Research on Supplier Selection for EPC Projects Based on G1 Empowerment Approach

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Abstract. As China vigorously promotes general contracting, EPC (Engineering Procurement Construc-tion) model has been rapidly developed and applied in the construction industry. By combing the existing literature, we constructed a supplier evaluation index system for EPC projects from six dimensions: comprehensive strength, technology and quality, supply chain management, cost and price management, service and cooperation. The fuzzy Delphi method is adopted to screen the indicators and the G1 method is used to assign weights to the indicators. Real supplier data were collected, and the evaluation system and indicator model were empirically analyzed, with a view to providing a theoretical basis for the selection of suppliers in EPC projects.

Keywords: EPC projects, supplier selection, G1 method

1 Introduction

As "One Belt, One Road" unfolds, China's construction engineering industry is embracing international expansion and new developmental stages. The selection of material suppliers in EPC project execution is crucial for project success, influencing construction smoothness and cost-effectiveness. Proper supplier selection not only satisfies project quality expectations, enhancing client satisfaction, but also aligns with project contracting standards. Furthermore, it aids in cost reduction and cultivates positive relationships among construction stakeholders, aiming for mutual benefits[1]. Therefore, studying material supplier selection in EPC projects is profoundly important[2].

2 EPC Project Supplier Selection Evaluation Index System Construction

The construction of an evaluation index system for supplier selection in EPC projects is crucial to ensure material security supply and mitigate the risks associated with selecting suppliers solely based on the lowest price bid[3]. These risks often lead to significant impacts on the quality and progress of engineering construction. Therefore, it

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is essential to establish a comprehensive set of supplier selection evaluation criteria before proceeding with supplier selection. The evaluation index system consists of 19 indicators categorized into five areas: comprehensive strength, technology and quality, supply chain management, cost and price management, service and cooperation. Please refer to the supplier selection evaluation index system for EPC projects is shown in Figure 1.

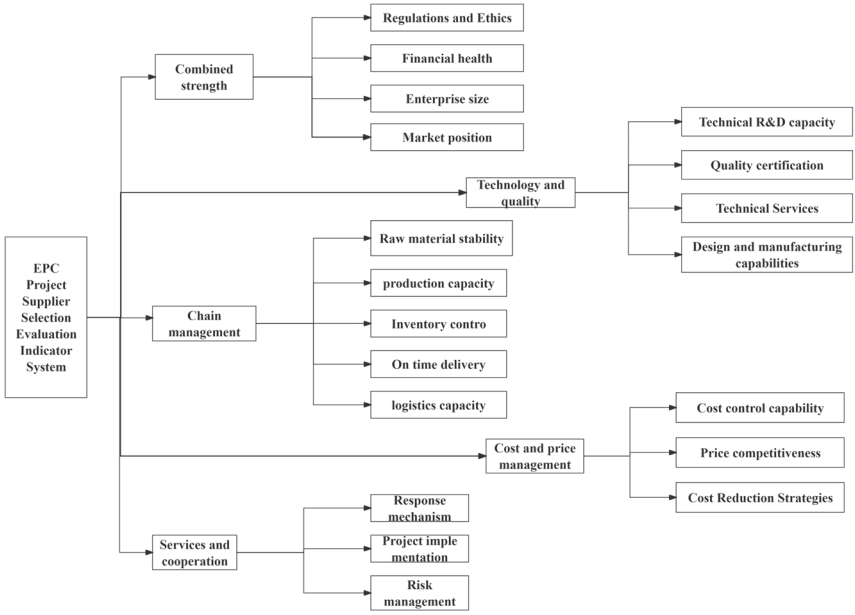

Fig. 1. EPC Project Supplier Selection Evaluation Indicator System

3 Supplier Selection Modeling Based on G1 Assignment Method

3.1 G1 Method for Determining Indicator Weights

The G1 assignment method, an enhancement of the AHP method, eliminates the need for consistency testing and reduces tedious calculations[4]. The operational steps are as follows:

