efficiency, manage cost budgets, and perform a variety of other essential functions. BIMS-GPT can maximize its intelligent role during the design period, and its functions of automatic model generation, intelligent analysis, automatic cost calculation, and intelligent collaboration can help designers utilize BIM for modeling and analysis in a more convenient and efficient manner. It also provides a more comprehensive and integrated program, reducing tedious and repetitive work and allowing for improved design efficiency and quality.

Table 7. Average Score for each period.

Stages	Average Score	Mode
Pre-design period	3.6842	4
Design period	4.0643	4
Construction period	3.9636	4
Operation and maintenance period	3.9123	4
Demolition period	3.7560	4

The second-highest score is for the construction period, underscoring the significant interest in BIMS-GPT’s capacity for real-time site monitoring and risk identification Once a project enters the construction period, on-site construction operations commence, and BIMS-GPT’s real-time site detection and automatic situation analysis and risk identification become particularly important, further showing the substantial value experts place on BIMS-GPT. By providing crucial support and assistance in real-time monitoring, risk identification, bills of quantities management, and safety management, BIMS-GPT helps to ensure a successful construction process and satisfactory project completion. As the construction period marks the onset of actual building activities and plays a pivotal role in the project’s progression, the application of artificial intelligence, such as BIMS-GPT, offers substantial opportunities for optimization and improvement. This explains, in part, why this stage receives a higher score from experts.

The O&M period also ranks highly in the building lifecycle, making it reasonable that BIMS-GPT scored 3.9123 in this period as a driving factor. When the project enters the O&M period, safety management, risk warning, and maintenance and repair become crucial, and the BIM model is also needed at this time to detect the building’s state and reflect it through the model. BIMS-GPT’s role in this process is more reflected in identifying potential risks, providing corresponding programs, and giving repair plans in a more scientific manner. Therefore, its score is not as high as the design and construction periods. However, since the work included in this period is still substantial, the importance of BIMS-GPT’s drivers in the O&M period is still higher compared to the demolition and pre-design periods, which is as expected. Across all periods, “Max = 5” proves that BIMS-GPT’s functions can be seen as “major drivers” by some respondents, validating their potential to boost work in each phase. However, Min values reveal period-specific divergence: Pre-Design and Demolition show more significant disagreement (with some Min = 1, “not a driver”), while Design has less divergence (Min mostly = 2, “weak driver”). These insights guide future optimization of BIMS-GPT to address uneven recognition across lifecycle stages.

Our findings that BIMS-GPT demonstrates the greatest driving effect during the design and construction periods are consistent with previous BIM-related studies. For instance, Tang *et al.*^[63] emphasized that many of the critical risk factors in BIM implementation in China arise during the design and construction phases, such as inefficiencies in coordination and challenges in site safety management, which aligns with our observation that experts expect BIMS-GPT to enhance model generation, collaboration, and real-time monitoring at these stages. Similarly, Somboolgrunk *et al.*^[64] highlighted that strategic integration of BIM and big data brings the most significant industrial benefits during design-intensive and construction-intensive processes, further confirming the strong applicability of intelligent augmentation in these periods. In addition, Correa *et al.*^[65] demonstrated that BIM-related skills are most tightly linked with project management and operational decision-making, indirectly supporting our result that BIMS-GPT can facilitate efficiency gains in both design modeling and construction monitoring tasks. Compared with these prior studies, our work extends the literature by explicitly incorporating GPT-based intelligence into BIM applications, showing how its automated analysis and reasoning capabilities can address longstanding pain points identified in traditional BIM adoption.

On a 1-5 Likert scale, the mode for each lifecycle period is consistently 4. This indicates that the most frequently reported perception among respondents is that BIMS-GPT functions as a strong driver in every phase, signifying that these functions are widely recognized as effective in facilitating work but have not yet reached the major driver level. The consistent mode of 4 across all periods reveals two critical takeaways: First, there is broad consensus that BIMS-GPT delivers meaningful driving value throughout the entire construction lifecycle. Second, despite this recognition, there remains ample room to enhance BIMS-GPT’s impact to attain the “major driver” status, which points to clear opportunities for further optimization.

3. 4. Barriers

For the construction industry, BIMS-GPT is a highly advanced and emerging technology. While it offers significant potential to address various challenges faced by construction companies through its intelligent capabilities, the introduction of new technologies will inevitably face numerous obstacles. Therefore, it is crucial to analyze the barriers to the integration of BIMS-GPT within the construction industry and assess their relative importance. Such an analysis will be more beneficial for construction company management, aid in the effective implementation of this technology and support its further development. From “Max = 5” across all barriers (Table 8), it is clear that some respondents perceived each listed issue as a major barrier. Meanwhile, Min values ranging from 1 to 2 reveal divergent perceptions. Barriers such as “High cost of technology development...” and “No clear legal framework of accountability...” have a Min of 1, meaning that some respondents didn’t view them as a barrier. In contrast, others like “Lack of comprehensiveness of information/programs” have a Min of 2, which is considered a weak barrier.

