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Research on BIM-based whole-process engineering consulting in construction projects

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Abstract: Due to the long time span and numerous external influencing factors of construction projects, which are prone to various constraints, how to conveniently and reasonably manage the entire process is a major challenge in construction projects. Whole process engineering consulting services have thus emerged. BIM technology, with its characteristics of visualization and facilitation of process management, is widely applied in construction project management. However, in current practical construction project operations, the application of BIM technology is limited to individual stages and cannot effectively serve coordination and collaboration between phases or departments. This paper focuses on whole process engineering consulting for construction projects, dividing the entire process into six stages: planning, design, construction, operation, delivery, and demolition. Through expert surveys and case studies, the application of BIM technology in construction projects is investigated, key influencing factors are analyzed, and measures to promote the application of BIM technology in construction projects are proposed.

Keywords: whole-process engineering consulting; BIM technology; construction project.

1. Introduction

Whole process engineering consulting refers to providing organizational, managerial, economic, and technical engineering consulting services throughout the entire life-cycle of a construction project. From 1984 to the present, China has successively issued a series of policy documents and effectively explored the relationship between design and consulting. In 1998, a consulting design service system for fixed asset investment throughout the entire process was proposed; in 2001, international interpretations of engineering consulting were referenced to define engineering consulting as encompassing eight aspects; and in 2017, Document No. 19 introduced the concept of “whole process engineering consulting” [1]. In summary, China had explored this model for over 30 years before explicitly proposing the development of the whole process engineering consulting mode.

To enhance the level of information management in whole process engineering consulting projects, some scholars have considered using information integration methods to further improve productivity in the construction industry. This paper studies the application of BIM technology in the information



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management of whole process engineering consulting projects, leveraging the advantages of BIM to achieve information integration and interactive sharing, thereby establishing a new whole process engineering consulting model. By utilizing BIM technology, building information is parameterized and digitized. Based on the digital model, information integration is enhanced, enabling the sharing of engineering information among project departments and fully leveraging BIM's advantages throughout the entire construction process.

2. BIM application in whole process engineering consulting

2.1. Theoretical foundations of whole process engineering consulting

Concept of whole process engineering consulting. Whole process engineering consulting refers to providing engineering consulting services that cover the entire life-cycle of a construction project, including preliminary research, decision-making, implementation, and operation, involving organizational, managerial, economic, and technical aspects [1]. The core ideas include reforming fragmented consulting practices through holistic consulting, allowing engineering design to lead whole process consulting, implementing integrated construction and operation modes, maximizing investment benefits, and achieving value addition throughout the project life-cycle.

Scope and content of whole process engineering consulting services. The goal of whole process engineering consulting services is to achieve integrated management of the entire construction process, known as the "turnkey project". Its scope mainly includes engineering consulting, engineering survey and design, bidding agency, engineering supervision, construction cost consulting, and construction project management.

2.2. Impact of BIM technology on the entire project process

BIM technology offers numerous benefits and advantages, with the five most important characteristics being visualization, coordination, simulatability, optimization, and drawing capability [2].

Entire life-cycle of engineering projects. The entire life-cycle of a construction project includes planning, design, construction, operation and maintenance, and demolition. The U.S. National Institute of Standards and Technology divides the project life-cycle into six stages: planning and programming, design, construction, project delivery and commissioning, operation and maintenance, and demolition [3].

BIM application status in various countries. The status of BIM technology adoption in major countries and regions is shown in Table 1.

Table 1. BIM adoption status in various countries.

Country	BIM Adoption Status
USA	Since 2003, the U.S. General Services Administration (GSA) has implemented the National 3D–4D–BIM Program; since 2007, all federal construction projects have been required to use BIM; since 2009, states like Wisconsin and Texas have mandated BIM in public projects.
UK	In June 2011, the UK published a BIM implementation plan aiming to achieve informatization in all public construction projects within five years.
Finland	Recent TEKES research projects in Finland, including VERA, ROADCON, SARA, and STRAT–CON, have applied BIM technology, positioning Finland as a global leader in BIM adoption.
South Korea	South Korea implemented the "Public Procurement Service" project in 2010, requiring all public construction projects to adopt BIM by 2016.
Singapore	Singapore introduced the CORNET plan in 1996, mandating BIM applications.

The data in the table indicate that various countries have long advocated measures to enhance BIM adoption in projects, highlighting the global emphasis on BIM technology in construction. It is essential to increase BIM application in construction projects.

