Research on Cost impact Factor Rating of Assembly Building Based on Structural Equation Modeling

Mengke Hou, Peng Liu*

Yunnan college of Business Management, Kunming University of Science and Technology
Oxbridge College, Kunming, Yunnan, 650500, China

*Liupeng611@163.com

Abstract. At present, there are few studies on the cost difference between prefabricated buildings and traditional cast-in-place buildings. In this paper, firstly, from the perspective of general contractor, combined with the four phases of design, production, transportation, installation and construction in EPC mode, 25 specific influencing factors in five dimensions of design, production, transportation, installation and construction and others are identified by using literature analysis method and expert interview method. Secondly, on the basis of the list of cost influencing factors of assembled buildings, a questionnaire survey on "cost influencing factors of assembled buildings under EPC mode" was conducted to put forward research hypotheses and construct a structural equation model of the influencing factors of assembled buildings, to verify the positive influence of influencing factors on costs through the study of path coefficients, and calculate the weights of influencing factors' degree of influence. The weights of the influencing factors are calculated. It is found that the influence degree of the assembly building cost influencing factors on the cost, in descending order, is as follows: design factors, other factors, installation and construction factors, transportation factors, and production factors.

Keywords: assembled buildings; SEM; construction cost; influencing factors

1   Introduction

Assembled building refers to a variety of factory prefabricated general-purpose components (PC) through a proprietary connection technology, on-site mechanized assembly for the main body of the building of the special construction technology system, the manufacture of its components, transportation and on-site installation fully reflects the characteristics of the modern industrialization of construction, is a fundamental change in the mode of production of the building is to achieve energy conservation and emission reduction, low-carbon environmental protection, construction of the "two-type society" is an important guarantee, but also a new model for the sustainable development of the construction industry.

As a pillar industry of the national economy, the construction industry is a key material production field in China. Along with the continuous expansion of the industry

scale, the prominent problems exposed during the development of the construction industry are increasingly visible: excessive energy consumption and structural shortage of resources co-exist, environmental pollution and ecological damage caused by the construction process is a serious problem, and the escalating labor costs continue to push up the construction costs. ...... The study of CII, an authoritative institution of the Construction Industry Institute, shows that The non-value-added work (including inefficient work and waste of resources) in the construction industry accounts for 57%, far exceeding the 26% level of the manufacturing industry in the same period. The traditional construction mode in terms of project quality control, cost control and schedule performance has been difficult to adapt to the modernization of production needs, and has become a key bottleneck restricting the upgrading of the construction industry. In the face of the resource and environmental constraints continue to tighten the reality of the pressure to promote the construction model innovation and construction industry transformation and upgrading has become an urgent need for the development of the industry. As a focus point of green transformation of the construction industry, assembly building can enhance production efficiency and resource utilization through industrialized construction in the construction process, and simultaneously realize the double benefits of reduced pollution emissions and construction safety risks. The innovation of this building production mode is essentially changing the logic of the traditional construction industry, providing an effective path to crack the industry's development dilemma.

2   Overview of Prefabricated Buildings

2.1   Government Strongly Supports the Development of Assembled Buildings

Since 2016, China's housing and urban-rural construction authorities have issued a series of guiding policy documents in response to the development needs of the modernization of the construction industry, systematically guiding the transformation and upgrading of the traditional construction industry to an industrialized construction model. The policy framework aims to optimize the efficiency of production resource allocation by promoting the application of prefabricated component technology, so as to enhance the production efficiency and comprehensive benefits of the whole life cycle of assembled buildings, and ultimately achieve the goal of supply-side structural reform of the construction industry and promote the sustainable development of the industry[1]. Combined with the current development of China's construction industry, the high efficiency and low energy consumption of assembled building structures is a key way to realize "carbon peak" and "carbon neutral", and to realize the shift of the construction industry to a resource-saving development industry. As the degree of industrialization of China's construction continues to improve, the superiority of assembly building energy saving and environmental protection, shorten the construction, improve the quality of construction will become more and more prominent, assembly building has also become an inevitable choice for the transformation of the construction industry.

2.2   Difficulty in Cost Control of Assembly Construction

At present, although the national level continues to promote the strategic deployment of construction industrialization, the economic bottleneck of the assembly construction mode has become a key factor restricting its market promotion. According to the 2022 annual industry research data from the Center for Science and Technology Development and Promotion of the Ministry of Housing and Construction, compared with the traditional cast-in-place construction method, there still exists an incremental cost of about RMB 500-700 per unit area of assembly construction, and this cost difference runs through the whole process of the project: from the insufficient optimization of the scheme at the standardized design stage to the amortization of the mold cost of industrialized prefabricated component production, and then extends to the logistics cost incurred by the special-purpose Logistics costs generated by transportation equipment, and ultimately reflected in the on-site assembly construction of special machinery leasing and training costs for skilled workers and other dimensions, forming a significant industry-wide cost pressure. In the process of assembly building construction, the factors affecting the cost are not clear enough, and the lack of effective measures for project cost control is a problem that needs to be solved for effective cost control.

