A Survey on the Establishment and Application of Social Capital Partner Selection System for the New Profit PPP Project

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Abstract

As the economy in China enters the new normal, Public-Private Partnerships have been an important measure for alleviating financial tensions and improving the administrative efficiency of the government. Based on the mode of open tendering for the selection of social capital partners for the new profit project, the open tendering procedures were analyzed. In addition, based on an improved TOPSIS model, the evaluation index system for the selection conducts a comprehensive evaluation of six aspects: reputation and performance, water pricing factor, financing program, construction program, operation and maintenance program, and transfer program.

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Keywords: selection of social capital partner, new profit PPP project, index system, improved TOPSIS model

1. Introduction

After more than 30 years rapid growth, the momentum of China's economic growth has begun to slow down. Medium-tohigh economic growth, rather than the previous rapid growth of the Chinese economy, has become a normalized and structural phenomenon. This new rate of growth is the only way to achieve and sustain China's economic structure transformation and maturity successfully. In the context of China's economy entering a new phase of normal and comprehensive, deepening reform, supporting and guiding the healthy development of social capital investment has become an important part of that economic reform. Faced with the potential difficulties of making public investment a normalized economy, how to guide social capital into the public sphere has become an important challenge for the Chinese government.

The development trend of social capital entering the field of infrastructure construction is inevitable. In the field of infrastructure construction, a project that can achieve a certain level of operating income through that project's own marketing operations is referred to as a "profit project." Since a profit project has a certain operating income and can bring at least some benefits to investors, the attractiveness of such projects (to those investors) is greater and hence more likely to attract social capital. A profit project is both able to and supposed to reduce financial burden, promote investment diversification, and thus enhance the effectiveness of project implementation and achieve a reasonable level of risk-sharing through the introduction of social capital. The adoption of the PPP (private-public-partnership) model by the profit project is not only a trend caused by the requirements of the times we live in. PPPs are also an important means of improving government (public) services. Such projects combine the government's strategic planning, market regulation, and public service with the efficiency and technological innovation of social capital management. As such, PPP projects help clarify the boundaries of government and market, and they enhance the government's legal consciousness, contract consciousness and market awareness. In addition, PPPs perform better in terms of public functions and enhance the level of public service.

The social capital partner is an important participant in any PPP project. In the PPP model, the investors of social capital are effectively in partnership with the government (Kosoy *et al.*, 2007). Both partners exert their respective advantages. Under the constraints of the contract, both parties share the risks, as well as the gains. Therefore, the selection of the most suitable social capital partner(s) has a very important influence on the success of any PPP project (Lee *et al.*, 2011). Taking into account the fact that the role played by social capital partners can vary widely from one project to the next, the factors to be considered when selecting social capital partners can also vary widely. Based on this, our research examines the social capital partners' selection system for a new profit project, which will operate under cooperation between

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the Government and the social capital investor.

2. Literature Review

In contrast to traditional models of government financing, public-private-partnerships are a type of financing that is used globally and in which the private sector signs long-term contracts with the public sector to deliver public infrastructure, as well as share projects and benefits (Jinbo Song *et al.*, 2018). Many previous studies have been conducted on the critical success factors of PPP projects. Chua *et al.* (1999) maintains that the success of a construction project is determined by four aspects: (1) project characteristics, (2) contractual arrangements, (3) project participants, and (4) interactive processes. Tiong and Alum (1997) have further identified distinctive elements of winning proposals in competitive BOT tendering. Gupta and Narasimham (1998) provide additional CSFs for promoters to win BOT contracts.

Much research has been conducted on the establishment of an efficient and reasonable partner evaluation system. Ouenniche Jamal et al. (2016) modeled the selection of a private sector partner problem as a static non-cooperative game of complete information and proposed a new ordinal game theory algorithm for finding an optimal generalized Nash equilibrium. Wang Wenxiong et al. (2007) established an index system to select privatesector partners by evaluating the abilities of the partners to finance and manage finances; design, build, operate and manage projects; and manage the safety, health and environment issues of projects. Zhang XQ (2005) classified the identified criteria into four evaluation packages for PPP projects in general: (1) financial, (2) technical, (3) safety, health, and environmental, and (4) managerial. facilitates the formulation of a multi-criteria best value source selection methodology for PPP projects in general, as well as develops both objective and subjective evaluation criteria to select the right private-sector partner for a particular PPP project. Gao Xu-Kuo et al. (2013) set up an evaluation index system of Private-Public-Partnership reclaimed water projects based on the characteristics of reclaimed water projects that combined the comprehensive characteristics of home and abroad.