3. Questionnaire survey and data analysis

3.1. AHP hierarchical analysis

Based on the construction project life-cycle described earlier, a hierarchical structure model is established. This paper divides the evaluation indicators into six first-level indicators and 29 second-level indicators, as shown in Table 2.

Table 2. Evaluation index system for BIM technology in whole process engineering consulting.

Primary indicator	Secondary indicator
U ₁ : Planning Stage	U ₁₁ : Project Scale
	U ₁₂ : Project Standards
	U ₁₃ : Project Location
	U ₁₄ : Technical Solutions
	U ₁₅ : Feasibility Study Report
	U ₁₆ : Budget Report
	U ₁₇ : Cost, Schedule and Quality Improvement
	U ₁₈ : Design Brief
U ₂ : Design Stage	U ₂₁ : Architectural Scheme Modeling
	U ₂₂ : Building Performance Analysis
	U ₂₃ : Construction Drawing Modeling
	U ₂₄ : Comparison and Selection of Building Model Solutions
	U ₂₅ : Layout of Walls, Columns, Beams and Slabs
	U ₂₆ : Load Determination for Walls, Columns, Beams and Slabs
U ₃ : Construction Stage	U ₃₁ : Bidding Process
	U ₃₂ : Bidding Document Preparation
	U ₃₃ : Bidding Evaluation
	U ₃₄ : Plan Determination
	U ₃₅ : Schedule Planning
	U ₃₆ : Identification of Design and Construction Errors
U ₄ : Delivery Stage	U ₄₁ : Visual Delivery of Building Models
U ₅ : Operation & Maintenance Stage	U ₅₁ : Inspection, Update, and Adjustment of Hidden Works
	U ₅₂ : Space Management
	U ₅₃ : Energy Conservation and Emission Reduction
	U ₅₄ : Emergency Equipment and Alarm System
U ₆ : Demolition Stage	U ₆₁ : Demolition Plan Determination
	U ₆₂ : Safety Management During Demolition
	U ₆₃ : Economic Analysis of Demolition
	U ₆₄ : Cost Control

Weight determination. The author surveyed five experts from consulting firms to assess the importance of first-level indicators for BIM application in whole process engineering consulting. The final weights of each indicator were determined using the Analytic Hierarchy Process (AHP), as shown in Table 3.

Table 3. Weight sets of first–level and second–level indicators.

Primary Indicator	Secondary indicators	Weight
U ₁ 0.352	U ₁₁ :	0.066
	U ₁₂ :	0.066
	U ₁₃ :	0.050
	U ₁₄	0.145
	U ₁₅	0.176
	U ₁₆	0.187
	U ₁₇	0.234
	U ₁₈	0.076
U ₂ 0.235	U ₂₁	0.157
	U ₂₂	0.155
	U ₂₃	0.159
	U ₂₄	0.194
	U ₂₅	0.195
	U ₂₆	0.141
U ₃ 0.165	U ₃₁	0.078
	U ₃₂	0.095
	U ₃₃	0.084
	U ₃₄	0.206
	U ₃₅	0.245
	U ₃₆	0.293
U ₄ 0.047	U ₄₁	1.000
U ₅ 0.102	U ₅₁	0.456
	U ₅₂	0.219
	U ₅₃	0.163
	U ₅₄	0.162
U ₆ 0.100	U ₆₁	0.125
	U ₆₂	0.224
	U ₆₃	0.327
	U ₆₄	0.324

3.2. Weight result analysis and countermeasures

Based on the data obtained, strategies are formulated to enhance the application and effectiveness of BIM technology throughout the project lifecycle. Stages with higher weight values are analyzed.

Enhancing BIM application (U17). When applying BIM technology to cost control in construction projects, pre–construction data can serve as a basis for digital simulations. BIM–5D technology allows real–time access to progress and resource information, enabling managers to analyze schedules and costs continuously. Through data analysis, construction progress can be expedited, and costs managed effectively, achieving real–time comparative analysis and control.

BIM–based layout of hidden works (U25). BIM visualization can be used to reasonably calculate hidden works such as walls, columns, beams, slabs, and reinforcement. For example, in bridge optimization design, BIM software like Revit can model structural and reinforcement components to ensure safety and stability, significantly reducing design errors.

Reducing design and construction errors (U36). BIM visualization can construct 3D models for critical, complex, or hidden construction components. This optimizes spatial usage, reduces site occupation, and improves machinery allocation. Construction simulations can also identify potential issues in advance, allowing adjustments to plans.

