Research on the Influencing Factors of Cost Management of EPC Old Neighborhood Renovation Project Based on DEMATEL-AISM Approach

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Abstract. At present, China is actively promoting the old neighborhood renovation project, and the introduction of EPC mode has significantly improved the efficiency of project execution. However, general contractors face higher risks under this model, so it is particularly important to strengthen project cost management. Based on the synthesis of existing academic results and the com-bination of questionnaire surveys and expert interviews, this study systematically identifies 16 key factors affecting the cost management of old neighbor-hood renovation projects under the EPC model. Through the DEMATEL-AISM method, the paths of these factors in cost management are visually revealed, and the interactions and logical relationships among the fac-tors are deeply analyzed. Based on this, this study puts forward suggestions such as improving the cost management mechanism, strictly controlling engineering changes, and strengthening communication, aiming to provide scientific references for general contractors in order to optimize the allocation of re-sources and improve the economic efficiency of the project.

Keywords: renovation of old neighborhoods; cost management; EPC model; DEMATEL-AISM

1 Introduction

In March 2021, the Outline of the Fourteenth Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Vision 2035 pro-posed to “accelerate the promotion of urban renewal, renovate and upgrade the functions of old neighborhoods and other stock areas”, and the renovation of old neighborhoods has an important role to play during the Fourteenth Five-Year Plan period. The transformation of old neighborhoods will play an important role in the “14th Five-Year Plan” period[1]. The transformation of old neighborhoods has begun across the country and has accumulated some experience and results[2]. At the same times, the EPC model, as a highly integrated project management model that assigns the whole process of design, procurement, and construction to the general contractor has the advantages of reducing costs and speeding up construction, and has been

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widely used in old neighborhood renovation projects in recent years[3]. At the same time, the EPC model not only completes projects efficiently, but also promotes area-linked renovation[4]. However, unlike new construction projects, old neighborhood renovation projects face many challenges in cost management under the EPC model due to the characteristics of outdated infrastructure, complex construction environments, and diverse needs of residents.

At present, a number of scholars have carried out relevant research on the cost management of old neighborhood renovation projects. According to Zhong Yunfeng[5] and Zheng Huichun[6], poor construction organization design, insufficient personnel quality, lax onsite management, poor communication with residents, and engineering changes are the main difficulties in cost management of old district renovation projects. From the perspective of the construction unit, Zhu Xiansheng[7] pointed out that the adjustment of residents' rights and interests, the impact of construction on residents' lives, and the inexperience of the participating units are the typical cost management difficulties of the old neighborhood renovation projects. Zeng Fanzhang summarized the advantages of the EPC model in improving the efficiency of renovation, and concluded that the determination of the design scheme, the accuracy of the budget, the market price and coordination during the procurement phase, the teamwork and construction technology during the construction phase are the factors affecting the cost changes. Meng Yuan[8] analyzes the comprehensive influence degree of each factor by AHP-DEMATEL method, studies its causal relationship, and clarifies the key factors affecting the cost management of the renovation projects in old neighborhoods.

In summary, academic research on the cost management of renovation in older neighborhoods lacks comprehensiveness and systematicity, and fails to reveal the hierarchical structure and internal logic among factors. Although scholars have used methods such as hierarchical analysis (AHP), explanatory structural modeling (ISM), structural equation modeling (SEM), and DEMATEL to analyze the coupling relationship between factors, they have paid insufficient attention to the ways and methods of problem formation and have limited guidance. Under the EPC model, costs are affected by a variety of complex factors, and it is necessary to systematically sort out their interconnections, identify the key influencing factors and formulate control measures. DEMATEL method helps identify and analyze the causal relationships among cost management factors, while AISM constructs a hierarchical structure among factors and reveals the internal logic. This combination fills the gap of previous studies and provides a new perspective to understand and manage cost control issues in old neighborhood improvement projects. Through literature review and questionnaire survey, this paper combines DEMATEL and AISM to construct a directed topology hierarchy diagram to deeply analyze the key cost influencing factors and provide theoretical support and management reference for general contractors.

