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Research on Partner Selection of Transportation Infrastructure Projects under PPP Mode

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Abstract

In the process of selecting partners for transportation infrastructure PPP projects, there are many uncertain factors in the decision-making index system, and also there are grayness and ambiguity, which lead to inaccurate decision-making results.So this paper eliminates the ambiguity of indicators by Basing on the combination of entropy weight and COWA operator, and calculates the closeness of the evaluation object to the idealized target by improving the TOPSIS method to obtain the preferred ranking of partners. And it shows by actual cases that the decision-making model has certain reliability and practicability.

Keywords

Transportation Infrastructure PPP Project; Entropy Method; COWA Operator; Improved TOPSIS Method; Partner Selection.

1. Introduction

As an indispensable part of infrastructure, transportation infrastructure plays a fundamental and leading role in promoting social and economic development. Due to its large investment, financial investment alone can no longer meet people's needs for transportation infrastructure, and insufficient investment has become a major bottleneck restricting the construction of transportation infrastructure in my country [1]. The PPP model transfers part of government responsibilities to social entities in the form of franchise rights, enabling the government and social entities to establish a community relationship of “sharing benefits, sharing risks, and win-win cooperation” [2]. This model can alleviate financial pressure, improve product supply rate, and achieve mutual benefit and win-win advantages, which is favored by the government .Akintoye[3] pointed out that choosing a suitable partner is the key to the success of PPP projects.Therefore, this paper mainly studies how to select the partners of the transportation infrastructure PPP project through scientific and reasonable selection methods, and maximize the overall benefits of the project by using the advantages of shared resources.

The above decision-making methods can effectively select partners and improve the operational efficiency of the project.However, most of the existing research methods ignore the ambiguity and uncertainty of the index information, which leads to certain deviations in the decision-making results.Or the ambiguity of indicators is considered, but factors such as the difference in the score of each indicator are not comprehensively considered in the final selection of partners, resulting in the selected partners having strong strength in one aspect, weak strength in one aspect.In order to solve the above problems, this paper combines the entropy weight method and the COWA operator, and weights the first-level index and the second-level index respectively to eliminate the ambiguity of the index. Considering the overall comprehensive strength of the evaluation object and other factors, the "equilibrium degree"

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factor is introduced to construct an improved TOPSIS partner selection model based on combined weighting, and the closeness of the evaluation object to the idealized goal is calculated, and finally a comprehensive ranking is obtained. The selection of partners for PPP projects provides a scientific basis for decision-making.

2. Establishment of an Indicator System for Partner Selection in Transportation Infrastructure PPP Projects

2.1. Dimensional Screening of Partner Indicators in Transportation Infrastructure PPP Projects

The index dimension, that is, the angle of evaluating the index, refers to the commonality of a certain type of index. Since the transportation infrastructure PPP project partners and other DB, BOT, EPC mode contractors have certain commonalities, this paper, by reading a lot of relevant literature, and using the literature frequency statistics method to analyze the current DB, BOT, EPC, PPP and other projects The selection dimensions of contractors are classified, and the evaluation index dimensions of PPP project partners are identified. as shown in Table 1.

Table 1. Partner evaluation dimension filter

Application field	Dimensional division	source
DB contractor	Finance, Design, Procurement, Construction, Experience Performance, Credit	Literature [4]
EPC contractor	Finance, Credit, Management, Technology, Experience	Literature [5]
BOT Franchisee	Finance, Credit, Management, Technology Finance, design, experience, organization and management, records of past engineering information	Literature [6] Literature [7]
PPP partner	Finance, reputation, operation and maintenance capabilities, organizational management capabilities, risk management and control capabilities Business reputation, financial capability, contract management capability, construction and operation capability, risk management capability Project nature, financing capacity and source of funds, bidding plan Finance, Technology, Management, HSE Finance, technology, management, experience, reputation	Literature [8] Literature [9] Literature[10] Literature[11] Literature[12]

Different researchers hold different opinions on the dimensions of partner selection in DB, BOT, EPC, and PPP projects, but most opinions focus on five aspects: finance, technology, management, experience, and reputation. This can provide reference for the selection of partners in transportation infrastructure PPP projects. Therefore, this paper takes the five dimensions of financial ability, technical ability, management ability, experience performance and reputation level as the first-level index evaluation dimensions for evaluating transportation infrastructure PPP project partners.

