Artificial Intelligence Based Scenario Design of Assembly Building Demonstration Teaching

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Abstract. Assembly-based construction is currently a form of construction that is vigorously promoted in China, and CAD, BIM, and intelligent building technologies are also new technical tools that are widely recognized in the construction field. Based on this, starting from the domestic and international research on intelligent construction management of assembled buildings, each stage of the demonstration teaching scenario of assembled buildings is studied in depth to determine its core activities. A parallel optimization of the smart building demonstration teaching scenario, a parallel engineering implementation strategy for the proposed construction and whole process management is proposed. Based on the parallel optimization of the construction process of the assembled building, the whole process management model of the intelligent construction of the assembled building is proposed. Based on the DSM method, the dependencies between the core activities of the construction process are clarified, and it is found that the use of parallel engineering in the assembly construction process can effectively shorten the project development cycle and reduce non-value-added activities such as rework. By analyzing and studying intelligent buildings based on BIM technology in each stage, the problems and advantages solved by BIM technology in each stage are proved, which provides useful methodological reference for BIM design of similar projects.

Keywords: Assembly Building; Artificial Intelligence; BIM.
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1 INTRODUCTION

As a necessary path to realize the industrialization of construction, the inherent requirements of standardization and digitalization of assembled buildings coincide with the informatization and visualization characteristics of BIM (Building Information Modeling). Based on the BIM application technology, the database formed by the 3D model is the core, which contains the whole process information of design, construction, use and demolition, and integrates the engineering graphic model, engineering data model and the behavior model related to operation and management [1].

At the same time, the BIM building engineering information model is introduced into the teaching scene to show the three-dimensional visualization of the building structure in teaching, which is an approximate understanding of practical design [2].

During decades, the nodal quality and seismic capacity of assembled buildings have been substantially improved, and the factors that constrained their development in the last century have gradually weakened. The advantages of assembled buildings are beginning to emerge. From the perspective of economic cost, prefabricated components and on-site installation can reduce the loss and waste of construction materials and related equipment [3]. The daily maintenance and management costs are also lower after the construction is completed. More importantly, it is the energy-saving and environmental protection attributes of assembled buildings. The promotion of assembly technology can reduce noise and air pollution at the construction site and control the generation of construction waste [4]. Ideally, Shen et al. [5] believes that prefabricated buildings can be combined with the main building to achieve decoration at the same time. Finally, some building materials can be effectively recycled in the recycling phase to reduce pollution and improve resource utilization. In 2013, the Ministry of Housing Construction and the National Development and Reform Commission clearly proposed to promote the prefabricated building system in the No.1 document Green Building Action Plan, forming a "new building industrialization". In the next few years, landing plans were launched continuously. Recently, the country clearly proposed the time to achieve carbon peak and carbon neutralization. The goal of "double carbon" is standardized from the top design. Since the real estate and construction industry is large in scale and accounts for a high proportion of GDP, it is also the highest end-consumer source of carbon emissions, and the transformation and upgrading of the traditional construction industry has become inevitable. Vargas et al. [6] believes that with the improvement of various standards and supporting policies, official support and leadership, and its own characteristics of "low carbon emission reduction", prefabricated buildings ushered in the "second spring". It has become the main focus of industrialization and green buildings. As the "Chosen Child" of the "Green Building Initiative", assembly technology is the most important technological change in the construction industry in many years. However, green building should not only focus on the assembly of the structure, but also look at it from the perspective of the "whole life cycle" to achieve energy saving and efficiency at every step. The design, production coordination, and logistics optimization of the whole building life cycle have been helped by digital tools [7].

2 STATE OF THE ART

The so-called assembled intelligent building combining CAD technology and artificial intelligence includes the integration of industrialization and informatization. The integrated application of BIM and new information technologies such as the Internet, the Internet of Things, big data, cloud computing, artificial intelligence runs through the whole process of project design and construction. Wen's [8] research has helped realize the intelligent construction of China's construction industry. In recent years, Xiao and Bhola [9] has combined BIM, RFID, 3D laser scanner, CAD and other new technologies with various stages of assembly construction. This has become a new research trend. Zhang et al. [10] combine BIM and 3D laser scanning technology for appearance quality inspection of prefabricated PC components to help achieve inspection automation. Combining BIM, CAD, cloud computing, 3D laser scanning, the Internet of Things and other emerging technologies, the overall architecture of the whole life cycle management system for industrial buildings was created.