2 Impact Factor Identification

In order to select the key factors for cost management of old neighborhood renovation under EPC mode, this paper combed 27 cost influencing factors through literature and research. It is refined and integrated into 16 by the research team and experts, and is divided into two target layers of internal (project management, design control, construction control, procurement capability) and external factors from the perspective of EPC general contractor, as shown in Table 1.

Table 1. System of indicators of impact factors

Dimensioning		influencing factor
Project management capacity	F1	Contract management
	F2	Cost control and management mechanisms
	F3	Teamwork and communication coordination
Design Control Capability	F4	Pre-design preparation
	F5	Quality of design
	F6	Designer capacity
Construction control capability	F7	Construction technology
	F8	Construction manager capacity
	F9	construction safety
	F10	Engineering Changes
Procurement capacity	F11	Supplier Selection
	F12	Procurement program and inventory management
Other external factors	F13	Market price volatility and trends
	F14	Policies and regulations
	F15	Integrated capacity and needs of construction units
	F16	Construction site conditions and constraints

3 DEMATEL-AISM Modeling of Impact Factors

DEMATEL is a method for analyzing the location of system elements and their interactions through graph theory and matrix tools. The method evaluates the importance and interactions of influencing factors by calculating the centrality and causality of each factor, while ISM constructs the adjacency and reachability matrices of influencing factors, and presents the causal relationships between influencing factors in a clear and intuitive ladder structure diagram based on graph theory, which is suitable for analyzing system problems with many variables and complex and ambiguous structures. AISM introduces the idea of adversarial game on the basis of ISM, and at the same time considers the two oppositely oriented hierarchical extraction methods of result-cause, and finally demonstrates the influencing relationship and hierarchical structure of factors through a set of adversarial hierarchical topology diagrams.

In view of the complexity and variability of the influencing factors of the cost management of the renovation of old neighborhoods under the EPC mode, this study utilizes the model constructed by the coupling of DEMATEL and AISM to systematically analyze the interconnection of these influencing factors and their causal relationships. First, on the basis of identifying the main influencing factors of the cost management of the renovation of old neighborhoods under the EPC mode, the DEMATEL[9] method is applied to construct the direct influence matrix and the comprehensive influence matrix, and the centrality and causality of the factors are calculated, so as to quantify the intensity of the influence between the factors and their causal relationships. Then, the AISM[10] method is used to calculate the reachability matrix and construct the hierarchical structure diagram to visualize the hierarchical relationship of these influencing factors. The framework of the model is shown in Fig.1.

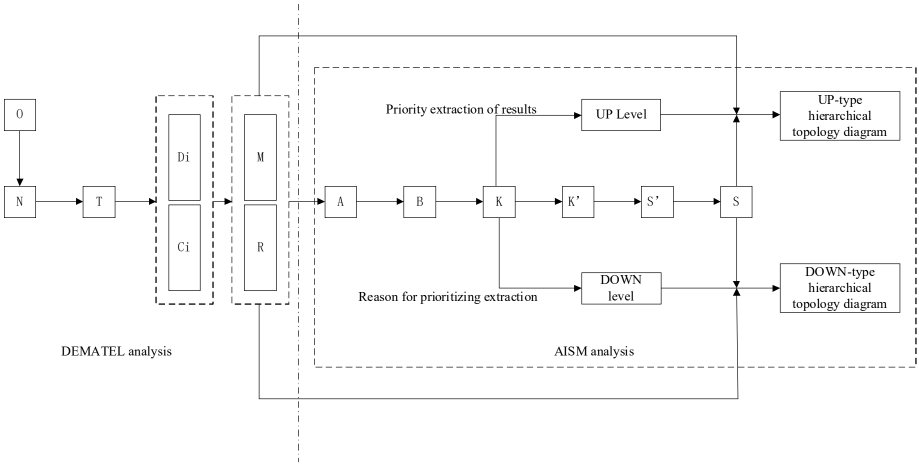
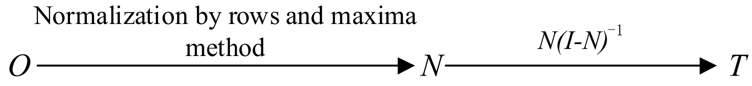


Fig. 1. Model framework diagram

where O is the direct influence matrix; N is the normalization matrix; T is the combined influence matrix; A is the relation matrix; B is the multiplication matrix; K is the reachability matrix; K' is the reduced-point reachability matrix; S' is the skeleton matrix; and S is the general skeleton matrix. Di is the degree of influence; Ci is the degree of being influenced; M is the degree of centrality; and R is the degree of cause.