2.2. Establishment of Partner Index System for Transportation Infrastructure PPP Projects

According to the screening idea of the index evaluation dimension, through reading a large number of documents, the document frequency statistics method is used to select and classify

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the partner evaluation indicators of the current DB, BOT, EPC and PPP projects, and finally 23 secondary evaluations are established. The evaluation index is shown in Table 2.

Table 2. Partner Index Evaluation System for Transportation Infrastructure PPP Projects

Indicator system	First-level indicator	Secondary indicators
Partner Index Evaluation System for Transportation Infrastructure PPP Projects	Financial capacity	Own financial strength
		Financing ability
		Financial Guarantee Ability
		Price competitiveness during operation period
	Technical skills	Reasonable construction plan
		Reasonable operation and maintenance plan
		Reasonable handover plan
		Adequacy ratio of key machinery and equipment
		Key talent adequacy ratio
		Technological innovation capability
	Management ability	Reasonable level of organizational structure
		The degree of standardization of the management system
		Strategic planning and implementation capabilities
		Coordination and communication skills
		Contract management capabilities
		Risk management capability
	Experience performance	Similar project construction experience
		Similar project financing experience
		Similar project management experience
	Reputation ability	Qualification
		Historical project contract performance
		Social reputation
		Similar project owner satisfaction

2.3. Setting of Evaluation Indicators for Partners in Transportation Infrastructure PPP Projects

According to the established indicator system for partners in transportation infrastructure PPP projects, the criteria for evaluating indicators are set. As shown in Table 3.

Table 3. Indicator Judgment Criteria

Judgment criteria	Very important	More important	Generally important	Not so important	No need to consider
Score	5	4	3	2	1

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3. An Improved TOPSIS Method for Transportation Infrastructure PPP Project Partner Selection Model based on Portfolio Empowerment

3.1. Entropy Weight Method and COWA Operator Combined Weighting

There are many uncertain factors in the decision-making index system of transportation infrastructure PPP projects, and there are gray and fuzzy. To a certain extent, eliminate the possible extreme effects of subjective scoring and empowerment.

(1) Constructing the judgment matrix of each evaluation index

$$R = \left(r_{ij}\right)_{m\times n} (i = 1, 2, \cdots, m; j = 1, 2, \cdots, n) \tag{1}$$

Among them, R represents the set of indicators; m represents the number of evaluation objects; n represents the number of evaluation indicators; r_{ij} represents the evaluation value of the i -th evaluation object to the j -th index.

(2) Calculate the entropy weight and COWA weight of each index separately

This paper uses the relatively mature entropy weight method and COWA operator method to calculate the entropy weight of the evaluation indicators at all levels and the relative weight of the COWA operator method respectively, marked as s_{ij} and o_{ij} .Among them $\sum_{j=1}^{n} s_{ij} = 1$,and satisfy0< s_{ij} <1, $\sum_{j=1}^{n} o_{ij} = 1$,and satisfy0< o_{ij} <1.

(3) Entropy weight and COWA combined weighting

The weight determined by the entropy weight under each index and the weight determined by the COWA operator are combined and weighted by the following formula.

$$w_{ij} = \frac{s_{ij} \times o_{ij}}{\sum_{j=1}^{n} (s_{ij} \times o_{ij})} \tag{2}$$

3.2. Improved TOPSIS Method

(1) The initial decision matrix is constructed by experts scoring the candidate units.

$$X = \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \tag{3}$$

(2) Standardize the initial decision matrix to obtain standardized decisions.

$$Z = \begin{pmatrix} z_{11} & \cdots & z_{1n} \\ \vdots & \ddots & \vdots \\ z_{m1} & \cdots & z_{mn} \end{pmatrix} \tag{4}$$

Among them, $Z_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x^2{}_{ij}}}$

(3) Build a standardized decision matrix.