2.3   The Cost of Assembled Buildings Under the EPC Mode has More Compression Space

EPC mode is different from the traditional mode of design, production and construction separation, with integrated contracting characteristics, can give full play to the advantages of integrated management of assembly building, can to a large extent shorten the construction cycle of the project[2]. In addition, owners and investors are able to coordinate resources more effectively, optimize processes, and anticipate possible problems and challenges through detailed planning and overall planning at the initial stage. This not only helps accelerate the project schedule, but also improves cost control while ensuring quality. The project implementation mechanism based on the EPC model, through the systematic integration of design, procurement, construction and other phases of the whole element of resources, can significantly enhance the synergistic efficiency of the engineering value chain, and thus achieve the optimization of the project's full-cycle investment returns. Assembled building projects such as EPC management mode and industrialized construction system to implement strategic coupling, build the whole industry chain integrated system covering R & D and design, parts manufacturing, logistics and distribution and assembly construction, can effectively dissolve the interface loss problems existing in the traditional construction mode, breaking through the cost rigidity constraints formed by the fragmentation of the industry chain. Based on the economic dilemma in the process of modernization of the construction industry, relying on the integration advantage of the responsible body for performance under the EPC contract system, and through the establishment of the BIM collaborative design platform, the implementation of the whole process of value engineering analysis, the improvement of the standardized component database

and other fine control measures, the industrialized construction technology system can be realized with the depth of the adaptation of the management structure of the general contracting system, and ultimately form a double value-added mechanism of the technological integration advantage and the organizational and management synergy. It can realize the deep adaptation of industrialized construction technology system and general contracting management structure, and finally form the double value-added mechanism of technology integration advantage and organization management synergy.

3   Analysis of Cost Influencing Factors of Assembly Building under EPC Mode

3.1   Design Factors

(1) Depth of design program. Studies have shown that the influence of the design stage on project costs can range from 75% to 95%, while this influence narrows to 5% to 25% after the project enters the construction stage. This shows that taking effective measures to control cost risks at the design stage is crucial to the quality and efficiency of the final cost control. Selecting an experienced and skilled design team and formulating a detailed design plan in conjunction with the specific characteristics of the project will help optimize the cost control effect of the construction project.

(2) Level of component integration. Nowadays, advanced technologies such as BIM (Building Information Modeling), and big data analysis are being widely used in the design stage, with the goal of promoting efficient collaboration and integration of multiple professional fields such as architecture, structure, equipment installation and interior decoration, and realizing efficient coordination among various professions. By improving the level of component integration, on-site conflicts and duplication of work caused by cross construction can be reduced, thereby enhancing the efficiency of subsequent construction. Therefore, a high level of component integration at the design stage can not only optimize the construction process, but also effectively reduce overall construction costs. The application of this method provides strong support for the cost management of assembly buildings.

(3) Degree of component standardization. It is found that the cost of assembly building construction is greatly affected by the main structure and the degree of standardization of prefabricated components. At present, prefabricated assembly construction has been realized in some areas of China, but in Yunnan Province, many structural components are still cast-in-place concrete structures due to the limitations of local intensity requirements. In the process of assembly building construction, if the standardization of prefabricated components can be improved, the types of molds for prefabricated components will be relatively less, and the utilization rate of molds will be increased, then the amortized cost will be relatively lower[3]. In addition, if the degree of standardization of prefabricated components is not improved, the prefabricated components are complex and diverse in shape, and have different size specifications and surface forms and other characteristics, which will have a greater impact on

the production efficiency. Therefore, in the process of in-depth design of assembly components, the higher the degree of standardization of prefabricated components not only helps to improve the production efficiency, but also reduces the manufacturing cost of components, and overall realizes the reduction of construction costs.

(4) Assembly rate and prefabrication rate. In view of the gradual promotion of assembly building, the prefabrication assembly rate and production efficiency have become one of the key factors restricting its development. Throughout the design and construction process, the assembly program plays a key role in cost management and control, while the assembly program, the core factors that have the greatest impact on cost are the assembly rate and prefabrication rate. Current regulations specify a standard that the prefabrication rate of components should be at least 20% or more, and the assembly ratio of components should be more than 50%[4]. Differences in component prefabrication or assembly rates for construction projects may cause differences in costs, and both may result in cost increases whether they are too large or too small. Therefore, the design should be based on scientific and appropriate assembly ratios and programs at the design stage to achieve effective and sustainable cost control.

(5) Rationality of component disassembly design. Research has pointed out that through scientific and reasonable prefabricated component splitting design, the cost of construction projects can be reduced by about 10%. The split design of prefabricated components is a key step in the deepening of assembly building design, which needs to be divided into specialties based on the characteristics of the building unit. In the stage of split design, the relationship between the split position and the turnover efficiency of production molds must be considered comprehensively. In addition, the appropriate disassembly size is of great significance to improve the lifting and assembly efficiency, and simplify the production and transportation process. For example, in the precast component splitting process should be combined with the lifting operation to accurately plan the location of the lifting point, in order to prevent damage to the component due to improper lifting point setting. This meticulous design and planning not only helps to reduce construction costs, but also enhances the overall economic efficiency of the project.