3.1 Construction of the DEMATEL Integrated Impact Matrix

Based on the 16 influencing factors screened out above, the study quantifies and scores the mutual influencing relationship between the factors through a questionnaire survey of a total of 12 experts, including builders' personnel, construction personnel, designers, and relevant researchers from universities in the field of old neighborhood renovation. The scoring was done on a 0-4 scale (0 no influence, 1 small influence, 2 average influence, 3 strong influence, 4 strong influence), and by processing and summarizing the data collected from the experts' scores, the mean value of the relationship of each quantified factor in the scoring table was calculated to form a 16 × 16 data square matrix, i.e., the direct influence matrix O. Subsequently, the direct influence matrix O was calculated step by step according to the process shown in Fig.2 to obtain the normalized canonical impact matrix N and the integrated impact matrix T after the normalization process.



Note: I is the unit matrix

Fig. 2. The process of constructing a comprehensive impact matrix

3.2 Calculate the Degree of Centrality and the Degree of Cause

The degree of influence Di refers to the sum of the values of each row of the matrix of T, the degree of influenced Ci refers to the sum of the values of each column of T, the centrality Mi is the sum of the degree of influence and the degree of influenced, and the degree of cause Ri is the difference between the degree of influence and the degree of influenced Plotting the Centrality -causality coordinates for each factor shown in Fig. 3.

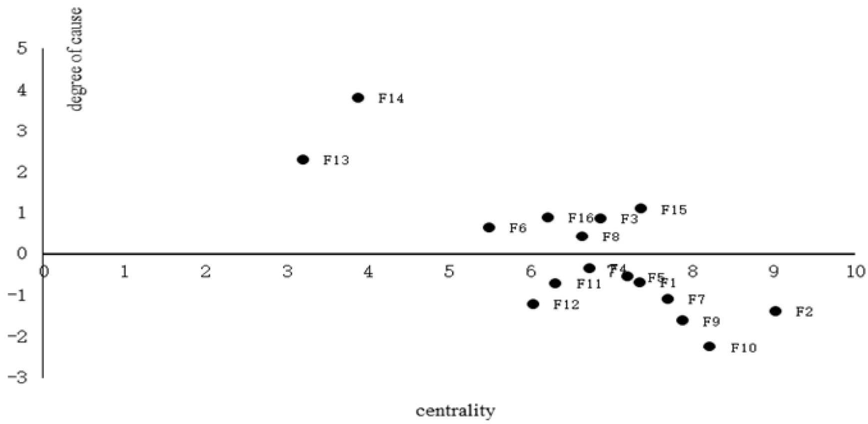


Fig. 3. Centrality-causality coordinates for each factor

3.3 Matrix Calculation and Hierarchical Extraction

The adjacency matrix A, the multiplication matrix B, the reachability matrix K, and the general skeleton matrix S are sequentially computed on the basis of the integrated in-fluence matrix T according to the process shown in Fig. 4.

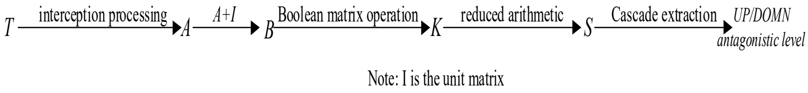


Fig. 4. Process of matrix calculation and hierarchical extraction

where, the intercept treatment introduces the intercept λ, λ=α+b, α is the mean of all factors in T, and b is the standard deviation of all factors in T. The results of the antagonistic hierarchical extraction results are as follows.