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Weight vector constructed by combining weights with formulas $w=(w_1,w_2,\cdots,w_n)$,pass through $u_{ij}=w_i \times z_{ij}$ to get the standard decision matrix.

$$U=\begin{pmatrix} u_{11} & \cdots & u_{1n} \\ \vdots & \ddots & \vdots \\ u_{m1} & \cdots & u_{mn} \end{pmatrix} \quad (5)$$

(4) Determine the positive and negative ideal solutions.

Since each index is of benefit type, the positive ideal solution and negative ideal solution are determined by the following formula, marked as u_j^+ and u_j^- .

$$\begin{aligned} u_j^+ &= \max u_{ij} \\ u_j^- &= \min u_{ij} \end{aligned} \quad (6)$$

(5) Calculate the distance from the ideal solution

Use Euclid's formula to calculate the distance to the positive and negative ideal solutions of each evaluation object, marked as D_i^+ and D_i^- .

$$D_i^+ = \sqrt{\sum_{i=1}^{m}(u_{ij}-u_j^+)^2} \quad (7)$$

$$D_i^- = \sqrt{\sum_{i=1}^{m}(u_{ij}-u_j^-)^2} \quad (8)$$

(6) Calculate closeness.

The relative closeness of the i -th evaluation object to the optimal partner is C_i ,The bigger the C_i ,the better the partner.

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \quad (9)$$

(7) Introduce the parameter "Equalization G ".

$$G_i = \frac{\bar{X}_{ij}}{\sqrt{\frac{\sum_{j=1}^{n}(X_{ij}-\bar{X}_{ij})^2}{n-1}}} \quad (10)$$

Among them, $\bar{X}_{ij}$ refers to the average value of the evaluation object for each index, $\sqrt{\frac{\sum_{j=1}^{n}(X_{ij}-\bar{X}_{ij})^2}{n-1}}$ refers to the standard deviation of each index score of the evaluation object.

(8) Introduce the parameter "comprehensive evaluation score H ".

$$H_i = C_i G_i \quad (11)$$

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According to the comprehensive evaluation score, the bigger the H_i , the better the comprehensive strength of the alternative partner, and vice versa. This provides decision-making basis for the selection of partners in transportation infrastructure PPP projects.

4. Case Analysis

A highway in Sichuan Province is a demonstration project of the provincial government-private partnership (PPP) project. The total investment of the expressway PPP project is about 4.6 billion yuan, and the construction is jointly funded by the government and social capital. Finally, three companies A, B, and C meet the requirements to bid. In this paper, 8 experts, scholars and industry elites with relevant experience are invited to score the importance of each indicator at different levels according to the corresponding scoring standards.

4.1. Determine Indicator Weights

Table 4. Weights of indicators at all levels of transportation infrastructure PPP projects

First-level indicator	Weights	Secondary indicators	Weights on first-level indicators	Weights
Financial capacity	0.1471	Own financial strength	0.1905	0.0251
		Financing ability	0.4286	0.0555
		Financial Guarantee Ability	0.2381	0.0314
		Price competitiveness during operation period	0.1429	0.0188
Technical skills	0.3278	Reasonable construction plan	0.1308	0.0251
		Reasonable operation and maintenance plan	0.0991	0.0190
		Reasonable handover plan	0.3955	0.0759
		Adequacy ratio of key machinery and equipment	0.1499	0.0288
		Key talent adequacy ratio	0.1499	0.0288
		Technological innovation capability	0.0748	0.0144
Management ability	0.3747	Reasonable level of organizational structure	0.1051	0.0314
		The degree of standardization of the management system	0.1051	0.0314
		Strategic planning and implementation capabilities	0.4662	0.1391
		Coordination and communication skills	0.0631	0.0188
		Contract management capabilities	0.1892	0.0565
		Risk management capability	0.0713	0.0213
Experience performance	0.0593	Similar project construction experience	0.4352	0.1054
		Similar project financing experience	0.4352	0.1054
		Similar project management experience	0.1296	0.0314
Reputation ability	0.0911	Qualification	0.5278	0.0717
		Historical project contract performance	0.0924	0.0125
		Social reputation	0.0924	0.0125
		Similar project owner satisfaction	0.2873	0.0390

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Through the scores of 8 experts and scholars, the scores of 23 secondary indicators were obtained, and the scores of secondary indicators were calculated by entropy weight method and COWA operator respectively to obtain the weights of indicators at all levels. Finally, through formula (2), the indicators at all levels are combined and weighted, and the corresponding weights are obtained, as shown in Table 4.