Table 8. Barriers and scores faced by BIMS-GPT.

Barriers	Average Score	Max	Min
High cost of technology development and related talent pool and training	3.8947	5	1
No clear legal framework of accountability and liability exists for damages caused by AI	3.6842	5	1
Possibility of data leakage when processing reports, designs, contracts	3.6316	5	1
Lack of transparency and credibility in data processing	3.4737	5	1
Possibility of delaying or failing to meet the schedule of the project due to incomplete information	3.4737	5	1
Lack of comprehensiveness and completeness of some information or programs given	3.3684	5	2
Old laws and regulations are followed in the preparation of relevant documents	3.2632	5	1
Low acceptance of new technology by employees, who may fear that artificial intelligence will replace jobs in the construction industry	3.2632	5	2

BIM: Building Information Modeling; GPT: Generative Pre-trained Transformer.

As can be seen in Table 8, what companies are most concerned about is the economic cost. As a highly advanced new technology, the development and maintenance of BIMS-GPT is bound to require substantial costs. Firstly, companies need to invest in research, development, and purchase of BIMS-GPT-related software and hardware equipment. Secondly, BIMS-GPT requires professional technicians for development and maintenance, so regular staff training, technological upgrades, and the recruitment of qualified professional and technical staff are necessary to ensure that employees can master and effectively use this technology and maintain software stability and optimize its performance. It is evident that talent training, software development, maintenance, and operation cannot be separated from economic expenses, and the real benefits and returns on these investments remain uncertain. Respondents 1, 2, and 5 all mentioned the difficulty of talent training and the pressure of capital investment in research and development, indicating that the high cost will be the main obstacle for construction companies to adopt BIMS-GPT technology^[66].

In addition, since BIMS-GPT is a new technology that combines BIM and GPT, it has not yet been put into actual business use. The application of AI in the construction industry is uncommon, so there is a lack of mature legal regulations and accountability norms in this regard. In the event that BIMS-GPT’s outputs result in damage or operational failures, there is currently no clear legal framework and accountability mechanism to address such issues. This gap in legal provisions concerning liability attribution and the definition of legal responsibility creates significant risks and uncertainties. These ambiguities constitute a major concern for construction companies considering the adoption of BIMS-GPT technology.

Moreover, data security and privacy protection related to BIMS-GPT are also serious concerns. BIMS-GPT is essentially a language processing model for generative artificial intelligence, and its more functional features are also related to text generation and data processing, which often need to deal with a large amount of sensitive data when processing reports, designs, and contracts, such as project details, financial information, and personal data. Therefore, the use of BIMS-GPT presents significant risks of data breaches,

potentially compromising important aspects such as trade secrets, personal privacy, and regulatory compliance. As such, data security issues represent a major challenge to the widespread adoption and deployment of BIMS-GPT technology.

Besides, BIMS-GPT will also face the problem that the procedures of data processing are not transparent, and the results are not convincing enough. Some given information or solutions may lack comprehensiveness, and imperfect information may adversely affect project planning, resulting in schedule delays and cost overruns. Moreover, the legal frameworks employed in the generation of relevant documents may be outdated, and the acceptance of the new technology by the staff is not high, as they fear that artificial intelligence may replace their roles in the construction industry. Respondent 1 also discussed that the immaturity of the BIMS-GPT technology may also bring about concerns in the organization. All of these barriers have an impact on the adoption of BIMS-GPT technology in construction companies. Therefore, although BIMS-GPT has great potential, its application faces many challenges and obstacles which must be taken seriously. Companies need thoroughly assess the costs associated with its deployment and take proactive steps to mitigate these issues to ensure successful integration and application.

Our identification of barriers to BIMS-GPT adoption aligns with and extends existing literature on BIM implementation challenges in the AEC industry. For instance, Lourenço *et al.*^[67] studied BIM barriers in late-adopting EU countries and identified “lack of top management support, resistance to change, and inadequate evaluation mechanisms” as core obstacles, while our study highlights economic cost as the top barrier for BIMS-GPT. Both works underscore that organizational and financial factors critically impede new technology uptake in construction. Similarly, Hatami and Rashidi^[68] investigated BIM barriers in Iran’s AEC sector and emphasized regulatory gaps and industry–academia disconnect as key issues; our finding that lack of mature legal frameworks for AI-integrated tools is a major concern echoes their emphasis on regulatory barriers, yet we further specify this risk as tied to BIMS-GPT’s AI-driven data processing and liability uncertainties. Additionally, Alshibini *et al.*^[69] explored BIM adoption barriers in Saudi Arabia and found lack of skilled personnel to be the top driving barrier; our study complements this by showing that talent training costs and employee anxiety over job replacement are salient sub-dimensions, illustrating how BIMS-GPT’s integration of GPT introduces workforce-related challenges distinct from traditional BIM tools.

