UDC 69.05

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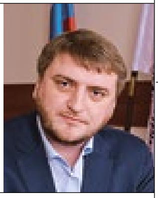

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Organizational and technological analysis of high-speed construction of civilian high-rise buildings in China

This paper presents a comprehensive organizational and technological analysis of accelerated construction processes for civilian high-rise buildings in China, focusing on the adoption of prefabricated construction techniques to address the country's rapid urbanization and surging housing demands. The study systematically identifies and evaluates essential organizational and technological innovations through an extensive comparative analysis and rigorous statistical data processing, which significantly expedite construction timelines while maintaining uncompromising safety and quality standards. It emphasizes strategic improvements in management processes, integration of modern technologies and materials, and enhanced coordination among project stakeholders to optimize efficiency and delivery speed. Prefabricated reinforced concrete frame structures are highlighted as a key solution for reducing on-site construction time and labor costs, providing a practical response to urgent housing needs in rapidly growing urban areas. Furthermore, the paper introduces an evaluation framework using the Analytic Hierarchy Process (AHP) to assess and prioritize the impact factors of prefabricated buildings, enabling more informed decision-making in project management. This integrated approach addresses both the practical challenges of rapid construction and contributes to theoretical advancements by offering insights applicable to similar urban development scenarios worldwide. The findings are anticipated to influence future construction practices, fostering more sustainable and efficient strategies to meet global urbanization challenges effectively.

Keywords: *rapid construction, construction technology, prefabricated structures, high-rise buildings, economic efficiency*

INTRODUCTION

As China faces accelerated urbanization, the demand for efficient high-rise construction has surged. This paper explores rapid construction methods that support the rapid erection of high-rise buildings while ensuring safety and structural integrity. The study focuses on prefabricated construction techniques, which could revolutionize building processes by reducing construction times and labor costs. A comprehensive organizational and technological model tailored for rapid high-rise construction in China is proposed, enhancing efficiency and economic feasibility.

SELECTING A MODEL FOR RAPID CONSTRUCTION

To further explore the factors influencing the rapid construction of civil high-rise buildings in China, it is necessary to identify a model suitable for rapid construction. A comparison and generalization of common building types, designs, and functions is presented below (Table 1).

The use of prefabricated constructions, particularly precast reinforced concrete frame structures, enhances the speed and efficiency of constructing high-rise buildings in rapidly growing cities. Concrete's ductility and adaptability support complex structural designs while maintaining high-quality control during assembly, accelerating the construction process [1]. Chosen for its rapid construction capabilities, this structure also ensures building stability and durability, thereby boosting construction speed and economic efficiency.

FACTORS AFFECTING THE IMPACT OF RAPID CONSTRUCTION

The establishment of a prefabricated building impact factor evaluation system (Fig. 1) is based on the cooperation of multiple prefabricated building-related enterprises [2]. Therefore, it is necessary to make a comprehensive evaluation of the elements involved and the complete process in the prefabricated building industry. In this chapter, the analysis of the hierarchy method (AHP) will be used to calculate the weights of the indicators and Kendall's concordance coefficient (W) to check the consistency.

Based on the research of other scholars on construction industrialization, housing industrialization, and prefabricated buildings, this paper examines some evaluation indicators of factors affecting the rapid construction of prefabricated buildings, and some of them are shown in Fig. 2.

The questionnaire was sent to 18 experts from research institutes, construction companies, design agencies, and other organizations. A rating scale from 1 to 5 points (1 — completely irrelevant, 5 — very important) was used to test the importance of the indicator system.

AHP is a widely used method for multi-criteria decision analysis [11]. In the study of the rapid construction of prefabricated buildings, the AHP model can help us to systematically evaluate the importance of different influencing factors.

