Study on Factors Affecting the Progress of Engineering Projects under the EPC Model

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Abstract: This paper studies the factors affecting the progress of engineering projects under the EPC model. By establishing a hierarchical comparison matrix and collecting respondents' ratings on the importance of these factors through a questionnaire survey, the data was analyzed and summarised using the Analytic Hierarchy Process (AHP). The study identified the key factors influencing progress management by the general contractor in EPC projects. Project participants can focus their efforts and resources on managing these key factors to more effectively manage construction progress, shorten project duration, improve management efficiency, and reduce social burdens and resource waste.

1. Introduction

EPC is a widely adopted management mode in international engineering contracting, actively promoted by China for its effective investment control and shortened construction cycles[1]. Despite various policy documents encouraging its use, recent engineering practices reveal challenges. Project delays due to progress disputes often negate the advantages of the EPC model, affecting project advancement. EPC projects typically involve large-scale construction, advanced technology, and complex processes. Owners aim to shorten construction periods through coordinated design-procurement-construction links, but changes in any project factors can impact the schedule[2]. This research identifies key risk factors affecting EPC project schedules and provides insights for managing these factors, contributing to both academic research and practical project schedule management.

2. Analytical hierarchy process

Analytical Hierarchy Process is a research method combining qualitative and quantitative by combining the subjective opinion of experts with the objective matrix calculation, first organizing and optimizing the factors influencing the progress of the project under the EPC mode into a hierarchical system and then carrying out the weight calculation of the factors influencing the progress through the matrix, and then the general contractors can take the corresponding measures according to the weights of the factors to control the progress of the project efficiently [3].

The process of constructing a model using the Analytic Hierarchy Process (AHP) generally involves the following four steps:

1. Establish the hierarchical structure model.

2. Construct the judgment matrix (the pairwise comparison matrix).

3. Perform hierarchical ranking and consistency checks.

4. Conduct the overall hierarchical ranking and consistency check.

3. Identification and determination of Schedule-Influencing factors

Using databases such as Scopus, Web of Science, and CNKI, we searched for keywords like "schedule influencing factors," "EPC schedule influencing factors," and "EPC schedule risks," retrieving 208 relevant papers from the past ten years. To ensure high relevance, it does not appear to modify the subject 23 papers. The literature review revealed multiple dimensions for studying schedule-influencing factors in EPC projects. We identified 32 key factors across five categories: technical, managerial, organizational, environmental, and resource-based[4].

To focus on core issues, we conducted semi-structured interviews with four industry experts[5]. Their input refined the factors, removing redundancies and weak influences. Based on these expert recommendations, the initial 32 factors were narrowed down to 24 representative ones, as shown in Table 1.

Table 1. Evaluation Index System for Factors Affecting Project Progress under the EPC Model

Target Layers A	Standardized Layer B	Indicator Layer C
Influencing factors of	Technical B$_1$	Accuracy of survey results C$_1$
		Degree of sophistication of design documents C$_2$

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project schedule under EPC mode		
		The complexity of whole process construction techniques C_3
		Maturity of the application of new technologies, processes, and materials C_4
	Management B_2	Level of experience of managers throughout the process C_5
		Degree of sophistication in management system development C_6
		Strength of implementation of the management system C_7
		Degree in quality and cost management of project C_8
		Rationalization of progress target planning C_9
	Organization B_3	Rationalization of the organizational structure C_{10}
		Rationalization of management staffing throughout the process C_{11}
		Communication and coordination among project participants C_{12}
		Degree of coordination in the cross-cutting implementation of phases C_{13}
		Rationalization of equipment configuration C_{14}
	Condition B_4	Engineering Geology C_{15}
		Regional cultural differences C_{16}
		Unpredictable site conditions C_{17}
		Adjustment of relevant policies, laws, and procedures C_{18}
		Level of government intervention and support C_{19}
		Economic forms and capacity to supply construction funds C_{20}
	Resource $B5$	Quality of materials and equipment C_{21}
		Timeliness of delivery of materials and equipment C_{22}
		Inadequate selection of material and equipment suppliers C_{23}
		Labor crew staffing and quality of personnel C_{24}

4. AHP modeling of influencing factors of project schedule under EPC mode

Invite a total of fifteen experts from various project stakeholders and related professions in the industry to score the indicators discussed in this paper using the "1-9 scale method" (see Table 2)[6]. To reduce subjectivity, extreme values, i.e., the highest and lowest scores, are removed from the evaluations. The average score obtained from the remaining values is used as the assigned value for the judgment matrix.