4. Results and Discussion

Although experts have clear scores for the different features and barriers of BIMS-GPT across each period, our primary interest lies in examining the variability in how different respondent groups score the drivers and barriers of BIMS-GPT. To explore this, we divided all the respondents by attributes and then averaged their scores again to compare the scoring preferences of different attribute groups. This analysis aims to explore which drivers or barriers are preferred by each specific group for the subsequent promotion of BIMS-GPT technology in the construction industry.

4.1 Differences between different years of experience in the industry

4.1.1 Differences in drivers

We divided the respondents according to their years of industry experience into 3 groups: 0-5 years, 6-10 years, and 11-15 years, and analyzed each driver and barrier at each period. From Table 9, it can be seen that respondents with 0-5 years of working experience are generally less interested in adopting the BIMS-GPT technology than those who have worked for a longer period, and this phenomenon is analyzed to be related to psychological factors of the workers. Those with less experience are still in the process of learning new knowledge, and when they are not skilled in the work they are performing, their interest in newer technologies is not as high as those with more experience. In contrast, those with 6-10 years of experience, who are more familiar with project and site operations, demonstrate a clearer understanding of the benefits of BIMS-GPT, making them more inclined to adopt the technology. While the most experienced workers (11-15 years) also show significant interest in BIMS-GPT, their greater familiarity with established workflows and resistance to change, possibly influenced by age, result in a slightly lower driver score than those with 6-10 years of work experience.

Table 9. Scores for different years of experience in the construction industry in drivers.

Functions	Years of experience		
	0-5 years	6-10 years	11-15 years
Automatically give project quote references and make purchasing decisions	3.0000	4.1250	4.7500
Automatically develop initial project summary	2.5000	3.5000	4.0000
Develop project management plans on a personalized basis	3.0000	3.7500	4.0000
Easier for novices to learn the shape of various components of the BIM model	3.3333	4.1250	4.0000

Automatically generate targeted design ideas	3.3333	3.6250	3.7500
Identify potential problems in the design period as early as possible	3.8300	4.2500	4.2500
Automatically check design solutions for regulation compliance	3.8300	4.3750	4.0000
Automatically evaluate materials for building components and select the optimal material	3.5000	3.8750	4.2500
Automatically prepare bills of quantities	3.5000	4.2500	4.2500
Automatically budget the cost of construction projects	3.8333	4.2500	4.5000
Automatically analyze the energy efficiency of the building and propose solutions to save energy costs	3.6667	4.2500	4.5000
Automatic generate relevant BIM base models	3.8333	4.5000	4.0000
Query and display all information related to BIM components at any time	3.3333	4.5000	4.2500
Automatically check current construction processes for regulatory compliance	3.0000	4.0000	3.5000
Monitor construction sites in real time and automatically generate project progress reports and monitor progress	3.5000	4.0000	4.5000
Automate risk assessment, explore potential dangers and visualize them in BIM	3.8333	4.0000	4.0000
Automatically identify high-risk and unnoticed areas of a construction site	4.1667	4.0000	4.5000
Automatically revise supervisory guidelines for effective risk avoidance	3.8333	4.1250	3.7500
Enable more intuitive interactive safety training for workers in conjunction with BIM	3.6667	4.3750	4.0000
Automatically categorize incidents, identify risk causes and make recommendations	3.5000	4.0000	4.5000
Allow reallocation and optimization of site resources	3.8333	3.8758	4.2500
Automatically generate quality control tests according to project requirements and safety rules	3.8333	4.0000	3.0000
Predict the possibility of encountering conflicts or claims in the project	4.0000	4.3750	3.3750
Automatically generate financial and cost forecasts	4.0000	3.8750	4.0000
Resolve conflicts formed by current stakeholders and provide solutions	3.5000	3.7500	4.0000
Update and replace the data of BIM-related components at any time	3.5000	4.0000	3.7500
Automatically generate preventive measures for targeted accidents	3.5000	4.1250	3.5000
Analyze optimal inspection and maintenance times in order to reduce expenses	3.5000	4.2500	4.0000
Automatically customize recommendations for energy-saving measures	4.0000	4.5000	3.7500
Automatically alert building equipment to the need for upgrades	3.1667	4.1250	4.0000
Automatically generate safety reports and solutions in case of equipment breakdown	3.6667	4.3750	4.0000
Accurately predict the remaining useful life of assets	3.6667	4.1250	3.7500
Act as a chatbot to communicate with users at any time	3.0000	3.1250	4.0000
Analyze waste materials and automatically generate step-by-step procedures and disposal methods for waste	3.6667	3.7500	3.7500
Automatically assess the severity of natural disasters and identify potential dangers	3.5000	4.2500	4.5000
Identify potential risks, establish the optimal demolition sequence and propose appropriate safety measures	3.5000	4.0000	4.7500
Predict and assess various risks in various fields	3.3333	3.7500	3.5000
Rapidly identify waste types and improve efficiency of waste sorting	3.3333	3.6250	3.7500
Simplify step-by-step procedures for disposal of harmful substances	3.8333	3.8750	3.7500