3.2   Production Factors

(1) Mechanization level and production efficiency of component production. In the manufacturing process of prefabricated components, prefabricated components production plant department usually use assembly line method and pedestal method, both production methods need manual and mechanical cooperation, if the prefabricated components standardization degree is high, the assembly line method can be better to achieve the purpose of efficient production and reduce the cost of labor. Prefabricated components production plant adopts advanced production technology and selects high-quality equipment, and uses optimized production process technology to ensure that the prefabricated components factory can complete the production task with high quality and precision within the specified time, thus effectively shortening the project duration and reducing the construction cost.

(2) Construction mold turnover rate. The study points out that the main reason for the increase in the cost of assembled building components is the apportionment of fixed costs compared to the production cost of traditional building components. To meet this challenge, prefabricated component design units should focus on how to scientifically and rationally split components, seeking to maximize the consistency of prefabricated component specifications and optimize their standard sizes. Doing so not only reduces the variety of precast component molds, but also improves the turn-over frequency of the molds. On this basis, prefabricated components production units should purchase reusable molds, and develop a reasonable production plan to further improve the use of mold turnover.

(3) Scale of component production. China's assembly building is currently in the promotion stage, due to its production scale has not yet been fully expanded, resulting in a relatively high apportionment of fixed costs, which has become the main reason why the price of prefabricated components continues to be high. If the scale of the assembly project is large, or if the manufacturer is able to produce components with the same specifications for multiple projects at the same time, the reuse rate of components can be significantly increased during the production process. This high reuse rate helps to improve the efficiency of mold use in the component production plant and reduces the fixed cost sharing of individual components, thus effectively reducing the overall cost of building components. By expanding the scale of production and increasing the sharing of components of the same specifications between multiple projects, not only can optimize the allocation of resources, but also further dilute the fixed costs, so that the cost of each component can be reduced.

(4) The level of component production technology. At present, the production methods of PC components are mainly divided into two categories, namely, assembly line production and fixed mold table production. Among them, assembly line production requires relatively high initial investment costs in the early stage, and the automation level is also high, while the labor input is relatively small. Assembly line production later requires manual auxiliary processing, but its production costs are relatively high, not conducive to enterprise scale development. In contrast, the fixed mold table in the initial investment cost is cheaper, but its production efficiency is relatively low, and rely on more manual operation. In order to optimize the production process, we need to combine the advantages of these two methods, according to the specific production process and specifications of the shape of the PC components in the production process, to develop the best production plan.

(5) Fluctuations in the market price of raw materials for components. The cost of building components including labor, materials, machinery, management fees, etc., of which the material costs accounted for a relatively high and the most obvious fluctuations with the market price changes, is the components of the production unit for the bidding price and the key to cost control. Therefore, the price of raw materials from the design stage to the completion and acceptance stage of the price fluctuations, the smaller the impact on the production cost of building components, and then the more controllable costs.

(6) The cost of temporary storage of components. The production speed of prefabricated components, if not matched with the schedule of the project, may lead to a

short-term imbalance between the supply and demand of prefabricated components, resulting in an oversupply or an oversupply. In order to meet the schedule requirements of the construction site and avoid delays, many component manufacturers choose to produce large quantities of components in advance and temporarily store them in their factories, and the component production factories should establish specialized management and protection mechanisms to ensure that the components are properly protected during storage. Component storage generally requires a wide storage site, level and solid ground, components placed with padding, support protection, site waterproofing, and so on.

3.3   Transportation Factors

(1) Reasonableness of transportation plan. In the process of prefabricated components transportation may be due to a variety of emergencies and cause cost increases, so it is particularly important to develop a reasonable and controllable transportation program in advance according to the known conditions of transportation routes, transport components, site materials stacking location . Through reasonable route planning, combination of transport modes and selection of transportation means in the transportation scheme, we can solve the problem of transportation efficiency to a large extent, and also reduce the transportation loss effectively. In addition, in the transportation program, by fully grasping the actual situation on site and construction progress, we can prevent prefabricated components from encountering long-time handling and potential secondary handling accidents on site . Early formulation of practical transportation plan can effectively avoid the above problems, which in turn helps to reduce the total cost of transportation.

