Research on cost control of Prefabricated Buildings under EPC Based on Contractor's Perspective

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Abstract. EPC is highly advocated cause of the utility of integration during the phase of Engineering-Procurement -Construction. Combined with the characteristics of prefabricated buildings, EPC and prefabricated buildings have inherent adaptability, it's feasible to apply EPC in prefabricated buildings. Based on the perspective of general contracting Grounded Theory was used to analyze the cost of influencing factors of prefabricated buildings under EPC, in addition, it puts forward suggestions on the cost control of EPC during the phase of Engineering, Procurement and Construction.

Keywords: EPC; general contracting; Grounded Theory; cost control; suggestions.

1 Introduction

EPC (Engineering, Procurement and Construction) refers to the whole process of engineering design, procurement, construction and delivery by the general contractor in accordance with the contract signed with the owner. Moreover, which is fully responsible for project cost, quality, safety, duration and trial operation, plays an integrated role and is highly respected, and is suitable for the development of prefabricated buildings [1-2]. Implementation of the engineering design, product components production, construction and procurement of the unified management is the hotspot of prefabricated buildings development research, current research and engineering practice [3-4] showed that the EPC and prefabricated buildings has a high fit. With the rise of prefabricated buildings, many studies have been conducted from different perspectives such as duration, quality, cost and construction risk. From the perspective of construction period, Van Heesch believes that more preparations must be made to shorten the duration and the use of prefabricated components is a good method [5]. Bansal showed that in prefabricated buildings, contractors can significantly reduce project construction costs through the application of low-energy and low-cost building materials [6]. Based on the construction process of prefabricated components, Liu

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Lingyu studied the quality problems, occurrence frequency and causes at each stage [7]. Wang Dan studied the construction risk assessment model of prefabricated buildings based on the improved matter-element extension theory [8]. Despite this, the EPC is still relatively less studied in prefabricated buildings. Therefore, based on the research of various scholars, this paper further discusses the cost influencing factors of prefabricated buildings under EPC, and from the actual situation of prefabricated buildings, puts forward suggestions on cost control measures in three stages under EPC.

2 Analysis of the suitability of prefabricated buildings and EPC

As a product of new construction methods, prefabricated buildings refer to some prefabricated parts of walls, beams, columns, panels, stairs, balcony components and other building components, which are assembled on site using prefabricated components provided by component prefabrication manufacturers [9]. Under the EPC mode, the general contractor can maximize the subjective initiative and mobilize the enthusiasm of the participants. Relying on the mature organizational process and the increasingly iterative management technology, it can create greater value for the owners.

(1) Analysis from the perspective of project management.

Project management includes the establishment of the project organization, the provision of organizational division of labor, the clarification of the rights and responsibilities of each participant, etc., through the establishment of a systematic objective management system and organizational management system, to solve the problem of fragmented management and segmented management of each organization, and to transform into the unified management of EPC general contractors, giving full play to the comprehensive advantages of all stakeholders.

(2) Analysis from the perspective of project duration.

The general contractor can carry out overall planning of the project, starting from the design stage through the whole process of the project, which can promote the close connection of each stage. In the EPC mode, the stages of design, procurement and construction are both clear and cross-integrated, thus speeding up the overall project progress.

(3) Analysis from the perspective of project construction cost.

In the EPC mode, the owner's investment objective is relatively clear, and the general contractor, as the lead party, coordinates the phased objectives of the participating parties, highly integrates the objectives of the participants and the overall objectives of the project, and realizes the maximum benefit.

(4) Analysis from the perspective of project informatization.

EPC implements integrated management, which is conducive to the collaborative, iterative and integrated application of design, production and transportation, component lifting and construction technologies, and forms a unified prefabricated building technology management system.

3 Cost factors of prefabricated buildings in EPC

3.1 Research methods and data collection

Rooted theory, jointly proposed by two scholars AnselmStrauss and BarneyGlaser in 1967, is a method to establish substantive theory from the bottom up, to find core concepts reflecting social phenomena on the basis of systematic collection of data, and then construct relevant social theories through the connections between these concepts [10]. From the perspective of general contracting, this paper, which belongs to the scope of project management, carries out the three-level coding work according to the process of "open coding - spindle coding - selective coding" in terms of the development, construction and application of prefabricated buildings under EPC mode.

