Research on Architectural Design Process Reengineering and Collaborative Innovation under the Background of Intelligent Construction

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Abstract: With the rapid development of intelligent construction technology, the traditional architectural design process is facing the challenge of transformation and upgrading. This paper analyzes the influence of intelligent construction on architectural design process, and puts forward a process reengineering model based on four principles: data-driven, collaborative orientation, intelligent empowerment and dynamic flexibility. The model reconstructs the traditional linear process into an integrated intelligent collaborative network of "requirements-design-verification-delivery", and realizes the automation, intelligence and co-assimilation of the design process by means of digital requirements collection, AI-aided design, multi-disciplinary collaborative verification, digital twin virtual construction and blockchain technology. In addition, this paper also designs a multi-dimensional collaborative mechanism to solve the problems of information island, unclear responsibilities and rights and insufficient incentives in the traditional model, and ensure the implementation of process reengineering. The research results show that architectural design process reengineering and collaborative innovation under the background of intelligent construction can effectively improve design efficiency and quality, reduce costs and risks, and promote the high-quality development of construction industry.

1. Introduction

With the deepening of the fourth industrial revolution in the world, intelligent construction technology is profoundly reshaping the production mode and management mode of traditional construction industry. However, the contradiction between rapid technology iteration and industry inertia is increasingly prominent. The traditional architectural design process is still dominated by "linear segmentation", and there are some problems, such as isolated information island, disjointed design and construction, and serious waste of resources [1]. At the same time, the national policy level is accelerating the high-quality development of the construction industry. The "Tenth Five-Year Plan" for the Development of Construction Industry clearly puts forward the core goal of "Empowering the whole industrial chain with digital technology". In this context, how to realize the transformation of architectural design from "experience-driven" to "data-driven" and from "isolated operation" to "whole life cycle collaboration" through process reengineering and collaborative innovation has become a key proposition for the sustainable development of the industry.

2. Analysis of the influence of intelligent construction on architectural design process

Intelligent construction refers to the use of modern information technology and intelligent technology to realize the digitalization, automation and intelligence of the whole process of building engineering design, construction and management [2]. Its core technologies include building information model (BIM), artificial intelligence (AI), Internet of Things (IoT), 3D printing and so on. The application of these technologies makes architectural design more efficient, accurate, collaborative and sustainable [3-4].

The application of intelligent construction technology leads to the reengineering of architectural design process. The traditional linear design process has been broken and replaced by a more flexible and iterative design mode. Designers can use tools such as BIM to simulate and analyze design schemes in real time and respond to design changes quickly [5]. In addition, AI-aided design

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tools can automatically generate a variety of design schemes to help designers make more reasonable choices [6]. Intelligent construction promotes interdisciplinary collaborative innovation through BIM, AI and other technologies, realizes efficient collaboration among design, construction and management parties on a unified platform, significantly improves design efficiency and quality, reduces errors and costs, optimizes building energy consumption and safety performance, and promotes the transformation of buildings to green and low carbon, and promotes the sustainable development of the industry. Intelligent construction has a far-reaching impact on the architectural design process [7]. It not only improves the efficiency and quality of design, but also promotes the reengineering and collaborative innovation of design process.

3. Construction of architectural design process reengineering model

3.1 Reconstruction principle

Process reengineering should closely focus on the technical characteristics of intelligent building and the goal of transformation and upgrading of the construction industry, and follow the four principles (Figure 1).

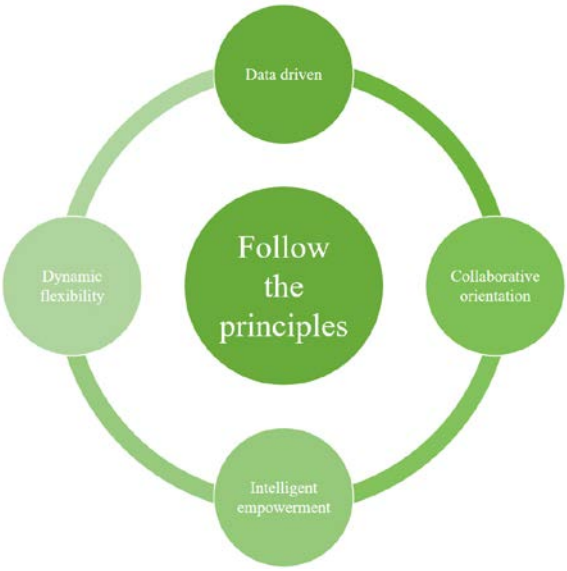

Figure 1 Four principles of process reengineering

3.1.1 Data-driven, all-factor digitization

With BIM as the core carrier, the geometric information, performance parameters, construction technology requirements and operation and maintenance requirements in the whole life cycle of a building are transformed into computable and transmissible digital information, which breaks the limitation of "drawing-oriented and information fragmentation" in the traditional process. Through the integration of multi-source heterogeneous data in the data center, it provides real-time and accurate basis for decision-making at all stages.