Table 2. Adversarial cascade extraction results

level	Results-first-UP type	Cause Priority - DOWN type
L1	F9, F10, F12, F13	F9, F10, F12
L2	F2, F6, F7	F2, F7
L3	F1, F5, F8, F11, F16	F8
L4	F4, F14	F1, F4, F5, F6, F11
L5	F3, F15	F3, F13, F14, F15, F16

3.4 Mapping the Topology Hierarchy

Based on the final confrontation hierarchy classification results in Table 2 and the skeleton matrix S, incorporating the centrality and causality ranking results, a topo-logical hierarchy map is drawn.

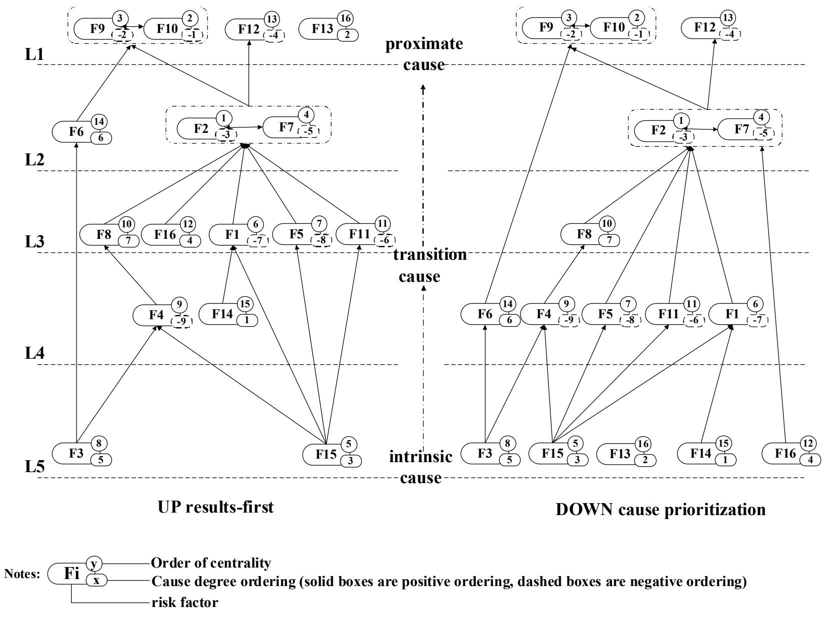


Fig. 5. Adversarial directed topology hierarchy diagram

4 Model Analysis

4.1 Loop Analysis

In the multilevel recursive order structure diagram, the directed arrow line indicates causality, and the bidirectional arrow line is a loop, indicating that the factors closely interact with each other. Fig.5 shows that there are 2 groups of circuits in the system of cost influencing factors in old neighborhoods: {F9, F10}, {F2, F7}, and for these groups of circuits the general contractor can adopt an integrated management approach in order to improve management efficiency.

4.2 Hierarchical and Causal Full Series Analysis

As can be seen from Fig.5, the cost influencing factors of the old neighborhood renovation project under the EPC model form a directed recursive order structure with five layers and three strata. The system can be divided into three strata: the bottom layer (L5) is the essential causal order, the middle L2-L4 is the transitional causal order, and the top layer (L1) is the proximate causal order. A lower stratum implies a stronger role as a cause; a higher stratum implies a stronger influence as an effect.

The intrinsic causal order consists of the bottom factors excluding the isolated factor F13, including F3, F15, F14, and F16, which are the main causal factors of the cost of the old neighborhood renovation project under the EPC mode. Therefore, in order to effectively control project costs, general contractors need to prioritize teamwork and communication, the conditions and constraints of the project construction site, and keep abreast of the needs of the construction unit as well as relevant policies and regulations. The proximity causation order contains top-level factors F9, F10, F12, which are fac-tors that directly affect project costs. If you want to control the project cost quickly, you can start from these factors to manage. However, because they are easily influenced by the antecedent factors, they need to be managed by simultaneously considering the regulation of the antecedent factors, or minimizing their connection with the antecedent factors. The transitional causal order is located in the middle layer and acts as a vector and may become a new source of influence. Therefore, it is critical to manage the transitional causal order, especially high centrality factors such as F2 and F7, and high causality factors such as F6 and F8. In addition, it may be difficult for the prime con-tractor to directly control some of the intrinsic causal order factors, such as F14 and F16; however, by adjusting the controllable transitional causal order factors (F2), the impacts of these unfavorable factors can be indirectly mitigated, resulting in more efficient cost Management.