Rapidly learn new waste recycling methods and update relevant datasets	3.1667	3.7500	3.5000
Develop better reconstruction plans through powerful data processing capabilities	4.1667	3.8750	3.7500
Automatically recognize compliance with relevant regulatory laws and regulations	3.1667	4.2500	3.2500
Identify potential environmental dangers and propose appropriate measures	3.6667	4.0000	3.7500
Enhance structural assessment by identifying hidden defects that may be overlooked by manual inspection	3.5000	3.8750	4.2500
Identify materials through powerful image recognition capabilities to develop material recovery programs	3.1667	3.8750	3.7500
Analyze various demolition risk factors and propose appropriate safety measures	3.3333	4.5000	3.7500
Average score	3.5323	4.0381	3.9701

BIM: Building Information Modeling.

For construction workers with 0-5 years of experience, they generally have a higher interest in the automatic identification of dangerous areas, automatic generation of plans using the database, prediction of clashes, cost prediction, and automatic analysis and proposal of measures features of BIMS-GPT. These functionalities are generally considered to be the main driving factors that drive them to use BIMS-GPT. For those with 6-10 years of experience, features related to designing BIM models received higher favorability. For workers with 11-15 years of experience, they focus more on BIMS-GPT's features for improving the database, identifying risks, analyzing energy efficiency, and automating site monitoring.

It can be seen that each group of workers in the construction industry has its own focus on functionality. For newcomers, who are generally younger, the new technology features are more automated and intelligent, which are more likely to be appreciated by young people. However, for workers with some working experience, the ability to generate, modify and query the relevant components of the BIM model in the form of a dialogue box has a strong attraction, which indicates that BIMS-GPT has a strong irreplaceable function that can be realized in the BIM design period. This innovative design method not only improves the design efficiency but also provides the designers with a more intuitive, convenient operation experience, which will be the trend of the future of building design and promote the digital transformation and intelligent development of the building industry. For workers with longer experience, they focus more on risk prevention and real-time monitoring of the construction sites due to their accumulated experience. These concerns align closely with the primary priorities of construction companies. This finding reveals the inadequacies of the current risk prevention and real-time monitoring in construction companies. However, the introduction of BIMS-GPT technology fills this gap and offers solutions that enhance risk detection and timely feedback at construction sites. In doing so, BIMS-GPT contributes significantly to improving construction safety and operational efficiency, emphasizing its critical role in the industry and its substantial value to enterprises.

4.1.2 Differences in barriers

As can be seen in Table 10, there are no significant differences between the different groups for barriers. Workers with more than six years of experience generally score higher than those with fewer years of experience, which reflects that as the number of working years increases, workers have a clearer understanding of both the potential benefits and the challenges associated with the introduction of new technologies, and have a more thorough consideration. Moreover, workers with longer working years tend to approach new technologies with a more cautious and discerning mindset, drawing on their broader experience and deeper knowledge of technology implementation. In contrast, those with fewer years of experience are more receptive and motivated, often overlooking potential barriers.

Table 10. Scores for different years of experience in the construction industry in barriers.

Barriers	0-5 years	6-10 years	Over 11 years
Lack of transparency and credibility in data processing	2.8333	4.0000	3.4000
Lack of comprehensiveness and completeness of some information or programs given	3.5000	3.1250	3.6000
Possibility of delaying or failing to meet the schedule of the project due to incomplete information	3.1667	3.7500	3.4000
Possibility of data leakage when processing reports, designs, contracts	3.0000	4.0000	3.8000
Old laws and regulations are followed in the preparation of relevant documents	3.5000	3.1250	3.2000

High cost of technology development and related talent pool and training	3.0000	4.3750	4.2000
Low acceptance of new technology by employees, who may fear that artificial intelligence will replace jobs in the construction industry	3.1667	3.5000	3.0000
No clear legal framework of accountability and liability exists for damages caused by AI	4.0000	3.6250	3.4000
Average score	3.2708	3.6875	3.5000

AI: artificial intelligence.