Based on the above findings, Zhao et al. [11] now recognize the important role of BIM technology in the development of prefabricated buildings. However, most of the research is limited to the application of BIM technology to a single construction process, such as design and construction and the establishment of information management platform. However, the research on the organic combination of various information technologies and BIM technologies for the whole process of intelligent construction of prefabricated buildings is less. Therefore, based on the lean value chain theory and integrating various information technologies, this paper studies the intelligent construction management in the whole process of design, production, transportation, construction, operation and maintenance of prefabricated buildings, and provides new solutions to the problems faced by prefabricated buildings.

3 METHODOLOGY

3.1 The Whole Process of Designing Demonstration Scenarios of Assembled Buildings Based on CAD Technology and Artificial Intelligence

The assembled building is a building supported by information technology, modular design, standardized production and lean assembly. Different from the traditional construction method, the assembled building has the characteristics of collaboration, integration, refinement and construction dry work in design, construction, decoration and management, as shown in Figure 1.

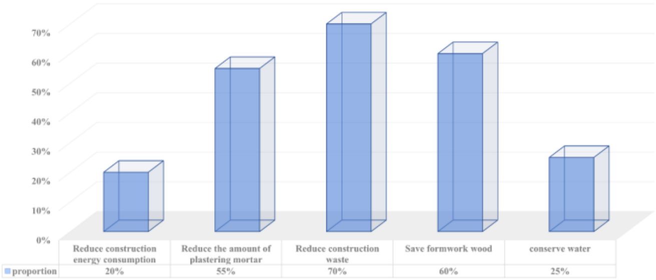

Figure 1: "Four Sections and One Environmental Protection" for prefabricated buildings.

3.2 Integrated Design Management Based on Artificial Intelligence and BIM

The assembled building is characterized by the integration of multiple systems such as building structure, electromechanical piping, interior decoration and building maintenance, while BIM has natural technical advantages in information integration. Therefore, in the design stage, a BIM-based collaborative design platform can be built with the full help of BIM to realize the integrated design management of assembled construction, as shown in Figure 2.

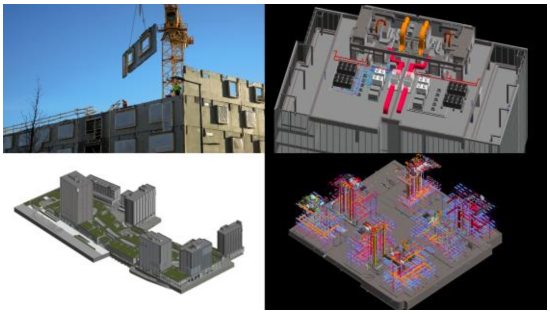

Figure 2: Integration of prefabricated construction.

Establish a three-dimensional model integrating architecture, structure, electromechanical and decoration, and carry out multidisciplinary collaborative design. In the BIM collaborative design platform, based on the same base point, coordinate, grid, unit and naming method, each unit selects appropriate standardized components from the component library, integrates architecture, structure, and electromechanical decoration, and establishes a comprehensive assembled building model integrating multiple disciplines. The construction drawing design adopts 3D intelligent subdivision. Based on the BIM collaborative design platform, the construction drawings of prefabricated buildings are designed. On the basis of multidisciplinary integrated model, specify prefabricated components and prefabricated component types.

3.3 Information Driven Lifting Management Based on BIM + Mobile Technology

The assembled building has strict quality requirements, and the on-site construction needs to be lifted to the corresponding parts for installation according to the component code, without the slightest deviation. In the on-site construction stage of assembled buildings, the comprehensive use of BIM, Internet, cloud computing, Internet of Things and other technologies can realize the visualization, digitalization and refinement management of the construction process through 3D visualization simulation, construction progress management and quality management. In the construction stage, the construction schedule and target cost are correlated with the BIM model to form a visualized 4D model. Combined with the BIM-based component coding system, it is connected with the construction schedule plan to dynamically simulate the construction change process and realize the efficient management of construction schedule. Based on the BIM model, it calculates and predicts the required capital, labor, materials and machinery usage, and compares and analyzes with the actual consumption cost to promote the refined cost management of the assembled building.