Table 1. Classification of building types

Category		Types	Suitability for rapid construction
Types of buildings		Skyscraper	Due to the complexity of the design, usually not suitable for fast-track construction
		High-rise buildings	The use of prefabricated structures can partially enable fast-track construction
Types of constructions	By material	Reinforced concrete construction	Prefabricated reinforced concrete elements can speed up construction
		Metal construction	Assembly speed is achieved due to the factory readiness of components
		Wooden construction	Particularly suitable for the rapid construction of small or low-rise buildings
	By load	Frame construction	Suitable for prefabricated structures to speed up construction
		Shear wall construction	The use of prefabricated wall elements makes it possible to significantly speed up the construction process
		Frame-sliding wall construction	The use of prefabrication technology optimizes construction speed and cost efficiency
	By method of construction	Prefabricated construction	Ideal for rapid construction, which reduces time on-site
		Monolithic construction	This takes more time but ensures overall structural integrity
Types of functions		Housing function	Prefabricated dwellings can be built very soon
		Commercial function	Prefabricated construction can speed up the construction of commercial buildings

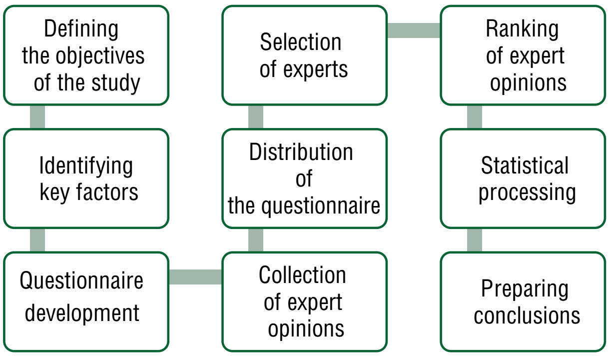

Fig. 1. Factor assessment process for the speed construction

Table 2. Weight of level criteria

Number	Stage	Quantity of factors	Weight
1	Design stage	4	0.1739
2	Production stage	3	0.1304
3	Transport stage	3	0.1304
4	Construction phase	5	0.2174
5	Project management stage	5	0.2174
6	External factors	3	0.1304

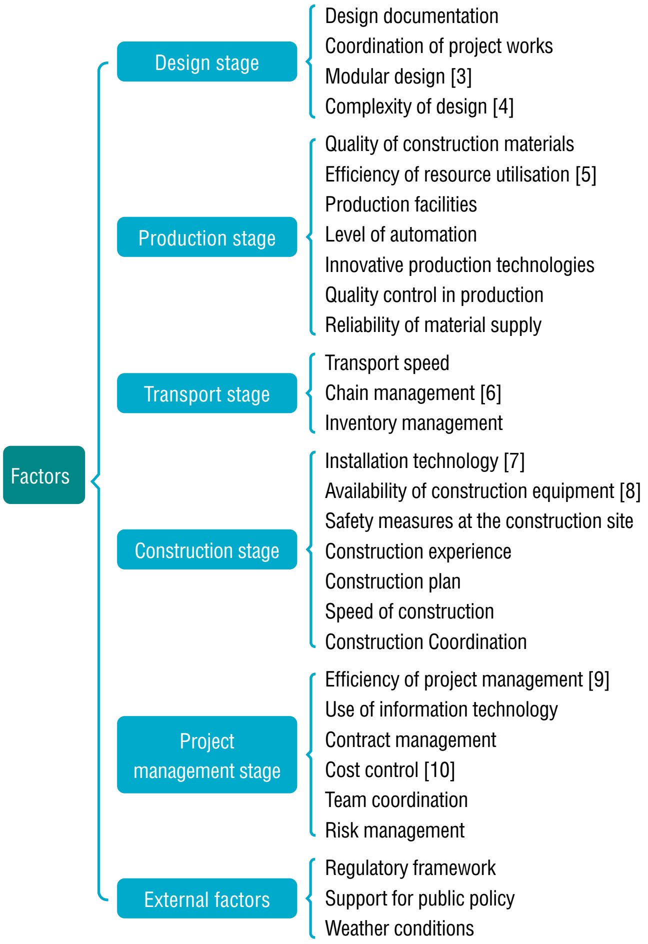

Fig. 2. Evaluation factors [3–10]

The construction of the AHP model based on the survey data is described in detail below (Table 2).