Construction staff with 0-5 years of experience are more concerned about barriers such as lack of legal frameworks, poor programmatic integrity, and old reference rules, suggesting that younger practitioners are more focused on more detailed work, and that their concerns are related to the specifics of their work. Construction workers with 6-10 years of experience are more likely to be worried about high capital costs and data security, while those with more than 11 years of experience are generally more anxious about the cost of technology development and the need for training. However, they do not consider the psychological rejection of new technologies and the possibility of job displacement to be significant barriers, which is somewhat unexpected. Normally, staff with longer working experience are well-acquainted with existing workflows, and may be a little reluctant to adopt new technologies, however, the results of this study suggest the opposite. Workers with longer experience do not view BIMS-GPT as a threat to their job security and, in fact, appear to be optimistic about the technology’s application. Respondent 2 talked about the fact that BIMS-GPT has a very bright future, and asserted that concerns about job displacement are unfounded. Instead, he hopes that companies can overcome these barriers and actively embrace the new technology by increasing investment, vigorously recruiting relevant talents, and strengthening the efforts of talent cultivation. He calls for construction companies to develop a series of strategic systems, preaching and promotion in major enterprises, for the future of the big data artificial intelligence generation in advance, and actively step into the AI trend.

4.2 Differences between investigators in different departments

We are also particularly interested in examining the attitudes towards BIMS-GPT among individuals from different departments in a large construction company like CSCEC. The head office, branch offices, general management departments, and technical business departments usually have unique perspectives and attitudes, which is exactly what we want to explore. By investigating different departments, we can gain a more comprehensive understanding of the needs and expectations of different departments for BIMS-GPT, which will provide useful reference and guidance for its further promotion and application.

4.2.1 Differences in drivers

As we can see from Table 11, in general, the branch offices are more optimistic about BIMS-GPT than the head office, and they have higher expectations for its introduction and full application. Branch offices may have a more positive attitude towards the introduction of the new technology because they are closer to the actual operation of project implementation and have a better sense of the direct benefits of the new AI technology. In contrast, the head office may focus more on overall strategy and long-term planning, and may be more cautious about the introduction of new technologies. Meanwhile, general management departments, which are usually responsible for the overall management and coordination of the enterprise, tend to be more favorable to the new technologies than technical departments. They expect that the introduction of BIMS-GPT can improve management efficiency and optimize processes, while the technical business departments may pay more attention to the professionalism and practicability of the technologies, with technical staff often having established preferences for specific tools. As a result, their overall score is not as high as that of the management staff. The attitudes of different departments towards BIMS-GPT are influenced by various factors, including departmental functions, project needs, and employee attitudes. Therefore, understanding the attitudes of different departments towards new technologies can help enterprises formulate better strategies for technology introduction and application, and realize the positive interaction between technology and business.

Table 11. Scores for different departments in drivers.

Functions	Departments			
	Head office management department	Head office technical department	Branch office management department	Branch office technical department
Automatically give project quote references and make purchasing decisions	5.0000	3.0000	4.7500	3.2857
Automatically develop initial project summary	4.5000	2.5000	4.0000	3.1429

Develop project management plans on a personalized basis	3.5000	2.5000	4.0000	3.4286
Easier for novices to learn the shape of various components of the BIM model	3.0000	4.0000	4.0000	3.8571
Automatically generate targeted design ideas	4.0000	2.5000	3.7500	3.5714
Identify potential problems in the design period as early as possible	3.5000	3.5000	4.2500	4.1429
Automatically check design solutions for regulation compliance	4.0000	4.0000	4.0000	4.1429
Automatically evaluate materials for building components and select the optimal material	3.0000	2.5000	4.2500	4.1429
Automatically prepare bills of quantities	3.5000	3.5000	4.2500	3.7143
Automatically budget the cost of construction projects	4.0000	3.5000	4.5000	4.1429
Automatically analyze the energy efficiency of the building and propose solutions to save energy costs	5.0000	3.0000	4.5000	4.0000
Automatic generate relevant BIM base models	3.5000	3.0000	4.0000	4.2857
Query and display all information related to BIM components at any time	3.5000	3.0000	4.2500	4.0000
Automatically check current construction processes for regulatory compliance	4.0000	2.5000	3.5000	3.7143
Monitor construction sites in real time and automatically generate project progress reports and monitor progress	4.5000	3.0000	4.5000	4.1429
Automate risk assessment, explore potential dangers and visualize them in BIM	3.5000	3.0000	4.0000	4.1429
Automatically identify high-risk and unnoticed areas of a construction site	4.5000	4.0000	4.5000	4.1429
Automatically revise supervisory guidelines for effective risk avoidance	3.5000	3.0000	3.7500	4.1429
Enable more intuitive interactive safety training for workers in conjunction with BIM	4.0000	4.0000	4.0000	4.0000
Automatically categorize incidents, identify risk causes and make recommendations	3.5000	3.0000	4.5000	4.0000
Allow reallocation and optimization of site resources	3.0000	3.0000	4.2500	4.0000
Automatically generate quality control tests according to project requirements and safety rules	3.0000	3.0000	3.0000	4.1429
Predict the possibility of encountering conflicts or claims in the project	4.0000	4.0000	3.3750	4.1429