3.4 Intelligent Operation and Maintenance Management Based on BIM+IOT

In the operation and maintenance link, the application of IOT + BIM can provide three-dimensional positioning of objects and equipment and systematic consideration of the surrounding environment and conditions, which is equivalent to adding vitality and perception to all building components and facilities. The intelligent operation and maintenance of the assembled building mainly includes intelligent space positioning management, equipment maintenance management and energy consumption management analysis, etc. Based on IOT + BIM technology, spatial positioning and information query can be made according to the demand of equipment safety management. Specifically include: Security monitoring management, video monitoring system access to the operation and maintenance platform, real-time remote monitoring of site conditions, such as access control, vertical traffic, public area lighting, etc. During the construction process, the non-geometric information of the BIM model (such as equipment production date, manufacturer, age of use, etc.) is constantly replenished, and the asset information of the building is viewed and replenished through the O&M management platform.

4 RESULT ANALYSIS AND DISCUSSION

4.1 Application of DSM in Parallel Engineering for Intelligent Assembly Construction

The DSM method (design structure matrix) was first applied in the field of modeling and analysis of complex systems. The "1" or "x" represents the information delivery and feedback relationship between the matrix elements, as shown in Figure 3. The orientation of "x" represents the direction of message propagation, bounded by the diagonal of the square matrix (the diagonal elements are meaningless), usually filled with active codes or black squares. information feedback.

According to the above description of the construction process of assembled buildings, the construction process contains four major aspects: design, production, transportation, and assembly. Applying the DSM method, the dependent activities among these four processes are found according to the system decomposition relationship, as shown in Table 1.

The upper half of the diagonal of the DSM square determines the existence of a feedback relationship. For example, the choice of component manufacturers will have an impact on the splitting and deepening design.

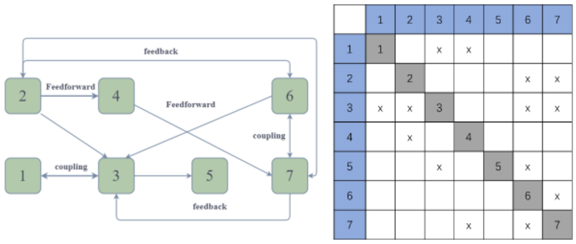

Figure 3: Dependency between DSM matrix and tasks.

Activity Category	*Code*	*Event Name*	*Abbreviation*
Design	1	Project Planning	AA
	2	Program Planning	BB
	3	Design work	CC
Production and processing	4	Material procurement	DD
	5	Production planning and development	EE
Transport	6	Route and vehicle selection	FF
	7	Transportation solutions	GG
Assembly	8	Site layout	HH
Design	9	Assembled construction	II

Table 1: The main dependent activities of the prefabricated construction process.

The manufacturer's equipment (such as the difference in steel mold size) determines the size of the component splitting, and if the designers ignore this limitation, it will cause reworking of the component splitting work later. If they ignore the component installation process, time and location, and directly develop the transportation plan and optimize the cost according to the component transportation combination, the components will be transported to the site and cannot be installed immediately, and need to wait until the lifting plan is completed to find again and carry twice for construction imagination. According to lean value chain theory, these are non-value-added activities.

4.2 Parallel Optimization of Assembly Construction Engineering

Pull production is the basic principle of lean value chain theory, that is, the upstream link work task arrangement and modification need to be determined with reference to the downstream link work. Therefore, it is important to first clarify the correlation between on-site lifting and splicing and other operations as a way to analyze the dependency between the core activities of the construction process. In the standard floor operations of PC structures of assembled buildings, prefabricated components such as interior and exterior wall panels, complex floor slabs, air conditioning panels, balconies and stairs are included. After the completion of the underground structure, the standard floor assembly work begins, and the assembly activities of each component are viewed as serially associated, limited by the deployment of tower cranes, formwork, brackets and other necessary appliances. And based on this, the key process operations of the assembly construction process are deeply analyzed, and a total of 22 core activities of the standard floor are identified. They are construction drawing design, split design, exterior wall panel deepening, interior wall panel deepening, balcony panel, air conditioning panel deepening, stacked floor panel deepening, staircase deepening, exterior wall panel production, interior wall panel production, balcony panel, air conditioning panel production, stacked floor panel production, staircase production, combined transportation, underground structure construction, exterior wall panel lifting and grouting, interior wall panel lifting, wall panel horizontal cast-in-place assembly, support erection, balcony panel, air conditioning panel lifting, stacked floor slab lifting, cast-in-place beam, floor slab pouring, staircase lifting.