Table 2. Criteria for Importance Ratings

Scale	Hidden meaning
1	Two elements have the same importance.
3	One element is slightly more important than the other.
5	One element is more important than the other.
7	One element is obviously more important than the other.
9	One element is absolutely more important than the other.

4.1. Calculation of indicator weights at the normative level

The five indicators in the criterion layer are technology, management, organization, environment, and resources. According to the principle of AHP, a hierarchical single-sort analysis is carried out. The judgment matrix can be constructed by combining the indicator evaluation system in Table 1. Then, the weights of the indicators are obtained by using the calculation software after the importance of the indicators is rated by the experts between the indicators two by two[7]. This paper calculates each indicator level's maximum eigenvalue, CI value, and CR value using SPSSAU software.

$$A = \begin{bmatrix} 1 & 0.363 & 0.18 & 1.726 & 0.876 \\ 2.751 & 1 & 1.093 & 2.031 & 1.31 \\ 5.551 & 0.915 & 1 & 2.393 & 1.226 \\ 0.579 & 0.491 & 0.418 & 1 & 0.652 \\ 1.141 & 0.764 & 0.816 & 1.533 & 1 \end{bmatrix}$$

λmax = 5.242, CI = 0.061, CR = 0.054 < 0.1, and passed the consistency test. The corresponding weights are 0.1233, 0.2674, 0.3131, 0.1109, and 0.1852, respectively.

4.2. Calculation of weights for indicators at the indicator level

The following steps involve calculating the weights of the indicators corresponding to the criteria layer's management, technical, economic, and organizational factors using software. Consistency checks are performed to ensure accuracy. Ultimately, the weights of the indicators in the indicator layer relative to the criteria layer are obtained.

$$B_1 = \begin{bmatrix} 1 & 1.175 & 1.019 & 1.444 \\ 0.851 & 1 & 1.352 & 1.376 \\ 0.981 & 0.739 & 1 & 1.476 \\ 0.692 & 0.727 & 0.677 & 1 \end{bmatrix}$$

λmax=4.022, CI=0.007, and CR=0.008 < 0.1, passing the consistency test. The corresponding weights are 0.2827, 0.2775, 0.2518, and 0.1880, respectively.

$$B_2 = \begin{bmatrix} 1 & 1.026 & 0.519 & 0.487 & 0.365 \\ 0.974 & 1 & 0.352 & 0.487 & 0.425 \\ 1.927 & 2.838 & 1 & 0.978 & 0.689 \\ 2.052 & 2.052 & 1.023 & 1 & 1.004 \\ 2.739 & 2.355 & 1.452 & 0.996 & 1 \end{bmatrix}$$

λmax=5.033, CI=0.008, and CR=0.007 < 0.1, passing

the consistency test. The corresponding weights are 0.1147, 0.1093, 0.2407, 0.2469, and 0.2885, respectively.

$$B_3 = \begin{bmatrix} 1 & 1.567 & 0.536 & 0.582 & 0.817 \\ 0.638 & 1 & 0.883 & 0.769 & 0.833 \\ 1.867 & 1.132 & 1 & 1.06 & 1.167 \\ 1.719 & 1.3 & 0.944 & 1 & 0.976 \\ 1.224 & 1.2 & 0.857 & 1.024 & 1 \end{bmatrix}$$

λmax=5.08, CI=0.002, and CR=0.018 < 0.1, passing the consistency test. The corresponding weights are 0.1673, 0.1634, 0.2383, 0.2258, and 0.2052, respectively.

$$B_4 = \begin{bmatrix} 1 & 2.536 & 1.476 & 0.408 & 0.31 & 0.297 \\ 0.394 & 1 & 1.06 & 0.412 & 0.306 & 0.228 \\ 0.677 & 0.944 & 1 & 0.495 & 0.302 & 0.325 \\ 2.451 & 2.428 & 2.019 & 1 & 0.402 & 0.622 \\ 3.231 & 3.273 & 3.307 & 2.485 & 1 & 0.865 \\ 3.369 & 4.39 & 3.081 & 1.607 & 1.156 & 1 \end{bmatrix}$$