(2) Protective measures for transportation of components. Prefabricated components are an indispensable part of the construction project, if the prefabricated components can not be transported to the construction site in a timely and effective manner, it will have a greater impact on the subsequent construction operations. In order to ensure that it will not suffer damage during transportation, in addition to the detailed transportation plan that must be formulated before transportation, it is also necessary to use specialized transportation vehicles for handling, to ensure that the vehicle selection matches the pre-fabricated components, at the same time, the bracket, the leaning frame and the insertion frame need to be specially designed and checked for the bearing capacity before they can begin to be used. In addition, appropriate fixing means should be adopted during transportation to ensure that the components do not shift or fall over, padding should be used to protect the edges of the components as well as the areas where the ropes come into contact with them, and appropriate balancing strategies should be implemented during the loading and unloading of the prefabricated components to ensure that the vehicle body is stable, among other things. In addition, according to the site conditions should be reasonable selection of lifting equipment and spreader. The comprehensive consideration and effective implementation of component transportation protection measures will help reduce the component loss rate, thereby reducing project costs.

(3) Reasonableness of loading program: The distribution of PC components is based on the orders of the target site for delivery, and arrange the corresponding workload. If the loading scheme is not properly designed, it may lead to excessive waiting time for transportation vehicles, which not only raises the risk of delayed arrival, but also increases labor and machinery costs due to frequent loading and unloading, and may damage the components due to improper operation, increasing the cost of secondary transportation. For this reason, an optimized loading and scheduling scheme is proposed for a specific PC component plant serving multiple projects, aiming to improve the loading efficiency in order to reduce the final distribution cost.

(4) Distance of component transportation. Projects should select PC component plants based on the actual project location, which has a significant impact on the transportation cost because the location of the component plant is directly related to the transportation distance and route selection[5]. Usually, the transportation cost rises with the increase of distance, and longer transportation distance is often accompanied by more uncertainties, such as changes in road conditions and transportation environment, which will further affect the transportation cost. Therefore, in the preliminary planning, PC component factories with closer distance should be selected as much as possible. At the same time, before transportation, it is necessary to understand in detail the basic conditions of each route between the project site and the PC component factory, and compare multiple routes in order to determine an optimal route with a short and feasible distance. This will not only improve transportation efficiency, but also effectively reduce transportation costs.

3.4   Installation and Construction Factors

(1) Degree of construction site mechanization. The labor cost, material cost and enterprise management cost of assembled buildings in the construction process are usually low, but the cost of machinery and equipment is significantly higher. The main reason is that the prefabricated assembly of assembly building is high, most of the components are manufactured in the factory and then transported to the construction site for assembly, and a small number of projects need to be cast in situ. In addition, assembly buildings usually adopt hoisting construction program, ordinary tower cranes are difficult to meet the demand, and often require large tower cranes, which increases the cost of machinery and equipment. Therefore, it is particularly important to choose suitable machinery and optimize the design and selection of tower cranes, which can significantly reduce costs.

(2) The rationality of construction organization design. In the installation and construction phase of the assembly building, when the project prepares the construction organization design, in order to achieve efficient construction site management, advanced technical tools should be used to visualize and manage the construction site, so as to determine the most reasonable layout plan, thus improving the overall installation efficiency. At the same time, the application of BIM technology to carry out detailed simulation of the installation sequence and lifting program of PC components helps to select the appropriate tower crane equipment, avoid the cost of secondary lifting, and improve economic efficiency.

(3) Construction site management level. At present, many engineering projects in China are still deficient in construction management and have not yet reached the standard of refined management. In order to solve this problem, the construction and installation units need to build a standardized management system according to their own specific conditions, select and send managers with rich experience and high level of professional knowledge, to ensure that the site of the good collaboration between the collaborative units, so as to achieve the construction site management of cost reduction and efficiency.

(4) Construction unit installation process level. Compared with the use of other construction materials, assembly concrete buildings have higher standards for the quality and strength of prefabricated components and their connectors during installation and construction. Especially the node installation of prefabricated components, as the core and potential weak point in the whole installation process, puts forward strict requirements for the installation process, selection of materials and workers' operating skills to ensure that the connection nodes of prefabricated components meet the technical specifications to ensure the solidity and safety of the structure. Reasonable construction technology can not only significantly reduce the need for rework caused by technical operation errors, but also effectively control construction costs.

(5) Technical level of construction personnel. Practice shows that the combination of prefabricated component construction mode and traditional construction mode requires experienced on-site managers to ensure the orderly operation of the construction phase of the project. Experienced project managers should have forward-looking thinking, be able to identify and assess unknown risks in advance, and take effective preventive and solution measures in time. In addition, cross operation is common in assembly building construction sites, and the ability to collaborate between various trades and the proficiency of prefabricated components installation operation directly affects the quality of installation[6]. Good collaborative ability not only ensures the schedule, but also efficiently completes the project, saves machinery rental costs and labor costs, and further optimizes costs.

3.5   Other Factors

(1) Project information technology level. By integrating the concepts of BIM technology, RFID technology and smart site, it is possible to realize dynamic construction management of the building construction process. In the design stage, BIM technology is utilized for virtual construction simulation to detect potential collisions between prefabricated components and immediately make the necessary adjustments, thus effectively avoiding cost increases and schedule delays triggered by design changes in later construction. This approach not only improves the overall efficiency of the project, but also enhances cost control[7]. In the construction process, the combined use of BIM technology and RFID chips, with the help of parametric information management platform of components, can quickly convey the warning information to the technicians, and realize effective man-machine calibration[8]. This method not only supports real-time tracking of component location information, but also saves project costs.