(1) Determination of order relations

Order relations are established by comparing the importance of evaluation indicators, following evaluation guidelines. Experts sequentially select the most significant indicator from the set of evaluation indicators[5]. $\{a_1, a_2, \cdots a_n\}$ Experts select the most important indicator from the set of evaluation indicators sequentially, with only one indicator chosen at each step. Marking each selection as $x_1 .x_2 .\cdots .x_m$, by $m-1$ times selection, a unique ordinal relationship is established through repeated selections.[6]

(2) Determination of the relative importance of evaluation indicators

Assess the relative importance of the indicators and establish a set of importance ratios. First, relevant experts were asked to evaluate the indicators x_{k-1} andx_k Importance Ratio to make a scientific judgment, and the ratio $r_k = w_{k-1}/w_k$ $(k = m, m-1, \cdots, 3, 2)$, ther$_k$ The assignment of the value refers to Table 1.

Table 1. Explanation of the relative importance assigned to the indicators

rk	clarification
1	Indicator UK-1 is as important as Uk
1.2	Indicator UK-1 is slightly more important than Uk
1.4	Indicator UK-1 is significantly more important than Uk
1.6	Indicator UK-1 is strongly more important than Uk
1.8	Indicator UK-1 is more extremely important than Uk

This leads to the set of importance ratios $R = \{r_2, r_3, \cdots, r_k\}$ The set of importance ratios is derived from the set of importance ratios. By means of the set of importance ratios, the weight coefficient w_k is calculated.

(3) Calculation of weighting factors

The calculation of indicator weighting factors requires the utilization of formulas:

$$w_k = [1 + \sum_{k-2}^{m} \prod_{i=k}^{m} e_i]^{-1} \quad (1)$$

wherew_k represents the indicator weights, andr_i represents the firstk case of the assignment of values to the first influencing factor, andk is the firstk importance of the first influence factor. Therefore, the

$$w_{k-1}=r_k w_k \quad (2)$$

where w_{k-1} denotes the weight of the indicator of lesser importance, and r_k is labeled as the assignment of importance between indicators, andw_k is the weight of the indicator that is more important in comparison[7].

By combining the formulas, a vector of weights for the impact factor indicators under the same category can be calculated $w = \{w_1, w_2, \cdots, w_k\}$.

3.2 Calculation of Indicator Weights

Combining the theoretical approach of the G1 ordinal relation method, the steps are as follows:

(1) The study employed the Delphi method for expert consultation, a significant qualitative research technique characterized by anonymity, statistical analysis, iterative rounds, and controlled feedback. This method involves collecting anonymous feedback, independently soliciting expert opinions, and then synthesizing and providing feedback on these insights regarding the evaluation outcomes. Fifteen experts were enlisted to anonymously rank the indicator factors across all levels in a questionnaire, with the ranking outcomes presented in Table 2.

Table 2. Vendor selection evaluation indicators

norm	Sorting results
validity	Cost & Price Management>Technology & Quality>Supply Chain Management>Market Strategy>Integrated Strength>Service & Cooperation
Cost and price management	Price competitiveness > Cost control ability > Cost reduction strategy
Technology and quality	Quality Certification>Design and Manufacturing Capability>Technology R&D Capability>Technology Service
chain management	On-time delivery > Production capacity > Raw material stability > Inventory control > Logistics capacity
Combined strength	Financial Health > Market Position > Business Size > Regulations & Ethics
Services and cooperation	Project Execution > Risk Management > Response Mechanisms

The expert will compare the importance of two adjacent indicators to judge, according to the judgment results of the assignment, get and get the result$R_2 = y_1/y_2 = 1.4$, the$R_3 = y_2/y_3 = 1.2$, the$R_4 = y_3/y_4 = 1.8$.$R_5 = y_4/y_5 = 1.2$. Whereby the set of importance ratios of the indicators is obtained and$R = \{1.4，1.2，1.8，1.2\}$ In accordance with the above steps, the same important ratios under other categories are assigned, so as to obtain the set of important ratios. The set of importance ratios of the secondary indicators corresponding to the comprehensive strength factor is $R_z = \{1.8，1.2，1.4\}$, the set of importance ratios of the secondary indicators corresponding to technology and quality factors is $R_j = \{1.4，1.4，1.2\}$ The set of importance ratios corresponding to the supply chain management factor is $R_g = \{1.6，1.2，1.4，1.6\}$ The set of importance ratios of secondary indicators corresponding to cost and price management factor is $R_c = \{1.8，1.2\}$ The importance ratio of the secondary indicator for the service and cooperation factor is $R_f = \{1.6，1.6\}$.The set of importance ratios for the secondary indicators corresponding to the factors of cost and price management is