λmax=6.139, CI=0.028, and CR=0.022 < 0.1, passing the consistency test. The corresponding weights are 0.1049, 0.0689, 0.0785, 0.1691, 0.2878, and 0.2909, respectively.

$$B_5 = \begin{bmatrix} 1 & 0.782 & 0.876 & 0.8 \\ 1.279 & 1 & 0.876 & 0.776 \\ 1.141 & 1.141 & 1 & 0.817 \\ 1.25 & 1.288 & 1.224 & 1 \end{bmatrix}$$

λmax=4.01, CI=0.003, and CR=0.004 < 0.1, passing the consistency test. The corresponding weights are 0.2140, 0.2401, 0.2519, and 0.2940, respectively.

4.3. Aggregate weights of each indicator layer for the target layer

4.3.1. Overall hierarchical ranking

The overall ranking of specific factor elements concerning the overall target layer is calculated, and the results are shown in Table 3.

Table 3. Comprehensive Weights of Each Indicator Relative to the Target Layer

	B₁ (0.1233)	B₂ (0.2674)	B₃ (0.3131)	B₄ (0.1109)	B₅ (0.1852)	comprehensive weight
C_1	0.2827					0.03485691
C_2	0.2775					0.03421575
C_3	0.2528					0.03117024
C_4	0.188					0.0231804
C_5	0.1147					0.01414251
C_6		0.1093				0.02922682
C_7		0.2407				0.06436318
C_8		0.2469				0.06602106
C_9		0.2885				0.0771449
C_{10}			0.1673			0.05238163
C_{11}			0.1634			0.05116054
C_{12}			0.2383			0.07461173
C_{13}			0.2258			0.07069798
C_{14}			0.2052			0.06424812
C_{15}				0.1049		0.01163341
C_{16}				0.0689		0.00764101
C_{17}				0.0785		0.00870565
C_{18}				0.1691		0.01875319
C_{19}				0.2878		0.03191702
C_{20}				0.2909		0.03226081
C_{21}					0.214	0.0396328
C_{22}					0.2401	0.04446652
C_{23}					0.2519	0.04665188
C_{24}					0.294	0.0544488

4.3.2. Consistency test of the overall hierarchical ranking[8]

$$CR = \frac{\sum_{j=1}^{5} B_j CI_j}{\sum_{j=1}^{5} B_j RI_j} = \frac{0.1233*0.007+0.2674*0.008+0.3131*0.02+0.1109*0.028+0.1952*0.03}{0.1233*0.9+0.2674*1.12+0.3131*1.12+0.1109*1.24+0.1952*0.9}$$

$$=0.016826305 < 0.1$$

The above calculations show that the consistency tests for the single-level rankings of each judgment matrix meet the requirements, and the consistency of the overall hierarchical ranking is also satisfactory. Therefore, the relative importance judgments of each judgment matrix are reasonable, and the computed weight results are reliable.

5. Results analysis and recommendations

As the organization and management have a large proportion in the policy layer, the 24 indicators in the indicator layer have a large weight concentrated in the

front, and the other indicators are in a state of overall dispersion. The top 3 are C_9 Rationalization of progress target planning, C_{12} Communication and coordination among project participants, and C_{13} Degree of coordination in the cross-cutting implementation of phases.

5.1. Reasonable Planning of Progress Targets

In the EPC mode, the general contractor must collect and review substantial project data and basic information to control the risk of schedule delays, given the strict schedule requirements. When preparing the schedule, it is advisable to integrate additional project data and industry regulations to enhance the objectivity and effectiveness of the planning process. Furthermore, it is recommended that experienced technical personnel be selected to mitigate potential risks.

5.2. Strengthening the level of coordination in cross-cutting implementation of phases

All phases of the project process must be closely coordinated, particularly the stages of design, procurement, and construction, which often overlap. Although Chinese law does not permit "design-build" practices, ensuring seamless cooperation between the various project phases is still necessary. Maintaining good communication and coordination can help minimize the impact on the project schedule.

5.3. Enhance communication and coordination among project participants

The complexity of large construction projects necessitates a multifaceted approach to cooperation. Errors or omissions by any involved parties can impact the construction schedule and result in economic losses. Therefore, a detailed communication plan should be developed, regular coordination meetings should be held, formal communication channels should be established, and visual management tools and project management information systems should be utilized to enhance information sharing and communication efficiency.

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