Automatically generate financial and cost forecasts	4.5000	4.0000	4.0000	4.0000
Resolve conflicts formed by current stakeholders and provide solutions	3.5000	4.0000	4.0000	3.7143
Update and replace the data of BIM-related components at any time	4.0000	4.0000	3.7500	3.4286
Automatically generate preventive measures for targeted accidents	3.5000	3.0000	3.5000	3.8571
Analyze optimal inspection and maintenance times in order to reduce expenses	4.0000	4.0000	4.0000	3.8571
Automatically customize recommendations for energy-saving measures	4.0000	4.0000	3.7500	4.2857
Automatically alert building equipment to the need for upgrades	4.5000	3.5000	4.0000	3.7143
Automatically generate safety reports and solutions in case of equipment breakdown	4.0000	3.0000	4.0000	4.1429
Accurately predict the remaining useful life of assets	3.5000	3.5000	3.7500	4.0000
Act as a chatbot to communicate with users at any time	2.5000	2.5000	4.0000	3.5714
Analyze waste materials and automatically generate step-by-step procedures and disposal methods for waste	3.0000	3.5000	3.7500	3.8571
Automatically assess the severity of natural disasters and identify potential dangers	4.5000	3.0000	4.5000	4.0000
Identify potential risks, establish the optimal demolition sequence and propose appropriate safety measures	4.0000	3.0000	4.7500	4.0000
Predict and assess various risks in various fields	3.0000	3.0000	3.5000	3.8571
Rapidly identify waste types and improve efficiency of waste sorting	3.5000	3.0000	3.7500	3.4286
Simplify step-by-step procedures for disposal of harmful substances	3.5000	3.5000	3.7500	3.7143
Rapidly learn new waste recycling methods and update relevant datasets	3.5000	3.0000	3.5000	3.2857
Develop better reconstruction plans through powerful data processing capabilities	3.5000	3.5000	3.7500	4.2857
Automatically recognize compliance with relevant regulatory laws and regulations	4.0000	3.0000	3.2500	3.4286
Identify potential environmental dangers and propose appropriate measures	3.5000	3.0000	3.7500	4.0000
Enhance structural assessment by identifying	4.0000	2.0000	4.2500	3.8571

hidden defects that may be overlooked by manual inspection				
Identify materials through powerful image recognition capabilities to develop material recovery programs	3.5000	2.5000	3.7500	3.8571
Analyze various demolition risk factors and propose appropriate safety measures	3.5000	3.0000	3.7500	3.8571
Average score	3.7500	3.2065	3.9701	3.8789

BIM: Building Information Modeling.

According to the survey results, the most important function for the general management department of the head office is the establishment of an effective decision-making process for product procurement and automatic analysis of building energy efficiency. This shows that group management, as the mastermind of macro decision-making, places significant emphasis on green energy-saving aspects of purchasing products and projects. The management of the head office is usually responsible for formulating and executing the enterprise's strategic planning, making decisions on major project investments, and coordinating the operation and management of various branches. The importance of purchasing product decision-making and building energy-efficiency analysis is not only due to the consideration of the enterprise's strategic objectives and image but also due to the need for coordination of the enterprise's overall operation and cost management. These two functions are important for the enterprise's long-term development and sustainable operation, which are therefore highly valued by the head office management. Respondent 5 expressed that for management, the adoption of new technologies by the enterprise needs to be considered not only in terms of cost but also with regard to its long-term sustainable development. The adoption of BIMS-GPT technology, in this context, can help construction companies complete the transformation into high-tech companies, facilitating significant advancements in intelligent construction.

The branch office management is very interested in BIMS-GPT's ability to establish a perfect decision-making system for purchasing products. But unlike the head office, they are also very interested in features related to actual project activities, such as detecting potential hazards during the dismantling process, automatically identifying high-risk areas, generating progress reports and monitoring progress through real-time on-site monitoring pictures. The high scores for these functions reflect the greatest difference in focus between head office management and branch office management. The latter management, closer to the actual project execution, pays more attention to the specific, detailed functions that ensure construction safety and effective project oversight.

The technical departments generally focus more on database querying with BIMS-GPT and the automatic generation and search function related to BIM, which is different from the focus of the general administration departments. The technical departments of the head office show more interest in the functions related to the BIM model during the design period. Since the technical department is more involved in implementation of the project and has a better understanding of the actual operation of each period of the building lifecycle, and its work is closer to the actual situation, they are more interested in the application of the GPT-BIM model in the design period in the form of a dialogue box for creating, modifying, and querying the construction of the BIM module, which can help them participate in the project and improve the design efficiency and quality, laying a solid foundation for the completion of subsequent projects. Technical departments in branch offices also focus on BIMS-GPT and BIM design-related functions, believing that such functions can minimize complicated and tedious design work. The reason behind this trend is that these departments are closer to the actual work at the basic level and therefore pay more attention to how to simplify complicated design tasks by using technology. Additionally, branch technicians are particularly interested in the suggestions and predictions provided by BIMS-GPT's powerful data processing capabilities. These functions can effectively provide targeted recommendations and forecasts based on the data, helping technology staff better understand the project's status and trends, thereby facilitating more informed decision-making and strategic planning. This is not only related to the nature of the technical staff's work, which is closer to the actual work, but also to the fact that technical staff tend to rely more on data and facts to support decision-making and trust the conclusions drawn from historical data.