(2) Government support. Although some progress has been made in the development of assembled buildings under the active promotion of national and local government policies, their market share is still less than that of traditional cast-in-place buildings, and they still face the challenge of high costs[9]. To meet these challenges, policy support at the government level should be strengthened by adopting a variety of incentives, including financial subsidies, tax exemptions and reductions, facilitation of land use approvals, and collaborative innovation between industry, academia, and research institutes, to optimize the balance between supply and demand in each region, expand the downstream industrial chain, and ultimately achieve effective control of project costs[10].

(3) Degree of industry standardization. Uniform industry standards are essential to promote the application of PC components, and the rich variety of PC components is often accompanied by an increase in cost. Therefore, there is an urgent need to develop and implement uniform industry standards, by reducing the variety of PC components to improve the turnover rate and versatility of the mold, thereby significantly improving production efficiency and standardized production capacity. In addition, the adoption of standardized PC components can optimize the workflow at all stages, improve the management efficiency and level of the construction site, and reduce the cost of assembled building construction.

(4) Maturity of local assembly building. In Yunnan Province, due to the limitations of geographic environment and seismic intensity, the assembly building technology system is not yet fully mature. On the basis of improving the industry norms and standards, the relevant departments should combine the local actual situation and prepare corresponding standard atlases and manuals according to different types of structural systems of assembled concrete buildings. At the same time, a modulus coordination mechanism should be established to enhance the interchangeability and circulation among PC components and parts and components, and promote integrated production. By applying new technical specifications in pilot demonstration projects and gradually introducing them to the market, a comprehensive, standardized, serialized and complementary technical standard system is constructed, which effectively improves the maturity of local assembled buildings.

(5) Degree of industry chain completeness. At present, China has not formed a complete set of standard system in the development of the assembly building industry chain, which to a certain extent restricts the rapid development of the industry and the standardization process. The industrial chain is not perfect enough, and all parties lack a collaborative processing mechanism, which at the same time restricts the development of assembly building and its cost control[11]. Although the combination of EPC mode and assembly building helps to reduce costs, it does not completely solve the problems caused by the incomplete industrial chain. Therefore, enhancing the depth of cooperation between upstream and downstream enterprises and promoting the synergistic development of each participant in R&D, design, production, construction, operation and maintenance is of positive significance for enhancing the scale effect and cost control of PC component production and assembled concrete buildings.

4   Construction of Cost Influence Factor Indicator System and Data Analysis

4.1   Constructing a System of Indicators of Cost Influencing Factors

By summarizing and analyzing the literature related to assembly building cost, as well as interviewing experts and scholars in the field of assembly building, the evaluation index system of assembly building cost influencing factors is constructed, which is shown in Table 1.

Table 1. Statistics of cost influencing factors of assembled buildings under EPC mode

No.	Category	Code	Influencing Factors
1		A1	Depth of design scheme
2		A2	Level of component integration
3	Design Factors (A)	A3	Degree of component standardization
4		A4	Prefabrication rate and assembly rate
5		A5	Rationality of component splitting design
6		B1	Mechanization level and production efficiency of component manufacturing
7		B2	Mold turnover rate
8	Production Factors (B)	B3	Component production scale
9		B4	Component production process level
10		B5	Market price fluctuations of raw materials
11		B6	Temporary storage cost of components
12		C1	Rationality of transportation plan
13	Transportation Factors (C)	C2	Component protection measures during transportation
14		C3	Rationality of loading scheme
15		C4	Transportation distance of components
16		D1	Mechanization level of construction site
17	Construction & Installation Factors (D)	D2	Rationality of construction organization design
18		D3	Management level of construction site
19		D4	Installation process level of contractors
20		D5	Technical skill level of construction personnel
21		E1	Information technology level of the project
22		E2	Government support intensity
23	Other Factors (E)	E3	Industry standardization degree
24		E4	Maturity of prefabricated construction in local market
25		E5	Completeness of industrial chain

4.2   Data Analysis

The questionnaire of this study consists of three parts: the basic information of the respondents, the question and answer on the importance of the cost impact factors of assembly buildings under the EPC model, and the evaluation index of the cost impact factors of assembly buildings under the EPC model. When evaluating the importance of specific cost influencing factors, the degree of influence of the influencing factors on the cost is set up as a 5-level scale from "very large" to "very small", which is convenient for data analysis at a later stage.

The questionnaires for this study were distributed with consideration of the validity of the data and data quality at a later stage, and were mainly focused on the managers of all relevant units, frontline staff, and scholars and experts who have been engaged in EPC mode projects or assembly building projects. The questionnaires for this study were mainly distributed through the Questionnaire Star platform, and as of October 2024, a total of 437 questionnaires were collected online and offline combined. By organizing these questionnaires and eliminating invalid questionnaires with hasty answers, too short answer time, obvious lack of understanding of the response content, unclear scoring or obvious irrationalities, 351 valid questionnaires were finally obtained, with an effective rate of 80.3%.