3.1.2 Collaborative orientation, deep integration across roles/stages

In the traditional process, design, construction, operation and maintenance are "independent", while intelligent construction requires a shift from "subsection relay" to "whole process symbiosis". Process reengineering needs to strengthen the multi-agent collaboration of "owner-designer-constructor-supplier-operator", and realize real-time interaction of requirements transmission, scheme iteration and conflict detection through unified data standards and collaboration platform, so as to reduce information attenuation and repetitive work [8].

3.1.3 Intelligent empowerment, tool chain automation and intelligent decision-making

Make full use of AI, parametric design tools, intelligent computing power and other technologies to replace traditional manual repetitive work, and upgrade the "trial and error decision" driven by

experience to "predictive decision" driven by data.

3.3.4 Dynamic flexibility, responding to uncertain demand

In the face of uncertainty such as demand change and external environment change in the whole life cycle of the project, the process needs to have the ability of "agile iteration" —— through modular design decomposition, digital twin real-time mapping and intelligent early warning mechanism, the transition from "fixed process" to "dynamic adjustable process" can be realized to ensure that the design results are always aligned with the construction goals.

3.2 New process framework design

The traditional architectural design process usually follows the one-way progressive mode of "scheme design → preliminary design → construction drawing design", which relies on manual handover between stages and the feedback is lagging behind. The new process framework under the background of intelligent construction needs to be reconstructed into an integrated intelligent collaborative network (Figure 2).

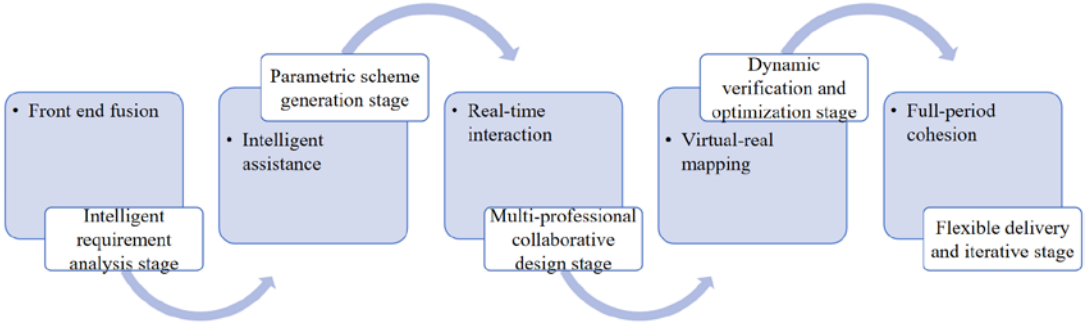

Figure 2 New process framework under the background of intelligent construction

In the traditional process, demand collection depends on the subjective description of the owner, which easily leads to design deviation. Through digital requirements collection tools and natural language processing (NLP) technology, the new process transforms the owner's fuzzy requirements into quantifiable design indicators, and binds them with the operation and maintenance objectives in advance, forming a target system of "requirements-design-operation and maintenance" linkage. Based on the demand index, a large number of alternatives are automatically generated by using the generative design algorithm combined with constraints, and the optimal solution set is quickly screened through the AI evaluation model [9]. On this basis, the designer makes manual optimization, focusing on aesthetic expression and humanized details, greatly shortening the iteration cycle of the scheme.

Multi-disciplinary models such as architecture, structure, electromechanical and curtain wall are integrated through cloud BIM platform, and cross-disciplinary real-time verification is realized by using collision detection algorithm and performance collaborative analysis tools. Professional designers work in parallel in the same data environment, and the modified information is automatically synchronized to the associated model to avoid the problem of "late rework". By introducing digital twinning technology, the design model is associated with the sensor data and construction technology database on the construction site, and the potential risks are discovered in advance by simulating the construction process through virtual construction. According to the verification results, the design details are dynamically adjusted to ensure the constructability and economy of the design scheme.