According to formula (1) and formula (2), the weights of evaluation indexes for supplier selection are calculated by MATLAB software, and the weights of each evaluation index are derived, and the results are shown in Table 3.

Table 3. Combined weights of evaluation indicators for vendor selection

target level	standardized layer	weights	indicator layer	weights	Combined weights
Supplier Selection	Combined strength Z	0.084772299	Regulations and EthicsZ_1	0.102739468	0.008709461
			Financial healthZ_2	0.469196472	0.039774864
			Enterprise sizeZ_3	0.167399353	0.014190828
			market positionZ_4	0.260664707	0.022097146
	Technology and Quality J	0.28200918	Technical R&D capacityJ_1	0.165026989	0.046539126
			quality certificationJ_2	0.419718642	0.118364551
			Technical ServicesJ_3	0.115455339	0.032559465

Supply Chain Management G	0.174438668	Design and manufacturing capabilitiesJ_4	0.2997990	0.084546079
		Raw material stabilityG_1	0.164553539	0.0287045
		production capacityG_2	0.260754069	0.045485593
		Inventory controlG_3	0.100171481	0.0174737 8
		on time deliveryG_4	0.417206511	0.072776948
		LogisticscapacityG_5	0.0573144	0.009997848
Cost and price management C	0.394812853	Cost control capabilityC_1	0.290511727	0.114697764
		Price competitivenessC_2	0.522921109	0.206455975
		Cost Reduction StrategiesC_3	0.186567164	0.073659114
Services and cooperationF	0.063967	Response mechanismF_1	0.162337662	0.010384253
		Project implementationF_2	0.515484515	0.032973998
		risk managementF_3	0.322177822	0.020608749

Through the optimization design of the supplier selection index system for EPC projects above, the following formula can be used: Total supplier score = comprehensive weight corresponding to each sub-criteria level index * scoring expert's evaluation of the sub-criteria level indexes of the competing suppliers. After obtaining the total score of each supplier to be evaluated, the suppliers with the highest scores are then ranked according to their scores and selected for contracting.[8]

4 Empirical Analysis

The author has chosen S company's EPC project for a case study, which utilizes an EPC general contracting bidding approach. Utilizing the revised supplier evaluation index system for EPC general contracting projects allows for the selection of a supplier for long-term collaboration[9]. Following initial market research and past cooperation experiences, a decision will be made among three suppliers: A06, A18, and A75. Details about these suppliers are provided in Table 4.

Table 4. Supplier information sheet

nicknames	Supplier Characteristics
A06	Established quality system certification with strong performance; outstanding technical R&D capabilities; moderate pricing of finished products and delivery efficiency; and adequate technical support for EPC turnkey projects.
A18	Extensive quality system certification with exceptional performance; moderate technical R&D capabilities; higher-priced finished products with superior delivery efficiency; substantial technical support for EPC general contracting projects.

A75	Poor quality system construction, with average quality performance; average technological research and development capabilities; the finished product is priced competitively; average delivery performance and technical support for EPC general contracting projects.

4.1 Expert Scoring of the Indicator Layer

In supplier evaluations for EPC projects, subjective biases, rooted in experts' personal experiences, preferences, or criterion interpretation, can distort results, affecting supplier selection[10]. To mitigate these biases, the study proposes: (1) diversifying the evaluation panel to include a broad range of professional backgrounds, ensuring varied perspectives; (2) employing structured scoring tools with clear, standardized criteria to limit subjectivity; (3) implementing anonymous scoring to minimize panel influence and personal biases.These strategies aim to enhance objectivity and fairness in the evaluation process.Finally, we compile the results into Statistical Table 5 by averaging the scores from all experts.