Among the various phases of a prefabricated building project, the construction stage and the project management stage have the greatest weight (Table 3). Therefore, strengthening the management and optimizing these two stages can be the key to improving the overall efficiency of the project.

The formula for calculating the complex weight is as follows:

$$W_{complex} = W_{stage} \cdot W_{factor}, \quad (1)$$

where $W_{complex}$ — the composite weight of a sub-factor;
W_{stage} — the weight of the stage to which the sub-factor belongs;
W_{factor} — the weight of a factor within its stage.

The calculation results are shown in Fig. 3.

In prefabricated buildings, construction and project management are critical for quick erection due to their high weighting factor. Modular construction significantly enhances construction efficiency. Moreover, efficient resource management and supply chain optimization during manufacturing underscore the complex nature of prefabrication project management and the need for an integrated approach to achieve success.

Kendall's coefficient of concordance (W) (Fig. 4) can be used to check the consistency of expert opinions [12]. If the value of W is high, it indicates a high consistency of opinions.

Based on the above data, the calculated $W = 0.713$ indicates that the experts were more consistent in their assessments of the importance of the factors.

IMPROVEMENTS FOR SPEEDY CONSTRUCTION

The BEI (Building Efficiency Index) was created to evaluate the criteria for rapid construction:

$$\text{BEI} = \frac{\text{TP} \cdot \text{QC} \cdot 100}{\text{TD}}, \quad (2)$$

where TP (Target Performance) is calculated based on the ratio of actual project completion time to planned target time, expressed as a percentage;
QC (Quality Coefficient) — a rating of the quality of a completed project, usually between 0 and 1, where 1 means no defects, 0.8 minor defects, and a lower value serious quality problem;
TD (Time Deviation) — the ratio of actual project completion time to the industry average.

For this purpose, set thresholds (Fig. 5).

Example: suppose a project has a target completion time of 30 days, an actual completion time of 30 days, a project quality score of 0.9 (minor defects), and an industry average completion time of 40 days:

$$\text{TP} = \frac{30}{30} \cdot 100\,\% = 100\,\%, \text{QC} = 0.9; \text{TD} = \frac{30}{40} \approx 0.75;$$

$$\text{BEI} = \frac{100 \cdot 0.9 \cdot 100\,\%}{0.75} = 120.$$

Thus, the project is a rapid construction project.

The following specific measures can be applied to optimize the efficiency and quality of prefabricated building construction:

1. Assembly technology for frame columns:

• location selection and node design: Locate frame column

Table 3. Weight of level sub-criteria

Number	Factors	Quantity of factors	Weight
1. Design stage			
1.1	Design documents	4	0.0471
1.2	Coordination of project works	3	0.0324
1.3	Modular design	5	0.0610
1.4	Complexity of design	4	0.0334
2. Production stage			
2.1	Quality of construction materials	5	0.164
2.2	Efficiency of resource utilisation	5	0.164
2.3	Production facilities	3	0.079
2.4	Level of automation	4	0.108
2.5	Innovative production technologies	3	0.079
2.6	Quality control in production	4	0.108
2.7	Reliability of material supply	5	0.299
3. Transport stage			
3.1	Transport speed	3	0.296
3.2	Chain management	4	0.370
3.3	Inventory management	4	0.334
4. Construction stage			
4.1	Installation technology	5	0.176
4.2	Availability of construction equipment	4	0.149
4.3	Safety measures at the construction site	4	0.149
4.4	Construction experience	5	0.176
4.5	Construction plan	4	0.149
4.6	Speed of construction	5	0.176
4.7	Construction coordination	4	0.176
5. Management stage			
5.1	Efficiency of project management	4	0.164
5.2	Use of information technology	3	0.123
5.3	Contract management	4	0.164
5.4	Cost control	5	0.215
5.5	Team Coordination	5	0.215
5.6	Risk management	5	0.215
6. External factors			
6.1	Regulatory framework	5	0.451
6.2	Support for public policy	3	0.274
6.3	Weather conditions	3	0.274