Overall, the existing literature has identified numerous critical factors, such as financial, technical, SHE, managerial, as well as the ability to design, to build, to operate and to manage, for the selection of the private-sector partner. However, these factors cannot be regarded as equal to the characteristics of a new profitable project and the methods for selecting social capital partners cannot be reasonable for evaluation. Therefore, on the basis of the factors and methods found in the literature, this study intends to explore a system for selecting social capital partners for the new profit PPP projects.

3. Framework of System

3.1 Selection Modes

According to the relevant Chinese laws and regulations, the selection modes for the new profit PPP project (especially



Fig. 1. The Basic Framework of the Social Capital Partners' Selection for New Profit PPP Project

government-funded projects and projects have bearings on public interest and public safety) should use public tender and bidding as the main selection method. If there is any degree of particularity in the new profit PPP project, or if the project fails to meet the standard conditions for the selection of social capital partners (by public bidding), the selection of the social capital partners should be conducted through invitation to tender, competitive negotiation and single source procurement, any or all of which should be conducted according to conditions and practical situation, after submission to the government for approval has been made by the project implementation party.

Based on the above analysis, the basic framework of the social capital partners' selection process for a new profit PPP project is shown in Fig. 1.

3.2 Evaluation Method

In the process of the selection of social capital partners for a new profit PPP project, in addition to the use of the single source procurement method, the adoption of other selection modes could include an invitation to tender and competitive negotiation (Sahooly *et al.*, 2003). The latter two methods face a number of difficulties, namely selecting one of the best social capital partners from a number of alternative social capital partners. In addition, there are many difficulties in making a comprehensive evaluation of the overall situation of all the selected potential social capital partners. In order to ensure the effectiveness of the social capital partners' selection process for profit PPP projects, it is necessary to establish a comprehensive and systematic method to evaluate potential social capital partners.

At present, the methods used to evaluate potential social capital

partners for profit PPP projects (as stipulated by the Chinese government) include the lowest bid evaluation method, the comprehensive evaluation method and the price ratio method. From an implementation point of view, the comprehensive evaluation method is the most common method adopted by profit PPP projects when selecting social capital partners (Ford *et al.*, 2017).

The basic idea of the comprehensive evaluation method is as follows: Under the premise of meeting the maximum substantive requirements of the tender documents, the government body responsible for the project will review the bidding documents one by one, in accordance with the provisions of the tender documents. The reviewing body will then take the total score of each potential partner as the basis to determine the successful bidder or the winning candidate, by integrating all factors.

4. Index System

The primary task to be faced when selecting social capital partners for a profit PPP project (when using the comprehensive evaluation method) is to establish an effective index system.

4.1 The General Idea of Index System Establishment

Social capital partners are supposed to assume the capital scheme design, construction scheme design, operation scheme design, transfer scheme design and other work in the process of implementing the new profit PPP project (Sardenne *et al.*, 2017). Thus, when establishing an evaluation index system for the new profit PPP project, all the social capital partners' efforts and responsibilities named above should be taken into consideration before any comprehensive judgment is made.

Furthermore, due to the complexity of the implementation of any new profit PPP project, and also due to the fact that social capital partners and government departments must carry out long-term cooperation, the reputation and previous performance of social capital partners ought to be considered when evaluating potential social capital partners for a new profit PPP project.

At the same time, for any new profit PPP project, future pricing is a core issue. Future pricing is not only related to social capital earnings, but also to the important basis of government decision-making (Dodd *et al.*, 2017). Hence, the establishment of an evaluation system of the relevant charges is also an important part of the evaluation system for potential new profit PPP project social capital partners.

Based on the above analysis, the evaluation of a new profit PPP project should be conducted from six aspects, namely: 1) reputation and performance evaluation, 2) price factor evaluation, 3) plan financing evaluation, 4) construction project evaluation, 5) operation and maintenance program evaluation and 6) transfer scheme evaluation.

Hereby, the basic framework of the evaluation index system for new business PPP project social capital partners is shown in Fig. 2.