4.3 Parallel Construction Optimization of Assembled Buildings

The feedback activities concentrated in assembled construction activities mainly exist in the process of component production and design, and on-site construction and production. After dividing the operation, the above-mentioned 22 core work sets of assembly building are obtained, and some of the operation processes should be developed and designed in an integrated way. The refined core work set shows that after the construction drawings are determined, the component splitting and underground engineering operations belong to parallel relationship and should be carried out simultaneously. After the split design is completed, for the production lifting part, the outer wall panel design deepening, processing and transportation issues should be implemented first, and the inner wall panel deepening operation and transportation can be carried out at the same time. Inner and outer wall panels are usually prefabricated in the factory without the same assembly line, and can be processed and produced in parallel, and their inner and outer wall panels are vertical components, and the transportation process can be designed to combine transportation solutions to reduce transportation costs.

4.4 Impact of Assembly Parallel Construction and Implementation Strategy

Although the DSM method can identify the dependencies between activities and determine the set of bogey and parallel relationships, it is impossible to determine how the activities are carried out in parallel and the risks of implementing parallel engineering. Therefore, based on the Upstream evolution and Downstream sensitivity theories, we analyze the changes of schedule and cost after implementing overlapping activities, further optimize the parallel engineering strategy, optimize the assembly construction process, and reduce the risk to a manageable level.

If the two activities A,B are in parallel, the concept of upstream evolution is the percentage of the time when the upstream activity A completes the information transfer in the total duration of the activity. The upstream degree of evolution represents the rate at which the information delivered upstream to downstream is transformed into the final result. If the upstream evolution degree is p, then p is the conversion rate of information from the upstream activity at the start of the downstream work. In the same time, a larger p indicates a faster information conversion rate and a higher degree of evolution, while a smaller p indicates a slower information conversion rate and a lower degree of evolution. Figure 4 shows the activity evolution curve, and the vertical axis indicates the proportion of transformed information in the total information. Different activities have different evolution curves. For the D_1 curve, if the information conversion of A is completed at t_3, the information completion degree is 100%. $p=30\%$ for B starting at t_1, and $p=0.8$ for B starting at t_2, according to the concept $p\in[0,1]$.

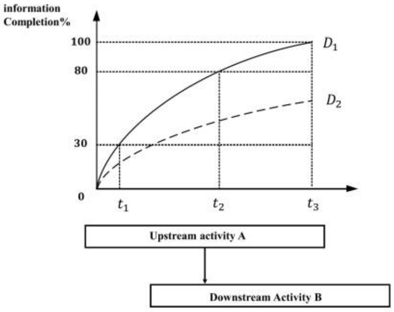

Figure 4: Evolution degree of upstream activities.

The start of activity B needs to receive information from activity A. If there is an error or change in A, it will directly bring the impact of modification or even rework to B. There is a dependency relationship between the two, and the degree of dependency is reflected by sensitivity. The higher the sensitivity, the greater the impact of upstream activities on downstream activities, and once A changes, B needs to carry out a lot of rework, and the lower the sensitivity, the easier it is for B to cope with changes in A. Sensitivity is usually represented by q, which refers to the proportion of rework performed by downstream activities along with the change of upstream information, ,the larger q is the more rework.