4.3 Comparative Analysis of the Results of the DEMATEL and AISM Methods

Fig.5 shows that there is no significant correlation between the centrality of factors calculated by the DEMATEL method and the tiers classified by the AISM method. The centrality degree, which is the sum of the factor influence degree and the influenced degree, leads to a weak correlation with the hierarchical structure model because it has both attributes. In contrast, in Fig.5, the cause degree shows a significant correlation with the results of the tier division. Overall, the larger the positive cause degree, the lower the hierarchy of the factor and the stronger its cause attribute; the larger the absolute value of the negative cause degree, the higher the hierarchy of the factor, indicating a stronger result attribute. It also shows that the cause-result properties of the factors derived from the two methods can be corroborated, calibrated and interpreted with each other.

5 Recommendations and Measures

This study focuses on the cost management of old neighborhood renovation projects under the EPC model, and uses the DEMATEL-AISM model for in-depth analysis to identify and quantify the key cost management elements, and then proposes corresponding optimization strategies. The following are the main findings and discussions based on the cost management challenges of old neighborhood renovation projects presented in the opening section of this paper:(1) Improvement of project management capability: the research results show that project management capability is a key factor affecting cost management. In view of the widespread problem of management inexperience in old neighborhood renovation projects, it is recommended that the general contractor establish a sound cost management system, implement refined management, and clarify the responsibilities and authorities of each responsible body in order to strengthen the systematic and standardized nature of project management. By strengthening communication and coordination, cost overruns caused by improper management can be effectively reduced. (2) Strengthening of design control ability: design control directly affects the cost prediction and control of the project. In order to cope with the problem of frequent design changes in the renovation projects of old districts, it is recommended to strengthen the cost control in the design stage, and reduce the cost fluctuations caused by design changes through refined design management and program optimization. This will help identify and avoid potential cost risks in advance, thus ensuring the smooth execution of the project according to the budget. (3) Optimization of construction control ability: Construction control plays an important role in cost management. To address the challenges of cost control in the construction process, it is recommended to implement strict construction cost monitoring and quality control measures, and to optimize the construction process and improve efficiency to reduce construction costs, reduce waste and rework, and thus improve the cost-effectiveness of the project. (4) Enhancement of purchasing ability: The influence of purchasing ability on project cost is equally significant. Facing the challenges of material procurement and supply chain management in the old district renovation project, it is recommended to optimize the procurement process, select cost-effective suppliers, and implement centralized purchasing to reduce costs, so as to effectively control the project material costs and enhance competitiveness. (5) Response to external factors: The external environmental factors of the project, such as policy changes and market fluctuations, also have an important impact on cost management. In order to avoid the cost risks brought by these uncontrollable factors, it is recommended to establish a flexible response mechanism, combined with policy analysis and market research, and make a good risk plan, so as to mitigate the negative impact of changes in the external environment on project costs.

6 Conclusions

This study focuses on the cost management of old residential area renovation projects under the EPC model, systematically identifies and quantifies the key factors affecting the cost management effectiveness, and proposes optimization suggestions. It is found that project management capability, design control and construction control capability are the core factors influencing cost management, while procurement capability and external factors also have a significant impact on cost control effectiveness. Based on this, this paper proposes a series of improvement measures, such as strengthening the cost management system, promoting refined management, strictly controlling the cost of engineering changes, and strengthening the communication and cooperation among project stakeholders. The study provides theoretical support and expands the perspectives of subsequent studies on the transformation of old residential areas under the EPC model. However, there are limitations in this study, as the data are mainly derived from the literature review and questionnaire survey, which may have sample selection bias, and the feedback rate and coverage of the survey may affect the generalizability of the results. Future research can further explore the specific mechanism of each factor to provide more precise guidance for cost management.

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