Deliverables are not only construction drawings, but also digital asset packages containing life cycle information. The blockchain technology ensures that the data cannot be tampered with, which provides the original basis for fault diagnosis, transformation and upgrading in the later operation and maintenance stage. At the same time, a feedback closed loop of "design-operation and maintenance" is established to collect performance data in actual use and feed back the design optimization of future projects.

3.3 Collaborative mechanism design

The landing of BPR needs a multi-dimensional collaborative mechanism to solve the problems of "unclear responsibilities and rights, isolated information island and insufficient incentives" in the traditional mode. The core mechanism is shown in Figure 3. Formulate data standards covering the whole process, and clarify the format, accuracy and transmission rules of data in each stage; Build an enterprise-level or project-level collaborative platform, integrate design tools, analysis software and management modules, and realize "one-time entry and whole-process sharing".Break the traditional role orientation of "designer leading and other parties passively cooperating" and clarify the digital responsibilities of all participants in the process. Through the process role mapping table, the decision-making subject and cooperation boundary of each link are defined to avoid buck passing. Integrate AI-aided design, automatic calculation, intelligent drawing review and other tools to form a "tool-process-people" collaborative chain [10]. For example, in the scheme design stage, the specification library is automatically called to check compliance, in the construction drawing stage, the bill of materials is automatically generated and compared with the budget limit, and in the conflict detection stage, high-risk nodes are automatically marked and pushed to relevant responsible persons. Through the automatic execution of tool chain, the manual intervention error is reduced and the process efficiency is improved. Aiming at the problems of "hitchhiking" and "information hiding" in multi-agent cooperation, an incentive system based on data transparency is established, and the data contribution and cooperation behavior of all parties are recorded through blockchain technology to build a credible cooperation environment. At the same time, regular cross-disciplinary training is carried out to improve the overall teamwork ability of the team.

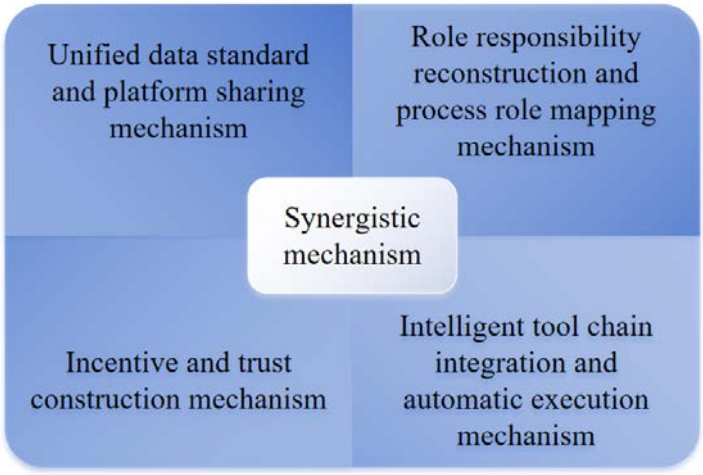

Figure 3 Multidimensional cooperation mechanism

The essence of the reengineering model of architectural design process under the background of intelligent construction is to upgrade the traditional linear process into a new system with dynamic, flexible and full life cycle integration through the three core elements of "data drive, intelligent tools and collaborative network". The key lies in taking BIM and digital technology as the base and collaborative mechanism as the guarantee, and finally realizing the leap from "experience-led" to "scientific decision-making" and from "isolated link" to "system integration", so as to provide process support for the high-quality development of the construction industry.

4. Conclusion

Intelligent construction technology is profoundly changing the traditional architectural design process, realizing digitalization, automation and intelligence through core technologies such as BIM and AI. In this study, a model of architectural design process reengineering based on data-driven, collaborative orientation, intelligent empowerment and dynamic flexibility is constructed, and a new process framework of "demand-design-verification-delivery" integration is proposed. The framework optimizes the design input through digital requirements collection and natural language

processing technology, and improves the efficiency of cross-disciplinary collaboration and design verification by using cloud BIM platform and digital twinning technology to ensure the constructability and economy of the design scheme. At the same time, a multi-dimensional collaborative mechanism is established, including data standard formulation, collaborative platform construction, clear roles and responsibilities, tool chain automation and incentive system design, which effectively solves the problems of unclear responsibilities and rights and information islands in the traditional model. The research shows that architectural design process reengineering and collaborative innovation under the background of intelligent construction can significantly improve design efficiency and quality, reduce errors and costs, promote the transformation of buildings to green and low carbon, and provide important support for the high-quality development of construction industry. Future research should further explore the application effect of process reengineering and collaborative innovation in specific projects, and how to better integrate emerging technologies to meet industry challenges.

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