The idea of evolutionary degree and sensitivity enables to find the full time required to complete parallel engineering. As shown in Figure 4, T1 and T2 are the completion times of upstream and downstream activities A, B. After implementing parallel development, the durations of activities A and B are T1 and T2, respectively, and usually T1=T2. Accordingly, the start time of activity B is the following equation.

$$T_1 - t_0 = T_1 - t_0 \tag{1}$$

A work is completed, B still has to last X_2 time, T refers to the full completion time, so :

$$T_2^{'} = X_2 + t_0 \tag{2}$$

$$T^{'} = X_2 + T_1^{'} \tag{3}$$

Under parallel engineering, downstream activities are carried out in advance and rework is unavoidable, then $T_2^{'} \geq T_2$. From the above equation, we can obtain:

$$X_2 \geq T_2 - t_0 \tag{4}$$

The maximum rework time for activity B is t_0, Then:

$$X_2 \leq T_2 \tag{5}$$

Equation (6) is derived based on the concepts of sensitivity and evolutionary degree.

$$X_2 = \begin{cases} T_2 - t_0, p \\ 0 > T_2 - t_0, 1 - p \end{cases} \tag{6}$$

In the case of small sensitivity, the rework can be approximated as in equation (7).

$$X_2 = T_2 - 0.5t_0 \tag{7}$$

The probability of occurrence is $1-q$.

$$0 = \begin{cases} T_2 - 0.5t_0, 1-q \\ T_2, q \end{cases} \tag{8}$$

From equations (7) and (8), the total completion time is shown below.

$$T' = (T_2 - t_0) \times p + \left[T_2 \times q + (T_2 - 0.5t_0)\right] \times (1-q) + T_1 \tag{9}$$

Solving for this yields the following equation.

$$T' = T_1 + T_2 - 0.5\overline{t_0} + 0.5t_0(q - p - pq) \tag{10}$$

If the schedule reduction factor is eeeee, the time shortened for parallel development of activities is:

If the schedule reduction factor is θ, the time reduced by implementing parallel development for the activity is:

$$S = T' - T_1 - T_2 = t_0 \times \theta \tag{11}$$

$$\theta = 0.5 \times (1 - q + p + pq) \tag{12}$$

The effect of sensitivity and evolution degree on the schedule reduction factor is shown in Figure 5. Increasing the upstream evolution degree P and decreasing the downstream sensitivity q can reduce the total development time. Figure 6 shows the change relationship of schedule reduction coefficient.

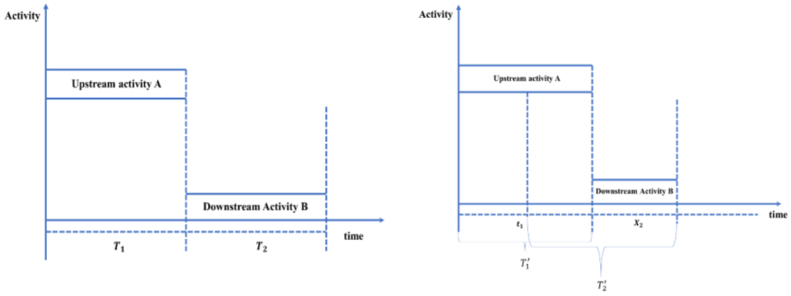

Figure 5: Serial make time (left) and parallel make time (right).

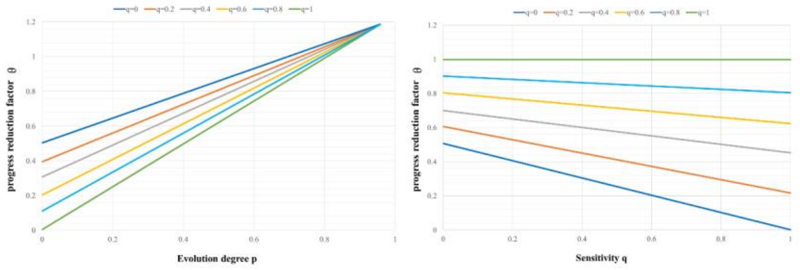

Figure 6: Change relationship diagram of schedule reduction coefficient.

Similarly, the impact of parallel engineering on costs can be analyzed if the operating costs of activities A and B under serial development are D_1 and D_2 respectively. under parallel engineering, the costs are D_1 and D_2 respectively, and the total cost of parallel development is D_1 and D_2. Let the construction cost of B and the time required are positively correlated, and the overlapping weight of parallel development works is λ then:

$$\lambda = \frac{t_0}{T_2}, \lambda \in [0,1] \tag{13}$$

The total development cost is given by the following equation:

$$D^{"} = (1-\lambda) D_2 + p\lambda D_2 + (1-P)(1+q)\lambda D_2 \tag{14}$$

$$D^{"} = D_1 + D_2 + q(1-p)\lambda D_2 \tag{15}$$

Because of the impact of the lack of information under parallel engineering, rework in downstream activities increases the cost inevitably. According to the above equation, it can be seen that the cost increases with the increase of λ.