Fig. 2. Schematic Framework of the eValuation Index System of Potential New Profit PPP Project Social Capital Partners

4.2 Formation of Index System

We can see from the above analysis that the evaluation and review of potential new profit PPP project social capital partners should be conducted from the perspectives of reputation and performance evaluation, price factor evaluation, financing plan evaluation, construction project evaluation, operation and maintenance program evaluation and transfer scheme evaluation. This also means that the first-level index system for the evaluation and review of new profit PPP project social capital partners is composed of six indexes. To ensure the effectiveness of the evaluation, the establishment of operable second-level indexes (which are aimed at the first-level indexes) is necessary, in order to form a comprehensive evaluation index system with regard to potential social capital partners (Meduri *et al.*, 2017).

(1) Second-level indexes establishment of reputation and performance evaluation under first-level indexes

Since the reputation and performance evaluation first-level indexes mainly reflect the ability and feasibility of each social capital partner in the implementation of new profit PPP project, these indexes can reflect the situation through corporate qualification, past performance and social influence (Hwang *et al.*, 2012).

Thus, the first-level indexes of reputation and performance evaluation are composed of four second-level indexes, namely, a) corporate credit rating, b) the business results of similar projects, c) corporate qualification conditions and d) corporate social influence.

(2) Second-level indexes establishment of price factor evaluation under first-level indexes

As the first-level index of price factor evaluation is related to the interests of both the public and social capital partners, the reasonableness of the project price should be evaluated. In addition, since any new profit PPP project is bound to involve government public investment and financial subsidies, the nonsubsidy price levels should be considered when evaluating the price factors. As there is no comparison significance for the absolute price, the concept of a non-subsidy price level should be introduced when evaluating the price factors.

The non-subsidy price level is the price proposal targeted at alternative social capital partners. Calculate the non-subsidy price level and take the average value as the reference value to compute the non-subsidy price level of each alternative social capital partner. The lower the non-subsidy price of each alternative social capital partner, the higher the non-subsidy price level.

Hence, the first-level index of price factor evaluation should include one second-level index, namely a non-subsidy price level.

(3) Second-level indexes establishment of financing plan evaluation under first-level indexes

Since the first-level index of a financing plan evaluation is used to evaluate the feasibility of the financing plan of each potential social capital partner in the new profit PPP project, this index can reflect the situation from the perspectives of financing schedule rationality, financing capability evaluation, the comprehensive capital cost rate of financing, financing channel evaluation and the risk evaluation of the financing plan.

Thus, the first-level index of financing plan evaluation include five second-level indexes, namely a) financing schedule rationality, b) financing capability evaluation, c) comprehensive capital cost rate of financing, d) financing channel evaluation and e) risk evaluation of the financing plan.

(4) Second-level indexes establishment of construction project evaluation under first-level indexes

Since the first-level index of construction project evaluation is used to evaluate the feasibility of the construction project proposed by each potential social capital partner in the new profit PPP project, that index can reflect the situation from the perspectives of project design organization, project evaluation and project construction organization scheme evaluation.

Thus, the first-level indexes of construction project evaluation should include two second-level indexes, namely a) project design organization project evaluation and b) project construction organization scheme evaluation (Abrera et al., 2010).

(5) Second-level indexes establishment of operation and maintenance program evaluation under the first-level indexes

The first-level index of operation and maintenance program evaluation is used to evaluate the feasibility of the operation and maintenance program of each potential social capital partner in the new profit PPP project (Iver et al., 2010). In addition, since operations and maintenance last longer and tends to have a more significant impact on any new profit PPP project, the evaluation of operations and maintenance should be taken into full consideration in an all-encompassing manner. As such, an operations and maintenance evaluation can and should reflect the situation from an operations team's ability assessment perspective, including a standard assessment of adopted techniques, an operational safety production scheme evaluation, operational environment protection scheme evaluation, operational emergency response assessment, operational specification document evaluation, maintenance technical scheme evaluation, maintenance team evaluation and finally, a maintenance specification document evaluation (Mahalingam et al., 2010).