4.2.2 Differences in barriers

From Table 12, we can see that differences in barriers are more significant across departments. In terms of departmental attributes, the management department is more concerned about the barriers to introducing BIMS-GPT into the construction industry than the technical department, and the attitudes of the head office departments towards the barriers vary more than those of the branch offices. This can be attributed to the generally cautious approach adopted by general management, which is particularly evident in their stance on the introduction of BIMS-GPT. The adoption of new technology will inevitably bring challenges such as rising costs, concerns over data confidentiality, legal compliance issues, and over-reliance of employees. Such a shift would lead to significant

changes in the company’s overall management. Therefore, management must undertake a comprehensive analysis of both the advantages and disadvantages before introducing the new technology into the construction company. For the technical staff, whose work is more related to technology, they are more concerned about the benefits and convenience of BIMS-GPT and do not consider the obstacles they face as much as management. This difference accounts for the variation in the scores of obstacles between the two departmental groups, which aligns with our expectations.

Table 12. Scores for different departments in barriers.

Barriers	Departments			
	Head office management department	Head office technical department	Branch office management department	Branch office technical department
Lack of transparency and credibility in data processing	5.0000	2.5000	3.2500	3.5714
Lack of comprehensiveness and completeness of some information or programs given	4.0000	2.0000	3.6250	3.2857
Possibility of delaying or failing to meet the schedule of the project due to incomplete information	4.5000	2.5000	3.7500	3.1429
Possibility of data leakage when processing reports, designs, contracts	5.0000	2.0000	4.0000	3.2857
Old laws and regulations are followed in the preparation of relevant documents	3.0000	3.0000	3.5000	3.1429
High cost of technology development and related talent pool and training	4.0000	3.0000	4.2500	3.7143
Low acceptance of new technology by employees, who may fear that artificial intelligence will replace jobs in the construction industry	3.0000	3.0000	3.0000	3.7143
No clear legal framework of accountability and liability exists for damages caused by AI	3.0000	4.5000	3.7500	3.5714
Average score	3.9375	2.8125	3.6406	3.4286

AI: artificial intelligence.

Specifically analyzed, the head office general management department is more concerned about data confidentiality and transparency of data processing, while the head office technology department is more concerned about the incomplete legal framework barriers of existing AI technology. The branch general management department is more concerned about the high training and research and development costs associated with introducing the technology, while the branch technology department is more concerned about the financial aspect, as well as the rejection of the introduction of the new technology by the employees and their acceptance of it. This conclusion is not entirely as we expected. Through interviews and research related to experts, we have gained some new insights. The comprehensive management staff of the head office are generally long-term construction workers who have been engaged in the construction field for many years. Due to the longer period of time in the field and the more projects they have experienced, there are bound to be more problems caused by the lack of perfection or improper use of the technology. Regarding whether to adopt the new BIMS-GP technology, they will pay more attention to the technology’s maturity, including factors such as data confidentiality and the reliability of data processing, to mitigate the risk of recurring issues. For the technical departments of the head office, BIMS-GPT can already realize more technical functions to help them complete their work efficiently, so they are more worried about how to divide the legal responsibility for the problems and consequences caused by the excessive adoption of this technology. Once the head office decides to use BIMS-GPT, the branch offices will promptly follow suit. The integrated management department of the branch is most concerned about their own interests. If the technology has already been applied, they are more concerned about the need for high technical personnel and technology development, and the high cost caused by these will be the biggest barrier in their opinion.

5. Conclusion

The purpose of this study is to identify the drivers and barriers of the new BIMS-GPT technology and to conduct an empirical study through questionnaires and expert interviews to rank the importance of each type of factor and analyze the differences in scoring by various personnel in the construction industry. From this, we can obtain a more comprehensive understanding of BIMS-GPT technology from the perspectives of diverse stakeholders and offer valuable insights for facilitating its adoption in the construction industry.

The construction industry, characterized by its complex and tedious projects and vast scale of tasks, desperately needs the continuous introduction of AI technologies to improve efficiency, reduce errors, and drive innovation and growth. The objective of this study is to gain insights into the drivers and barriers to BIMS-GPT technology, as well as the level of awareness and acceptance of the technology among various personnel in the construction industry.