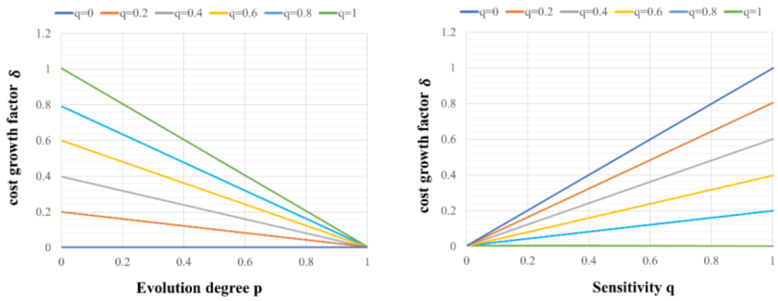

Figure 7: The relationship diagram of the change of the cost increase coefficient.

Assuming that $q(1-p)$ is the cost increase factor δ, the effect of evolution degree and sensitivity on δ is shown in Figure 7. Increasing the upstream evolution degree and decreasing the downstream sensitivity help to reduce the cost.

4.5 Parallel Engineering Implementation Strategy

Based on the above theoretical analysis of the implementation of parallel engineering in assembly buildings and the analysis of schedule and cost impacts, relevant suggestions are given for the implementation of parallel development in assembly buildings.

The degree of evolution of split design in the construction process has a direct impact on the start time of downstream activities such as design deepening and material procurement, and adopting standardized design or specifying the optimization criteria of split design in advance can increase the degree of evolution. In the case of a certain pre-production rate, the improvement criteria can be clarified with the experience of previous project cases, which can help increase the evolution degree. At the same time, continuous design improvement will also increase the evolution of upstream activities, and the early implementation of the split design freeze will help to promote the overall project progress.

With BIM-based forward prototyping, there is no need to wait for all designs to be completed, and downstream activities can be prepared by viewing the model before construction, which improves upstream evolution. It can also help general contractors to clarify customer requirements before in-depth development, avoid rework later, and reduce the sensitivity of downstream activities q.

In the case of more complex assembly building projects, it is difficult to determine the splitting criteria due to multiple factors, resulting in a small degree of evolution P for downstream activities regardless of when they start. In this case, integrated design is used, and multiple design teams start the design at the same time, and the optimal design is found by comparing solutions along with the design depth. More accurate information dissemination of upstream activities helps to reduce the sensitivity of downstream activities.

5 CONCLUSION

In this paper, the combination of various information technologies such as CAD, BIM technology, artificial intelligence technology, computer-aided manufacturing, and Internet of Things with the assembled building is the main line of research, and the whole process management mode of intelligent construction of assembled building is proposed. The concept of the whole process management of intelligent construction of assembled buildings is proposed, the framework of overall design and information application of the whole process of assembled construction is given, and five aspects of this management mode are elaborated from integrated design, intelligent production and transportation, information-based hoisting management, and intelligent operation and maintenance. On the basis of a full understanding of the concepts, characteristics, classification and current problems related to assembled buildings, the construction process is analyzed in detail, and it is clear that the assembled construction mainly includes four processes: design, production and transportation, on-site assembly, and operation and maintenance. On this basis, the DSM theory is applied to analyze the scourge relationship of each construction process of the assembled building, and 18 core dependent activity items are identified, and the set of engineering activities that can be optimized is given by dividing the operation. Finally, based on the concepts of evolution degree and sensitivity, the impact of parallel engineering optimization on the construction schedule and cost of assembled buildings is analyzed, and it is determined that measures such as frozen and standardized design, integrated design, and BIM-based virtual construction and whole-process management can effectively shorten the development cycle of assembled buildings and reduce rework and other non-value-added activities, which are beneficial to the development of assembled buildings.

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