Thus, the first-level index of an operation and maintenance program evaluation is composed of nine second-level indexes, namely a) an operations team ability assessment, b) a standard assessment of adopted techniques, c) an operational safety production scheme evaluation, d) an operational environment

arget layer	First-level index	Second-level index
		Corporate credit rating X ₁₁
		Dusiness negates of similar projects V

Table 1. The Index System for the Selection of a Social Capital Partner in the New Profit PPP Project

Target layer	First-level index	Second-level index	
		Corporate credit rating X ₁₁	
	Reputation and performance evaluation X_1	Business results of similar projects X ₁₂	
		Corporate qualification conditions X ₁₃	
		Corporate social influence X ₁₄	
	Price factor evaluation X ₂	Non-subsidy price level X ₂₁	
		Financing schedule rationality X ₃₁	
		Financing capability evaluation X ₃₂	
	Financing plan evaluation X ₃	Comprehensive capital cost rate of financing X ₃₃	
		Financing channel evaluation X ₃₄	
		Risk evaluation of financing plan X ₃₅	
New Profit PPP Project Social	Construction project evaluation X ₄	Project design organization project evaluation X ₄₁	
Capital Partner Evaluation and		Project construction organization scheme evaluation X_{42}	
Review under PPP Model		Operations team ability assessment X ₅₁	
		Standard assessment of adopted techniques X_{52}	
	Operation and maintenance program evaluation X.	Operational safety production scheme evaluation $X_{\scriptscriptstyle 53}$	
		Operational environment protection scheme evaluation X_{54}	
		Operational emergency response assessment X_{55}	
	,	Operational specification document evaluation X_{56}	
		Maintenance technical scheme evaluation X ₅₇	
	Transfer scheme evaluation X ₆	Maintenance team evaluation X ₅₈	
		Maintenance specification document evaluation X_{59}	
		Project transfer plan evaluation X_{61}	
		Project transfer project risk assessmentX ₆₂	

protection scheme evaluation, e) an operational emergency response assessment, f) an operational specification document evaluation, g) a maintenance technical scheme evaluation, h) a maintenance team evaluation and i) a maintenance specification document evaluation.

(6) Second-level index establishment of a transfer scheme evaluation under first-level indexes

Since the first-level indexes of transfer scheme evaluation is used to evaluate the feasibility of the transfer scheme evaluation of each social capital partner in the new profit PPP project, the index can reflect the situation from the perspectives of a project transfer plan evaluation and project transfer project risk assessment.

Thus, the first-level index of a construction project evaluation includes two second-level indexes, namely a project transfer plan evaluation and a project transfer risk assessment.

According to the above analysis, we can establish an index system for the social capital partner selection process by implementing a comprehensive evaluation method, as shown in Table 1.

We can reach numerous conclusions from the evaluation index system of potential social capital partners established under the comprehensive method outlined in Table 1. First we see that, based on the characteristics and practices of any new profit PPP project, this index system combines the requirements and specific procedures required by all social capital partners in any new profit PPP project. In addition, our system has established an evaluation index system of new profit PPP project potential social capital partners which uses a total score evaluation method. This method, in turn, is composed of six first-level indexes and twenty-three second-level indexes. These indexes relate to reputation and performance evaluation, price factor evaluation, financing plan evaluation, construction project evaluation, operation and maintenance program evaluation and transfer scheme evaluation. Once compiled, this information can fully reflect the level of compatibility between potential social capital partners and specific new profit PPP projects (Gurgun et al., 2014). As such, our index can provide reference points for the selection of social capital partners carried out. The selection can be made jointly by the project implementation party and the government.

5. Methodology

The essence of establishing an effective process for the selection of social capital partners is to set up a model that can find the best candidate from the multiple options. In addition, all alternative partners should be placed in order of suitability, which calls for the adoption of the Optimization Theory (Suh *et al.*, 2017). The Optimization Theory is designed to pinpoint the best solution from a number of programs through certain qualitative and quantitative analyses. More commonly used methods include the ideal solution, fuzzy comprehensive evaluation method, matter element analysis method, and principal component analysis, among others. On the basis of a comprehensive comparison of the various methods, this paper attempts to improve the traditional ideal solution (Technique for Order Preference by Similarity to an Ideal Solution, TOPSIS).Based on our findings, the selection model for a new profit PPP project social capital partners is constructed.

Compared with other optimization methods, the advantage of TOPSIS is its applicability to ranking all schemes by use of the original data matrix, which is based on standardization, to find the optimal and worst schemes out of limited schemes. The distances between the optimal and the worst schemes, as well as the degree of closeness between the optimal and all other schemes, can be obtained. This method can make full use of the original data, maximally exclude the influence of other factors, and maintain impartiality.