Confidence testing is a key method for assessing the reliability and stability of a structure, based on the accuracy and persuasiveness of the data. The most commonly used reliability test today is the "Cronbach's alpha" coefficient method. This method measures the reliability of a questionnaire or scale by calculating the internal consistency. Equation (1) shows how the Cronbach's alpha coefficient is calculated.

$$\alpha = \frac{k}{k-1} \times \left(1 - \frac{\sum_{k=1}^{k} \delta_i^2}{\delta_x^2} \right) \tag{1}$$

Where: k - number of test question items;

δ_i -Observed sample variance;

δ_x - total sample variance.

In this study, the reliability of the questionnaire data was analyzed using SPSS software to assess the reliability of the data from this questionnaire. The results of data analysis showed that the overall Cronbach's alpha (α) coefficient of the current questionnaire was 0.804, which indicated that the overall data had high reliability and was suitable for subsequent testing and analysis. Among them, the reliability coefficient (Cronbach's α) of the design factor is 0.937, the reliability coefficient (Cronbach's α) of the production factor is 0.882, the reliability coefficient (Cronbach's α) of the transportation factor is 0.820, and the installation and construction reliability coefficient (Cronbach's α) was 0.872, and other factors reliability coefficient (Cronbach's α) was 0.951.

The data validity analysis revealed that the KMO values of each latent variable exceeded 0.7, and the overall KMO value was likewise higher than 0.7. In addition, the Bartlett's test of sphericity showed that the P-value was less than 0.001, which confirmed the existence of a significant correlation between the variables in the questionnaire data, which in turn verified its suitability for factor analysis.

The computational analysis revealed that the eigenvalues of the first five principal components were greater than 1, and their cumulative variance contribution ratio was 72.407%, which was higher than the minimum criterion of 60%, indicating that the five components proposed in identifying the factors affecting the costs were reasonable. In addition, the rotated component matrix showed that all factor loadings were above 0.7, a result that indicates that the structural validity met the expected criteria.

5   Structural Equation Modeling of Cost Influencing Factors

It can be seen through the data reliability and validity analysis that the indicators basically meet the requirements and can be analyzed by structural equation modeling. Substituting the data into AMOS, the first simulation is shown in Figure 1.
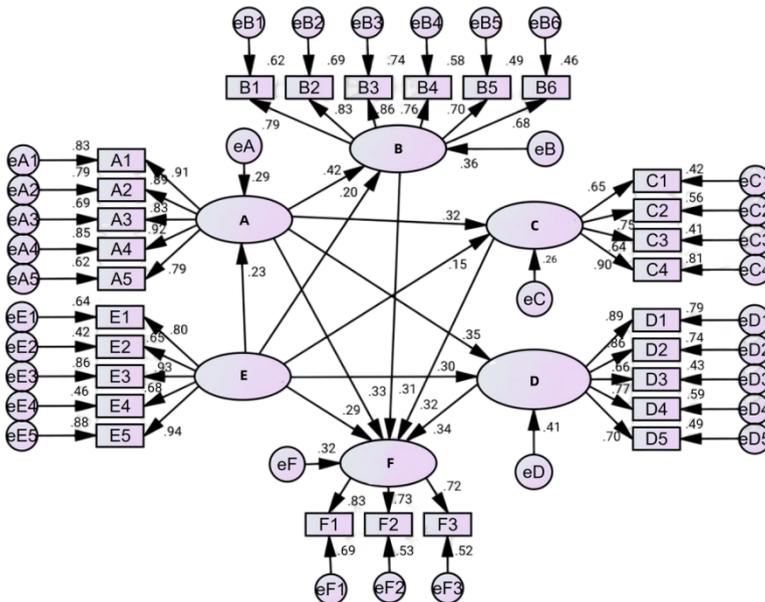

Fig. 1. Validated factor analysis model for initial structural equations

After the first simulation, it was found that the fitting index RMSEA value was 0. 069, AGFI value was 0.877, the chi-square to degrees of freedom ratio was 2.653, GFI value was 0.843, which did not reach the standard fitting value, so the model was considered to be further corrected. The model was corrected several times by the MI