Safe demolition practices (U62). While software like Revit provides a comprehensive project overview, demolition plans often involve safety risks such as structural collapse or debris handling. BIM simulations can preemptively model demolition processes, visualize risks, predict challenges, and develop countermeasures, thereby enhancing safety and management efficiency [4].

4. Enhancing the application of BIM technology in construction projects

Based on the literature related to the utilization of BIM technology in current construction projects, the following applications of BIM technology throughout the entire life-cycle of construction projects are summarized.

4.1. Application in the planning phase

The application of BIM technology in the planning phase of construction projects is mainly reflected in site condition modeling, design representation, cost estimation, site analysis, design review, project planning, spatial planning, and other aspects.

Site condition modeling: By applying BIM technology, constraint condition simulations are achieved. The site and facility conditions during the project construction process are modeled using BIM technology, providing planners with necessary on-site information. Planners can utilize the project estimates calculated from BIM models to make scientific decisions, plans, and budgets, thereby safeguarding the interests of stakeholders.

Design review: During the design review process, planners can use BIM-3D models to present structural designs, hidden works, and spatial layouts to stakeholders. The simulation capabilities of BIM technology allow for virtual implementation of design schemes, collision detection of detailed components, and resolution of design issues based on practical considerations.

Spatial planning: In spatial planning, planners can simulate spatial layouts using BIM-3D models. By evaluating and comparing the simulation results, the optimal spatial planning scheme is selected [5,6].

4.2. Application in the design phase

In the design phase of construction projects, the application of BIM technology focuses on 3D model visualization, spatial planning, and environmental analysis. By comparing design parameters derived from models, design optimization is achieved. Planners must also emphasize the arrangement of building equipment, automated generation of drawings and documents, and details of materials and construction techniques to enhance the effectiveness and usability of the models.

4.3. Application in the construction phase

The application of BIM technology in the construction phase primarily includes collision detection, multi-dimensional collaboration, virtual reality, and collaborative management.

Multi-dimensional collaboration: By adding a time dimension to BIM–3D models, a BIM–4D model is created to simulate construction schedules and design schemes. Further integration of cost data transforms the model into a 5D comprehensive information model. This enables multi-dimensional collaboration across time, space, and cost, ensuring comprehensive control of the project, reducing rework, and mitigating risks related to quality, safety, and budget.

Virtual reality: Construction teams can use 3D models combined with virtual reality (VR) technology to present buildings in an immersive format. This allows intuitive inspection and real-world experience for construction validation.

4.4. Application in the operation and maintenance phase

The application of BIM technology in the operation and maintenance phase includes space management, hidden works management, emergency management, and energy-saving management.

Space management: This involves managing equipment and office systems through 3D graphical representations of facility locations, with regular updates to labels or text for improved spatial management.

Emergency management: For large public or high-rise buildings, BIM technology aids in positioning emergency equipment, setting up alarm systems, and planning evacuation routes to enhance emergency response capabilities.

Energy-saving management: BIM combined with Internet of Things (IoT) technology enables the visualization and analysis of building energy consumption data for sustainable management.

4.5. Application in the demolition phase

The application of BIM technology in the demolition phase focuses on cost control and safety management.

Cost control: BIM computational capabilities allow for comprehensive quantification of demolition, estimation of waste generation, and simulation of demolition costs.

Safety management: BIM technology simulates demolition processes to identify and eliminate safety hazards. It also helps formulate on-site safety measures, focusing on accident-prone areas and enabling rapid response to emergencies.

5. Conclusions and prospects

Whole-process engineering consulting is a novel project management model proposed in response to China's rapid economic growth, urbanization, and the expansion of infrastructure. This paper examines the impact of BIM technology across all stages of construction projects (planning, design, construction, operation, delivery, and demolition), with a focus on key influencing factors.

Through expert consultations, it is concluded that BIM technology has the most significant effect in the planning phase. Critical indicators for BIM utilization in each phase are analyzed to improve construction efficiency and quality. Current BIM application trends are also discussed. However, challenges remain, such as increased budget requirements for BIM equipment, the need for professional training, and data security concerns.

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Authors' contribution

Conceptualization, Ping Wu and Yidong Xu; methodology, Mingming Li; validation, Mingming Li, Ping Wu and Yidong Xu; formal analysis, Mingming Li; investigation, Mingming Li; resources, Ping Wu; data curation, Ping Wu; writing—original draft preparation, Mingming Li; writing—review and editing, Ping Wu; supervision, Yidong Xu; project administration, Ping Wu; funding acquisition, Ping Wu. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflicts of interest.

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