It can be seen from Table 4 that, in terms of the weight of the first-level indicators, management ability>technical ability>financial ability>credibility level>experience performance.

4.2. Using the Improved TOPSIS Method to Determine the Winning Candidates

(1) The three units A, B, and C are scored by the expert scoring method, and the scoring matrix is normalized.

$$U=\begin{pmatrix} 0.5869 & 0.5727 & 0.5666 & 0.5803 & 0.5720 \\ 0.5693 & 0.5776 & 0.5882 & 0.5806 & 0.5782 \\ 0.5754 & 0.5815 & 0.5770 & 0.5710 & 0.5817 \end{pmatrix}$$

(2) Determine the positive and negative ideal solutions according to equation (6).

$$u_j^{+}=\begin{pmatrix} 0.5869 & 0.5815 & 0.5882 & 0.5806 & 0.5817 \end{pmatrix}$$
$$u_j^{-}=\begin{pmatrix} 0.5693 & 0.5727 & 0.5666 & 0.5710 & 0.5720 \end{pmatrix}$$

(3) Calculate the positive and negative ideal distances according to equations (7) and (8).

$$D_i^{+}=\begin{pmatrix} 0.0253 & 0.0184 & 0.0188 \end{pmatrix}$$
$$D_i^{-}=\begin{pmatrix} 0.0200 & 0.0250 & 0.0178 \end{pmatrix}$$

(4) The closeness is calculated according to formula (9).

$$C_i=\begin{pmatrix} 0.4413 & 0.5755 & 0.4860 \end{pmatrix}$$

(5) Calculate the equilibrium degree according to formula (10).

$$G_i=\begin{pmatrix} 31.3820 & 23.5107 & 30.5080 \end{pmatrix}$$

(6) According to formula (11), the comprehensive evaluation score is calculated, and the candidate unit is selected according to the best.

$$H_i=\begin{pmatrix} 13.8499 & 13.5304 & 14.8283 \end{pmatrix}$$

According to the comprehensive evaluation results, if the comprehensive evaluation score is C company>A company>B company, then C company should be selected to participate in the construction of the transportation infrastructure, which is consistent with the actual investment contracting result.Therefore, the improved TOPSIS method based on portfolio weighting constructed in this paper has certain applicability and can provide a certain reference for the selection of partners in similar PPP projects in the future. Although Enterprise C is not necessarily the strongest in a certain aspect, its comprehensive evaluation score ranks first, indicating that from an overall consideration, Enterprise C is more suitable to participate

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in the construction of this project, as shown in Table 5. In addition, by comparing the calculation results of the first-level indicators of these three companies, it can be seen that although the management and technical capabilities of company C are not the strongest, the comprehensive strength of company C is balanced, which is in line with the importance of the transportation infrastructure PPP project for each partner. The comprehensive requirement of aspect capability also shows that the model has certain applicability.

Table 5. TOPSIS model calculation results

Alternative Business	Closeness	Ranking	Equilibrium	Comprehensive Evaluation Score	Corrected Ranking
A	0.4413	3	31.3820	13.8499	2
B	0.5755	1	23.5107	13.5304	3
C	0.4860	2	30.5080	14.8283	1

5. Conclusion

Aiming at the problem of ambiguity and uncertainty in decision-making indicators, this paper establishes a decision-making index system for transportation infrastructure PPP projects, and uses entropy weight and COWA operator to combine weights to abandon the shortcomings of the single weighting method and eliminate the ambiguity of indicators. , by introducing the correction coefficient of "balanced degree" and considering factors such as the inaccurate comprehensive strength ranking of the evaluation objects caused by the difference in the scores of each index, an improved TOPSIS method optimization model based on combination weighting is established, and a scientific and reasonable partner is finally selected. Through the verification of the example, the obtained results are consistent with the actual results, which proves the practicability and reliability of the model. To sum up, the improved TOPSIS method based on entropy weight and COWA operator combined weight provides an effective basis for the selection of partners in transportation infrastructure PPP projects.

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