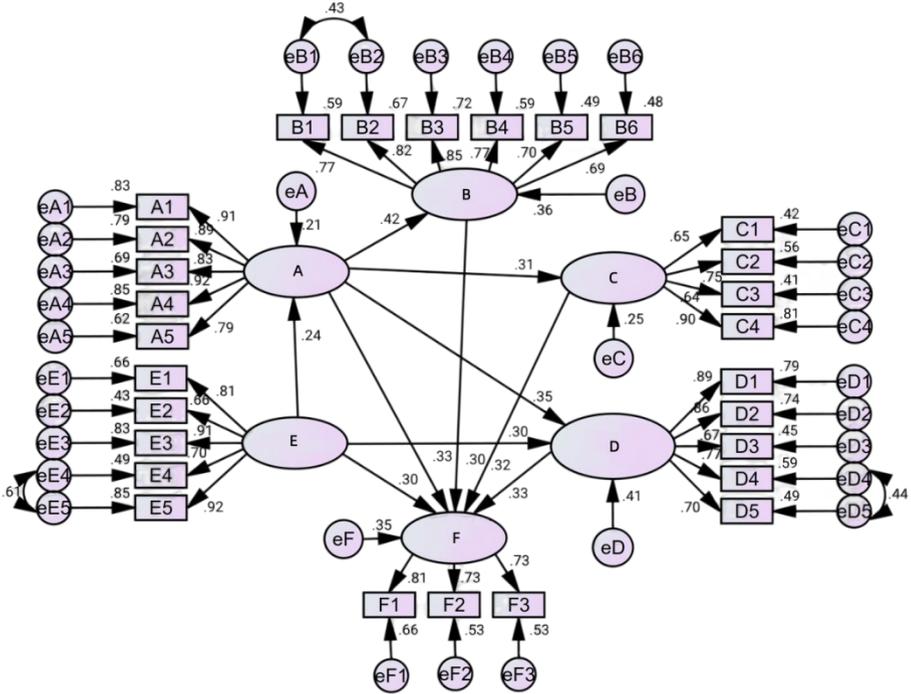value, and the indicators basically reached the fitting standard, and the fitted model is shown in Figure 2.

Fig. 2. Modified structural equation model

The parameter estimates of the factors influencing the cost of assembled buildings are shown in Table 2.

Table 2. Structural equation modeling factor loads

			Esti-mate	S.E.	C.R.	P	Stand-ardized Estimate
Design Factor A	<---	Other Factor E	0.246	0.087	2.834	***	0.236
Production Factor B	<---	Design Factor A	0.419	0.084	5.534	***	0.421
Transportation Factor C	<---	Design Factor A	0.312	0.096	4.892	***	0.309
Construction Factor D	<---	Design Factor A	0.339	0.084	5.919	***	0.354
Construction	<---	Other Factor E	0.326	0.092	4.712	***	0.301

			Esti-mate	S.E.	C.R.	P	Stand-ardized Estimate
Factor D							
Cost Control Effect F	<---	Design Factor A	0.352	0.086	5.541	***	0.331
Cost Control Effect F	<---	Production Factor B	0.327	0.092	4.985	***	0.305
Cost Control Effect F	<---	Transportation Factor C	0.334	0.072	5.248	***	0.322
Cost Control Effect F	<---	Construction Factor D	0.346	0.074	5.376	***	0.329
Cost Control Effect F	<---	Other Factor E	0.321	0.078	4.268	***	0.296
A5	<---	Design Factor A	1.167	0.087	13.397	***	0.794
A4	<---	Design Factor A	0.986	0.034	28.817	***	0.919
A3	<---	Design Factor A	0.933	0.043	21.616	***	0.833
A2	<---	Design Factor A	.986	.035	28.111	***	0.894
A1	<---	Design Factor A	1.000				0.911
B1	<---	Production Factor B	1.000				0.773
B2	<---	Production Factor B	1.188	0.074	14.451	***	0.816
B3	<---	Production Factor B	0.843	0.032	18.633	***	0.855
B4	<---	Production Factor B	1.013	0.081	10.934	***	0.769
B5	<---	Production Factor B	0.722	0.072	9.645	***	0.701
B6	<---	Production Factor B	0.905	0.074	9.521	***	0.688
C1	<---	Transportation Factor C	1.000				0.653
C2	<---	Transportation Factor C	1.363	0.132	10.502	***	0.747
C3	<---	Transportation Factor C	0.813	0.082	9.284	***	0.643
C4	<---	Transportation Factor C	1.044	0.04	25.859	***	0.896
D1	<---	Construction Factor D	1.000				0.893
D2	<---	Construction Factor D	0.883	0.071	12.571	***	0.857
D3	<---	Construction Factor D	0.617	0.055	14.683	***	0.672

			Esti-mate	S.E.	C.R.	P	Stand-ardized Estimate
D4	<---	Construction Factor D	1.134	0.099	11.225	***	0.771
D5	<---	Construction Factor D	1.089	0.089	11.597	***	0.703
E5	<---	Other Factor E	1.005	0.032	29.489	***	0.922
E4	<---	Other Factor E	0.993	0.074	12.078	***	0.699
E3	<---	Other Factor E	1.049	0.033	27.655	***	0.915
E2	<---	Other Factor E	0.996	0.068	10.301	***	0.657
E1	<---	Other Factor E	1.000				0.813
F3	<---	Cost Control Effect F	0.922	0.091	11.553	***	0.727
F2	<---	Cost Control Effect F	0.946	0.093	11.688	***	0.734
F1	<---	Cost Control Effect F	1.000				0.812

As can be seen from Table 3, we found that the factors that most affect the cost of assembled buildings are design factors, followed by other factors, installation and construction factors, transportation factors, and production factors[12].