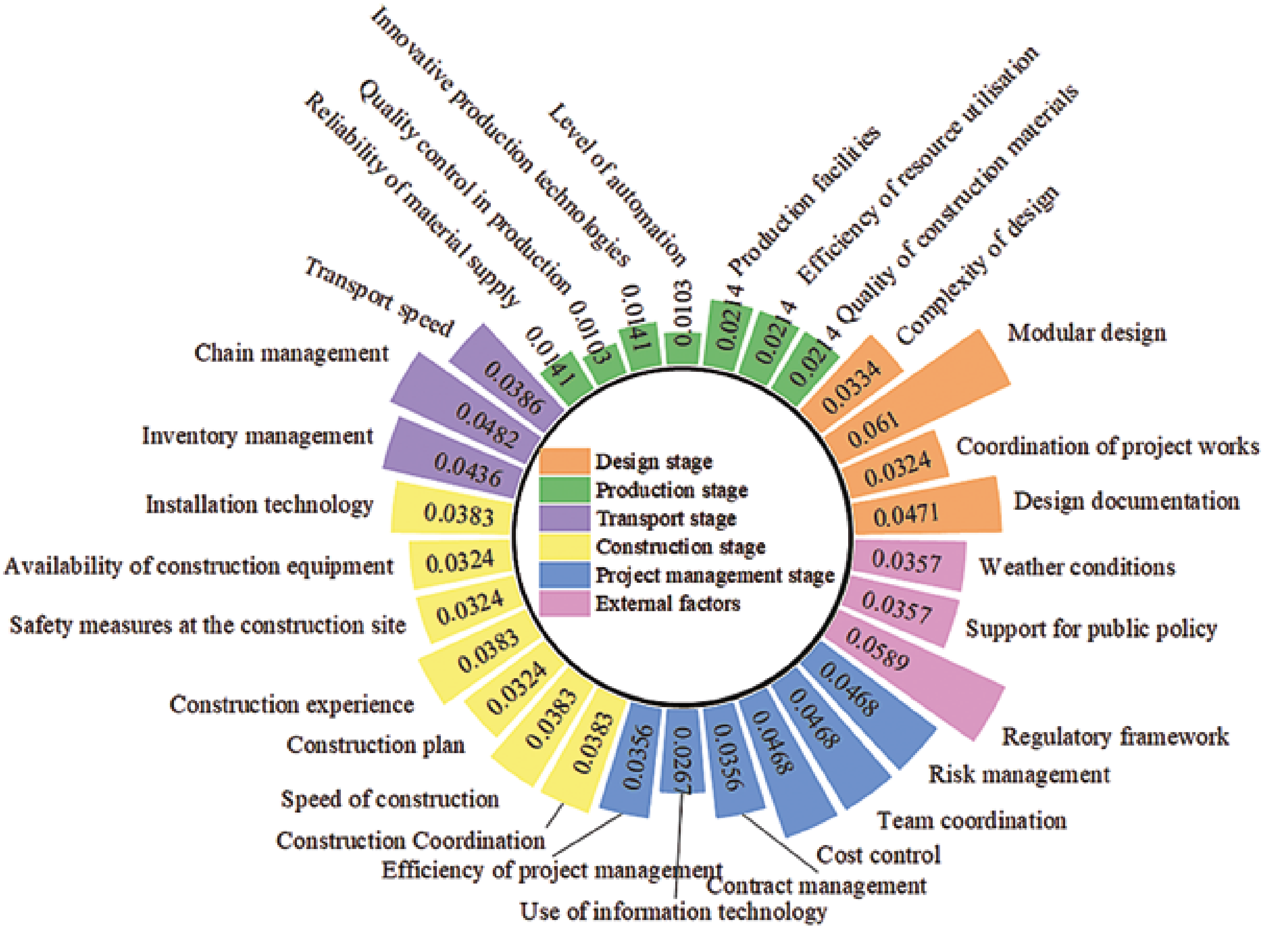

Fig. 3. Complex weights of factors

Step 1 Calculate the sum of ranks for each factor
Let R_{ij} be the rank assigned to factor n_j by expert m_j. Then the sum of ranks for factor n_j:
$$R_{nj} = \sum_{i=1}^{k} R_{ij}$$

Step 2 Calculate the average rank for all factors
$$R_{avg} = \frac{1}{j}\sum_{j=1}^{j} R_{nj}$$

Step 3 Sum of squares of deviations of ranks from the mean value
$$S = \sum_{j=1}^{j} (R_{nj} - R_{avg})^2$$

Step 4 Calculation of Kendall's coefficient of concordance (W)
$$W = \frac{12 \times S}{k^2 \times (j^3 - j)}$$
Where k - the number of experts, j - the number of factors.