There are two methods to collect the original data of the rooted theory, one is to read and organize the literature, and the other is to record the interview. Literature reading and sorting is to input keywords "EPC", "prefabricated buildings" and "cost" on CNKI, and the search scope is above the core journals and master and doctoral papers. The principle of selection is related to engineering management, and the literature publication year is selected in the past 5 years, and it is related to the cost management of prefabricated buildings. Therefore, 33 literatures were selected, 27 of which were coded and analyzed as original data, and the remaining 6 were used for theoretical saturation test. In addition, on the basis of literature research, 12 interview subjects were invited, among which 6 were people who had chosen engineering management related majors and engaged in assembly from the author's unit and project suppliers, 3 were industry experts, and 3 were people from relevant industry authorities.

3.2 Process Analysis

Open coding. It’s the first level coding work of rooted theory, which conceptualizes any sentence or fragment recorded in the literature that can be encoded, and realizes the conceptualization of the original data. Secondly, the selected 27 non-technical literatures and 8 interview records were analyzed. In this process, the principle of openness was maintained to minimize the influence of the original "bias" and "orientation", and concepts were extracted and initially named. In the process of open coding, a total of 38 initial concepts are obtained, which are classified into different initial categories through comparative analysis and further abstraction, and 18 initial categories are obtained.

Spindle coding. It’s to conduct in-depth research on the connotation of each initial category, eliminate, combine, refine and integrate, and establish a more accurate and specific main category. Based on the first-level coding work, the main axis coding results of cost influencing factors of prefabricated buildings under EPC mode, Table 1:

Table 1. Main axis code of cost influencing factors of prefabricated buildings under EPC

Principal category	Initial category	Initial category relation connotation
Component design	Assembly rate and prefabrication rate set values	Assembly rate refers to the proportion of prefabricated components in the building, and prefabricated rate is the proportion of the volume of prefabricated components to the volume of all components in the whole building.
	Component decomposition rationality	Rational separation of prefabricated components, such as walls, beams, columns, floors, stairs, etc. from different vertical and horizontal angles;
	Professional level of designers	The professional level of the designer will directly reflect the rationality of the design, the redundancy of the component, and the landing
Component production	Die reuse rate	The higher the standardization of components, the higher the reuse rate
	Component production scale	Whether the scale of the project or the scale of the component can form the scale effect
	Degree of engineering specialization	Production automation, intelligence, specialization of different components, etc
Structural transport	Transport distance and efficiency	The longer the transport distance, the greater the cost; It is necessary to give fully consideration to the modulus and quantity of the components, which affect the transportation efficiency
	Protective measures for components during transportation	It mainly aims at the protection of components to avoid stress mutation and damage of components during transportation
Component assembly and lifting	Hoisting process rationality	Reasonable lifting sequence can effectively improve the assembly efficiency of components
	Secondary handling of member	Reasonable planning site layout
	Field personnel management level and technical level	Field personnel management level and technical level, such as project control, coordination, problem solving ability directly reflected
	Ability to cooperate and coordinate different types of work	At the same time or stage, the cooperation between different types of work, scheduling ability, etc.
Information technology application	BIM technology application	It is helpful for field personnel to correctly understand the design information and improve the cooperation of work
	Smart site platform application	It can effectively improve management efficiency and reduce security risks
Other external environmental influences	Market price fluctuation	It generally refers to the impact of price fluctuations of raw materials and labor on component prices
	National policy support	The support and guidance of national policies for prefabricated buildings, the scope of application, etc
	Industry standards and specifications	Prefabricated buildings policy and construction technical guidance standards
	Force majeure events, etc	It generally refers to unforeseeable, unavoidable and insurmountable objective situations, such as earthquakes, typhoons, floods, etc

Selective coding [11]. On the basis of the above completed two-level coding, the influence factors of prefabricated buildings cost under EPC mode are further extracted into 18 initial categories and 6 main categories. Through careful analysis and compar-

ison, this paper takes component design, component production, component transportation, component assembly and lifting, application of information technology and other external environmental influences as the core categories. Among them, external environmental influences play an adaptive, guiding and policy-oriented role in the design of prefabricated buildings components. Then in the production link, the transportation system and the subsequent lifting and assembly will have a conductive effect, and at the same time, under the promotion of information technology and the iteration and update of new processes and new technologies, it will also form a two-way feedback. Based on this "story line", a "model of influencing factors of prefabricated buildings cost under EPC mode" can be established, Figure 1.