Table 5. Summary of ratings by relevant experts

standardized layer	indicator layer	A06	A18	A75
Combined strength	Regulations and Ethics	98	97	97
	Financial health	92	93	89
	Enterprise size	90	90	90
	Market position	92	94	90
Technology and quality	Technical R&D capacity	94	87	86
	Quality certification	92	85	80
	Technical Services	86	94	89
	Design and manufacturing capabilities	87	95	85
Chain management	Raw material stability	85	90	87
	Production capacity	89	90	88
	Inventory control	90	89	87
	On time delivery	87	95	89
	Logistics capacity	90	92	90
Cost and price management	Cost control capability	90	86	93
	Price competitiveness	89	81	98
	Cost Reduction Strategies	86	84	89
Services and cooperation	Response mechanism	84	91	86
	Project implementation	89	95	90
	Risk management	92	93	85

4.2 Vendor Evaluation Results

Multiply the average of the five experts' scores with the combined weights of the sub-criteria layers on the target layer to get the combined score of each sub-criteria layer on

the target layer, and then summarize and sum up the combined scores of each sub-criteria layer to get the final scores of each supplier, as shown in Table 6:

Table 6. Breakdown of vendor ratings

standardized layer	indicator layer	A06	A18	A75
Combined strength	Regulations and Ethics	0.853527167	0.844817706	0.844817706
	Financial health	3.659287455	3.699062319	3.539962864
	Enterprise size	1.277174521	1.277174521	1.277174521
	market position	2.032937475	2.077131768	1.988743182
Technology and quality	Technical R&D capacity	4.374677783	4.048903949	4.002364823
	quality certification	10.88953493	10.06098336	9.469160806
	Technical Services	2.800114029	3.060589753	2.897792425
	Design and manufacturing capabilities	7.355508884	8.031877469	7.186416683
chain management	Raw material stability	2.439882512	2.583405012	2.497291512
	production capacity	4.048217734	4.093703327	4.002732142
	Inventory control	1.572640167	1.555166387	1.520218828
	on time delivery	6.331594479	6.913810063	6.477148375
	logistics capacity	0.899806291	0.919801986	0.899806291
Cost and price management	Cost control capability	10.32279874	9.864007687	10.66689203
	Price competitiveness	18.37458176	16.72293396	20.23268553
	Cost Reduction Strategies	6.334683835	6.187365607	6.555661179
Services and co-operation	Response mechanism	0.872277273	0.944967045	0.893045779
	Project implementation	2.934685822	3.132529081	2.967659082
	risk management	1.896004885	1.916613634	1.751743644
add up the total		89.26993574	87.93484536	89.67131815

According to the above table, we can clearly see the score of suppliers. The sorting result is: A75＞A06＞A18, for the EPC general contracting project, A75 is the optimal solution, then A06, and A18 is relatively poor, so the EPC general contracting project selects supplier K043 as the supplier for long-term strategic cooperation, and the other two as the suppliers for general cooperation.

5 Conclusion

Currently, China is actively promoting the EPC model, although research into EPC supplier selection remains nascent, lacking a robust evaluation framework.The study investigates optimal supplier selection within the EPC model, integrating China's current EPC development and process traits to develop an objective, comprehensive, and pragmatic framework for evaluating and selecting suppliers for EPC general contractors. Considering the unique traits of suppliers in the EPC context, this study employs the fuzzy Delphi method for filtering evaluation indices and the G1 method for weighting these indices. Through a case study, three suppliers were assessed using this criteria, ultimately selecting the one with an overall strength score of A75 for long-term strategic partnership.In developing the new index system, both selecting indicators and assessing their importance frequently involved expert scoring. While these experts possess extensive industry experience and representativeness, the influence of personal biases cannot be overlooked, possibly rendering the index system not fully appropriate. Going forward, our research will delve deeper into identifying effective strategies to minimize the impact of subjective biases.

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