Fig. 4. Algorithm for calculating Kendall's concordance coefficient

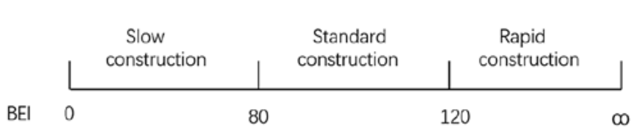

Fig. 5. Scheme of construction speed thresholds

assembly nodes in areas with lower bending moments to reduce stress in the structure (Fig. 6). Development of standardized mounting nodes and use of prefabrication to increase the early load-carrying capacity of the nodes, which speeds up construction and reduces costs [13];

- auxiliary support measures [14]: Optimization of the auxiliary support system at the construction site, reduction of dependence on temporary support structures, and increase of installation efficiency.

2. Installation technology for frame beams. Assembly of frame girder assemblies outside of beam and column assemblies: the assembly of frame beam assemblies in the area outside the beam and column assemblies allows them to be installed together with whole prefabricated frame columns, thus simplifying the construction process and increasing the speed of the overall assembly [15].

3. Installation technology of floor slabs. The application of the overlap method of a one-piece slab maximally simplifies the installation of supports at the construction site, expands the working surface when erecting lower floors, and increases the efficiency of construction [16]. According to the optimized structure separation plan for the prefabricated frame structure, the proposed construction process is as follows (Fig. 7):

- delivery of prefabricated samples to the site — assembly of frame column assemblies;
- installation of columns and prefabricated columns and beam

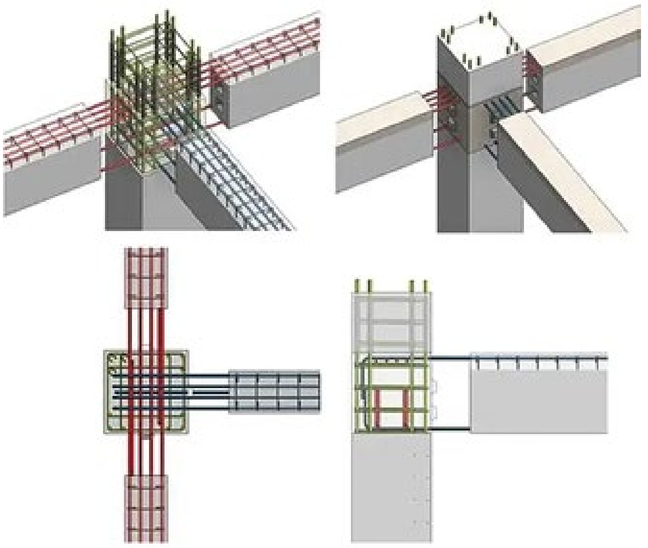

Fig. 6. Column and beam joint assembly diagrams[1]

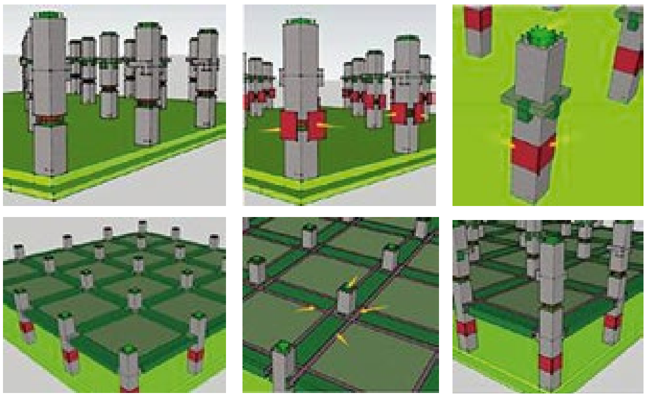

Fig. 7. Schematic diagram of the concrete frame structure assembly process [17]

assemblies, use of steel sleeves to connect longitudinal reinforcement;