Table 3. Weights of Primary and Secondary Indicators for Cost Influencing Factors of Prefabricated Buildings

Primary Indicators (Criterion Layer)	Weight	Secondary Indicators (Factor Layer)	Weight
Design Factors (A)	0.3447	A1 Depth of design scheme	0.2094
		A2 Level of component integration	0.2055
		A3 Degree of component standardization	0.1914
		A4 Prefabrication rate and assembly rate	0.2112
		A5 Rationality of component splitting design	0.1825
Production Factors (B)	0.0977	B1 Mechanization level and production efficiency	0.1680
		B2 Mold turnover rate	0.1773
		B3 Component production scale	0.1858
		B4 Component production process level	0.1671
		B5 Market price fluctuations of raw materials	0.1523
		B6 Temporary storage cost of components	0.1495
Transportation Factors (C)	0.1454	C1 Rationality of transportation plan	0.2222
		C2 Component protection measures during transportation	0.2542
		C3 Rationality of loading scheme	0.2188

Primary Indicators (Criterion Layer)	Weight	Secondary Indicators (Factor Layer)	Weight
		C4 Transportation distance of components	0.3049
		D1 Mechanization level of construction site	0.2292
		D2 Rationality of construction organization design	0.2200
Construction Factors (D)	0.1485	D3 Management level of construction site	0.1725
		D4 Installation process level of contractors	0.1979
		D5 Technical skill level of construction personnel	0.1804
		E1 Information technology level of the project	0.2030
		E2 Government support intensity	0.1640
Other Factors (E)	0.2637	E3 Industry standardization degree	0.2284
		E4 Maturity of prefabricated construction in local market	0.1745
		E5 Completeness of industrial chain	0.2302

6   Conclusion

In this paper, from the perspective of general contracting in EPC mode, we sorted out 5 dimensions and collated 25 factors that have an impact on the cost of assembled buildings, and accordingly constructed the SEM model of the cost impact factors of assembled buildings, researched and analyzed the path relationship between the impact factors, and verified that all the impact factors have a positive impact on the cost, and the degree of impact, from largest to smallest, is as follows: the design factor, the other factors, Installation and construction factors, transportation factors and production factors, of which the observed variables with the greatest influence on the cost of each potential variable are, in descending order: the degree of industrial chain completeness, the assembly rate and prefabrication rate, the degree of mechanization of the construction site, the distance of transportation of the components, and the scale of production of the components. The weights of the influencing factors were calculated by combining the path coefficients and correlations of the structural equation model, which provides some reference value for the subsequent control of assembly building costs.

Reference

1. CHEN Hong, ZHAO Lei. Research on the influence mechanism of industrialized production of assembly building on cost[J]. Journal of Civil Engineering and Management, 2019, 36(2): 112-118.
2. WANG Jianguo, LI Zhiqiang. Critical path analysis of assembly building cost control under EPC mode[J]. Construction Economy, 2021, 42(5): 45-51.

3. LIU Yang, WANG Peng. Impact of prefabricated components standardization on assembly building cost[J]. Progress in Building Steel Structure, 2020, 22(6): 89-95.
4. Chen L, Wang Y. Cost Drivers of Prefabricated Construction under EPC Mode: A Case Study in China[J]. Journal of Cleaner Production, 2021, 298: 126753.
5. XU Qiang, SUN Li. Research on optimization model of assembly building logistics transportation cost[J]. Logistics Technology, 2022, 41(1): 56-61.
6. Liu H, et al. Structural Equation Modeling for Evaluating Critical Factors in Prefabricated Housing Cost Management[J]. Engineering, Construction and Architectural Management, 2021, 28(9): 2567-2586.
7. LI Ming, ZHOU Tao. Optimization research on collaborative design of assembly building based on BIM[J]. Construction Technology, 2021, 50(8): 34-40.
8. Zhao S, et al. BIM-Based Optimization of Prefabricated Component Splitting Design for Cost Reduction[J]. Automation in Construction, 2022, 136: 104189.
9. Li X, Zhang Q. Impact of Government Incentives on the Adoption of Prefabricated Buildings: Evidence from China[J]. Sustainability, 2020, 12(18): 7563.
10. Huang M, Wu H. Analysis of driving effect of policy support on assembly building development[J]. Building Science, 2022, 38(4): 63-69.
11. ZHOU Jie, YANG Fan. Empirical study of industry chain synergy on assembly building cost control[J]. Systems Engineering Theory and Practice, 2019, 39(7): 1785-1793.
12. ZHANG Wei, LIU Xiaoming. Research on cost influencing factors of construction project based on structural equation modeling[J]. Journal of Engineering Management, 2020, 34(3): 78-84.