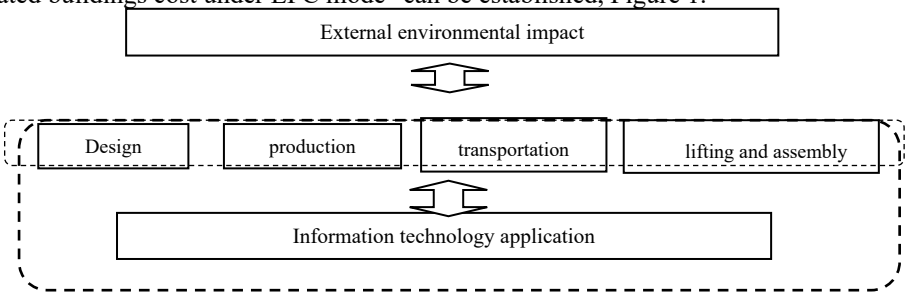

Fig. 1. Model of cost influencing factors of prefabricated building under EPC mode

Theoretical saturation test. In this paper, 6 out of 33 literatures are randomly selected for theoretical saturation test. The results show that the theoretical categories obtained by grounded theory have been relatively perfect, and no new categories have been found. Therefore, it can be considered that the theory has reached the saturation state.

4 Factors of prefabricated buildings cost under EPC-Entropy weight -TOPSIS analysis

The above 12 invited interviewees scored the correlation among the factors affecting the construction cost of prefabricated buildings under EPC mode according to Likert scale, and numbered the cost factors according to the scale. The original decision matrix of experts on the factors affecting the cost of prefabricated buildings was obtained. After the deviation standardized linear transformation, The standardized matrix of influencing factors of prefabricated construction cost is obtained. The specific gravity *Pij* and entropy *ej* of each expert indicator corresponding to different indicators are calculated, as well as the redundancy of 18 influencing factors. Then the entropy weight of each influencing factor is calculated, and the entropy weight of the first level index of influencing factors is finally obtained, Table 2.

Table 2. The Entropy weight calculation

Index	Component design	Component production	Structural transport	Component assembly and lifting	Information technology application	Other external environmental influences
Weight	0.497	0.256	0.134	0.053	0.032	0.028

The weight of influencing factors in the design stage is 0.499, accounting for the highest proportion of influencing factors, which plays a key role in cost control. The weights of influencing factors in production and transportation stage are 0.257 and 0.131, indicating that these two factors have a greater impact on cost control. The weights of assembly and hoisting, information technology application and other external environment influencing factors are 0.053, 0.032 and 0.028, respectively, indicating that these factors have a moderate impact on cost control.

5 Suggestions on cost control measures

Combined with the characteristics and advantages of prefabricated buildings and the adaptation to EPC management mode, based on the grounded theory, 18 initial categories and 6 core categories are obtained, and the cost control measures are proposed in the three stages of prefabricated buildings design, procurement and construction.

5.1 Cost control in the design phase

The design stage is the most important stage of cost control, and the weight is 0.497 according to the analysis of the above influencing factors. Normally, design costs account for about 2% of the total development cost, but can be constrained to about 70% of the total cost[12].

(1) Familiar with the national industrial policy, industry incentive system, etc., pay attention to early program planning. Designers should take full account of the specifications, use the relevant requirements and incentive policies of prefabrication rate and assembly rate, and try to maximize the interests of owners.

(2) Applying lean design, reasonably split prefabricated components, and do a good job in design optimization. Combined with the "lean design" idea to improve the level of fine management and integration of the project, consider the utilization of resources, improve component turnover, reduce inventory and reduce costs. Before mass production, the precast component is designed and split scientifically and reasonably to meet the standardization and versatility, and improve the reuse rate of the precast component mold.

(3) Improving design-production collaboration. Through the establishment of a professional deepening design team, establish the integrated management of the design, production and installation of components, and promote three-dimensional collaborative design with the help of digital information platform, BIM, etc., to achieve

visual disclosure. In addition, cultivate the ability of industrial workers to recognize maps, and form a two-way positive feedback of design-production.