Through an empirical study of literature review, questionnaires, and expert interviews, we identified a series of drivers and barriers to the application of BIMS-GPT technology in the construction industry and ranked the importance of these factors. The results show that the functions of BIMS-GPT technology are more valued by experts at each period of the full building lifecycle, with the functions achievable in the design period valued the most, such as automating cost budgeting and greatly simplifying the BIM software modeling process. During the construction, operation, and maintenance periods, the most valued features include real-time site monitoring, interactive safety training for employees, automatic identification of high-risk areas not detectable by humans, provision of rationalized suggestions, and the automatic generation of reports to reduce tedious tasks. For the demolition period, the focus shifts to functionalities that can automatically identify potential risks and ensure compliance with relevant regulations. In conclusion, construction industry workers place high value on the convenience and thoroughness brought by BIMS-GPT and deeply hope this new generative AI technology, which fully serves the construction industry, can be introduced more quickly and efficiently to serve their work. It also shows that for the successful promotion and application of BIMS-GPT, it is crucial to ensure that these functionalities are realized and supported with appropriate training and technical assistance. Meanwhile, major barriers such as high implementation costs, the absence of relevant legal frameworks and standards, and concerns over data security were identified. This means that when referring to the application of BIMS-GPT technology, relevant standards and norms need to be developed to address the high cost, and data processing processes need to be adjusted to accommodate the new technology's adoption.

In addition, we analyze the differences in the scoring of BIMS-GPT technology by different personnel in the construction industry. The results show that respondents with around 6–10 years of experience generally pay more attention to the introduction of new technology and are more concerned about its ability to perform real-time automated BIM modeling in a conversational mode, as well as the barrier of excessive capital costs associated with its advanced functionalities. New staff with less than 5 years of experience are generally still learning and are not very interested in the introduction of new technologies. Older staff are familiar with the workflow but remain optimistic about new technologies that can greatly improve work efficiency.

Meanwhile, different departments have different attitudes towards BIMS-GPT. The head office is generally more optimistic about the new technology with a greater inclination to leverage it for macro-level decision-making, holds a more cautious attitude regarding barriers and undertakes a more thorough consideration on whether to adopt this technology. Comprehensive management departments pay more attention to macro functions such as low-carbon environment and project dynamic monitoring, but they also express significant concerns about data security. In contrast, technical departments pay more attention to the convenience and practicability of actual operation, such as automated BIM operation and automatic generation of text reports. This suggests that there are various differences in the perceptions and demands of BIMS-GPT technology among different personnel, so targeted training and support is critical to the successful adoption of the technology.

This study is limited to the construction industry practitioners in China Construction Third Engineering Bureau Co. Ltd, which limits the scope of the empirical research. Additionally, not all interviewees possess an in-depth understanding of AI technology during the research process, which further constrains the breadth of insights gained within the relatively short timeframe of the study. However, this study can still show that the use of BIMS-GPT technology in the construction industry is of great significance for the development of change in the industry.

The novelty of the technology and its complexity in the construction industry has resulted in a very limited number of studies on the topic, which means that further research is needed on BIMS-GPT technology and its wider adoption in the construction industry. Firstly, it is possible to search for policies regarding the application of AI in construction companies and its counterparts, identifying the impact drivers and the relevant policies needed to reduce barriers, which will have higher practical significance for the adoption of BIMS-GPT. Respondent 1 talked about the fact that in the future, the government is likely to have high expectations for the introduction of this technology and is also likely to give high policy support, for example, by conducting trials in some focused projects. In this case, the company will further improve the relevant systems and strategies, and conducting research on this technology again at this time will help gain a deeper understanding of the potential and application prospects of BIMS-GPT technology in the construction industry. Besides that, it is also possible to conduct a special study on the drivers and barriers to the

application of BIMS-GPT technology in various organizations and departments of the construction industry. This will help identify the ways in which BIMS-GPT technology is being applied in each period and help developers improve the functionality of BIMS-GPT in a more targeted way, resulting in a more integrated and efficient construction industry.

In summary, this study provides the construction industry with a comprehensive understanding of BIMS-GPT technology by empirically examining its drivers and barriers. We have emphasized the importance of key factors regarding the features and barriers of the new technology and explored the attitudes of different individuals towards this technology. These findings provide useful insights for the construction industry when introducing and applying BIMS-GPT technology, which can help improve efficiency, reduce costs, and drive the construction industry towards a smarter and more sustainable future. Future research can further explore and validate these factors, investigate the potential and applicability of BIMS-GPT technology, and develop targeted educational programs, training initiatives, and more strategic guidelines to foster its adoption and continued development.

Declarations

Authors contribution

Lin TL: Methodology, data curation, formal analysis, writing-original draft.

Wang H: Validation, writing-review & editing.

Chen ZS: Conceptualization, Supervision, writing-review & editing, project administration.

Guo JW: Validation, writing-review & editing.

Conflicts of interest

The authors declare no conflicts of interest.

Ethical approval

Not applicable.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

They can be obtained from the corresponding author upon reasonable request.

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