- connection of reinforcement and erection of laterally supported and laterally restrained frame column assemblies using standardized formwork systems;
- placement of concrete mix inside and outside the frame columns at nodes, with the concrete at the nodes poured 300 to 500 mm below the node to ensure safe spacing between the old and new concrete at the core of the column;
- installation of beams, slabs, and their support systems: First, the beam support system and its connection with columns are installed, and then the suspended slab support system is installed after the support system is installed, the prefabricated slabs are installed, and finally the reinforcement of countersunk floor beams is tied;
- pouring concrete mix in the beam and countersunk floor beam assembly units;
- under the auxiliary support of the assembly nodes, the frame columns of the next level are erected.

CONCLUSION

This study presents a comprehensive organizational and technological analysis of high-speed construction methods for civilian high-rise buildings in the context of accelerated urbanization in China. Particular attention was given to the adoption of prefabricated construction technologies, which have demonstrated effectiveness in reducing construction time and labor costs while maintaining rigorous safety and quality standards.[1]

Furthermore, the in-depth analysis of the frame column, frame girder, and slab assembly technologies and the optimization of the overall construction process have made the construction of prefabricated reinforced concrete frame structures faster and safer. Frame column assembly technology has accelerated the construction process by optimizing the arrangement of nodes, and frame beam assembly technology has simplified the construction process by installing assembly nodes outside the node areas. The slab assembly technology improved construction efficiency by utilizing a whole-slab scheme and a self-supporting beam and slab system.

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Организационно-технологический анализ скоростного возведения гражданских высотных зданий в Китае

В данной работе представлен подробный организационно-технологический анализ ускоренных процессов строительства гражданских многоэтажных зданий в Китае с акцентом на использование технологий предварительного изготовления для решения задач стремительной урбанизации и растущего спроса на жилье. Исследование выявляет ключевые организационные и технологические инновации с помощью сравнительного анализа и статистической обработки данных. Эти инновации значительно сокращают сроки строительства, обеспечивая при этом строгие стандарты безопасности и высокого качества. В работе подчеркивается важность стратегического улучшения управленческих процессов, внедрения современных технологий и материалов, а также укрепления координации между участниками проектов. Это позволяет значительно повысить эффективность и скорость реализации проектов строительства высотных зданий. Особое внимание уделено предварительно армированным бетонным каркасным конструкциям, которые существенно сокращают время строительства на месте и трудозатраты, предлагая жизнеспособное решение для удовлетворения неотложных жилищных потребностей в условиях стремительно растущих городских районов. Дополнительно предлагается система оценки факторов влияния на предварительно изготовленные конструкции, основанная на методе аналитической иерархии (AHP). Эта система позволяет проводить приоритизацию факторов и принимать более обоснованные управленческие решения. Данный интегрированный подход не только решает практические задачи ускоренного строительства, но и вносит вклад в теоретическую базу гражданского строительства. Исследование предоставляет практические рекомендации, которые могут быть применимы в аналогичных условиях развития городов в глобальном масштабе. Результаты работы призваны повлиять на будущие строительные практики, способствуя формированию устойчивых и эффективных стратегий для решения актуальных вызовов урбанизации.

Ключевые слова: *скорое возведение, технология строительства, сборные конструкции, высотные здания, экономическая эффективность*

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For citation: Chong L., Fomin N.I., Shuoting X. Organizational and technological analysis of high-speed construction of civilian high-rise buildings in China. *Real Estate: Economics, Management*. 2024; 4:52-58.

Для цитирования: *Чун Л., Фомин Н.И., Шотин С.* Organizational and technological analysis of high-speed construction of civilian high-rise buildings in China // Недвижимость: экономика, управление. 2024. № 4. С. 52–58.

Эвкалипты. Офорт. Л.И. Павлова