(4) Professional training and extensive communication. Pay attention to the hot spots in the industry, with the promotion of intelligent and digital buildings and the popularization of green buildings, it is equally important to improve the professional level of designers. Through the organization of relevant training, participation in industry or association exchanges, designers should be able to understand both design and construction.

5.2 Cost control in the procurement phase

In the procurement stage, under the premise of satisfying the quality and not at the cost of sacrificing the quality of components and later services, the comprehensive benefits of the supplier and the interests of the owner should be maximized.

(1) Optimize screening suppliers, establish good cooperative relations, and achieve win-win results. Establish supplier evaluation standards, through investigation and investigation of its production scale, mechanization level, specialization level of labor division, component qualification rate, etc., combined with the feedback of projects under construction, as supplier evaluation warehousing standards. During the performance of the contract, the supplier shall be evaluated regularly during the performance of the contract, and the supplier shall be evaluated after the end of the contract.

(2) Rationally plan the path and build a scientific transportation and distribution network. The factors affecting the cost of the transportation stage of the components mainly refer to the transportation and distribution time, and the effective organization of transportation vehicle scheduling through the application of computer technology. Establish a transportation and distribution network system, introduce the supply chain information platform, and set up the optimal radius warehouse division of standardized components, so as to reasonably control the transportation and distribution time, reduce the on-site storage cost of prefabricated parts and the on-site secondary handling cost.

(3) Improving the mold production yield and pass rate to ensure the accessibility and storability of components. By optimizing the production line mode, the main structure of the mold is changed, and the precision of the mold is gradually improved from the hardware. The standardized mold is reusable and optimized for typesetting to reduce the loss rate and improve production efficiency. Optimize production scheduling, introduce automatic numerical control process, promote fully automated production of steel bars, and create intensive value with modern scale production.

5.3 Cost control in the construction phase

The construction stage is the last stage of cost control. The countermeasures are studied from the perspectives of site management, project team management and construction organization.

(1) Doing a good job in construction organization and planning, and improve the level of on-site construction and installation management. According to the construc-

tion characteristics of the project, the construction organization is prepared in advance, the stacking position and method of prefabricated components are reasonably planned, and the protection measures of finished products are paid attention to. The prefabricated components of different sizes and functions are hoisted on site according to the design number to improve the hoisting efficiency.

(2) Reasonable selection of vertical transport and assembly hoisting machinery and equipment. According to the specifications of the prefabricated components, the transportation and hoisting equipment are considered in advance in combination with the field layout in the construction planning, which makes the transportation, hoisting and installation optimal and most economical. According to the transportation and lifting operations, formulate the construction process and flow, build a professional construction and assembly team of prefabricated buildings, and improve the conversion rate of personnel professional training.

(3) Definning the scope management of EPC general contracting, and balance the management and control of subcontractors. The scope and construction interface are clearly defined in the EPC general contract. During the whole construction stage, the general contractor is regularly evaluated by suppliers, and the problems found are given early warning, improvement plans are formulated, and risk elimination measures are taken in a timely manner.

(4) The introduction of information technology and the establishment of information platform architecture with the help of BIM. Establish a process simulation program based on BIM technology, visualize technology and disclose construction information to on-site technicians and installers through assembly technology, reduce fault tolerance and improve assembly and hoisting efficiency.

6 Conclusion

Due to the characteristics of industrialization of prefabricated buildings, the whole process management requirements of design, procurement and construction under EPC mode are high, and cost control has become one of the key contents of prefabricated buildings project management under EPC mode. Based on the research method of grounded theory, this paper establishes the cost influencing factor model of prefabricated buildings in EPC mode based on the perspective of general contracting, including component design, component production, component transportation, component assembly and lifting, information technology application and other external environmental influences. Therefore, it further puts forward the cost control countermeasures and suggestions under the three stages of design-procurement-construction of prefabricated buildings under EPC mode, hoping to provide a reference for the whole process cost control of prefabricated buildings under EPC mode in related engineering fields in China. With the deepening of research on the application management of prefabricated buildings and EPC mode in China, it is suggested that future scholars should apply building information model BIM to strengthen the research on the cost control of prefabricated buildings under EPC mode.

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