5.1 Limitations Analysis of the Traditional TOPSIS Method There are two limitations in the traditional TOPSIS model:

(1) The determination of index weight cannot be conducted. Thus, the TOPSIS method is mainly aimed at the analysis of numerical processing. TOPSIS cannot determine the weight of each index, which leads to deficiencies in solving problems while carrying out multi-level and multi-index problem discussions.

(2) The TOPSIS method cannot handle the problem of multiperson decision-making. The traditional TOPSIS method fails to offer the index characteristic value processing method under conditions of multi-person decision-making. This failure results in deficiencies when solving multi-person decision-making problems.

5.2 Establishment and Implementation of a Social Capital Partner Evaluation Model, Based on an Improved TOPSIS Method

According to the previous analysis, the traditional TOPSIS method has certain limitations. Based on this fact, we found it necessary to improve the traditional TOPSIS method to solve its deficiencies and establish an improved social capital partner evaluation TOPSIS model. Our new method operates under the conditions of cooperation between the government and a social capital investor, working together on a new profit PPP project. Our method ensures the effectiveness of evaluating new profit PPP project social capital partners.

Specifically, the ideas for the improvements to the traditional TOPSIS model are as follows:

(1) Introduce the GAHP method to determine the weight. At the same time, take into account the inherent deficiencies of the traditional GAHP method. Based on this approach, our study tends to improve the traditional GAHP method, thereby forming a better GAHP method and also providing effective support for the weight determination of the new profit PPP project social capital partner evaluation.

(2) In view of the fact that the traditional TOPSIS model cannot deal with multi-person decision-making issues, a model with index characteristics which value multi-person decision-making is to be established. This model is used with a TOPSIS model to provide effective support for the conducting of social capital partner evaluations, and especially for the determination of index characteristic values.

Thus, the steps to establish a social capital partner selection model (based on the improved TOPSIS method) are as follows:

STEP1: Establish an index system of social capital partner selection for the new profit PPP project.

The index system used for social capital partner selection in the new profit PPP project is shown in Table 1.

STEP2: Determine the index weight for social capital partner selection in the new profit PPP project.

As the traditional TOPSIS model cannot determine the weight of the index system, this study introduces the GAHP method. GAHP is a method whereby multiple experts determine the index weight based on the AHP method. This process makes up for the deficiencies of the AHP method inherent in a singleperson decision-making process. In the GAHP method, experts should determine the weight of the index system according to the steps and requirements of the AHP method. The arithmetic mean of the index weights given by the experts is then taken as the final weight.

The GAHP method can achieve the objective of multi-person decision-making. However, the relative importance of the two comparison values between the two indexes can only be achieved among sets from "1-9" (Fatemeh Torfi *et al.*, 2011). As the experts' judgment of the relative value of the two indexes cannot be expressed as a single number, the interval value can better reflect the views of the experts. Furthermore, experts, due to their different experiences and statuses, may differ in their opinions of the importance of weight determination in the process of index weight determination. It is necessary, therefore, to clarify the weight determined by the experts.

Thus, this study intends to improve the traditional GAHP method, thus forming a superior GAHP method, one which can be applied to the weight determination of social capital partner selection in the new profit PPP project.

As the core intention of the GAHP method is to determine the relative importance comparison value between indexes, this study mainly discusses the method of determining the relative importance comparison value between indexes.

Assume that a total of *K* experts participate in the selection of social capital partners. In the process of determining the weight of index system, the relative importance comparison interval value of x_g and x_h under the same hierarchy of the K (k = 1, 2, ..., K) experts is $[d_{1e}^{(k)}, d_{2e}^{(k)}]$ ($d_{2e}^{(k)} \ge d_{1e}^{(k)}$), and the weight of each expert is $c_k(k = 1, 2, ..., K)$, respectively. Then, the relative importance comparison value is

$$f_{g,h} = \frac{1}{2} \cdot \frac{\sum_{k=1}^{K} \{ [d_{2e}^{(k)}]^2 - [d_{1e}^{(k)}]^2 \} \cdot c_k}{\sum_{k=1}^{K} [d_{2e}^{(k)} - d_{1e}^{(k)}] \cdot c_k}$$
(1)

After determining the relative importance comparison value between indexes under the same hierarchy based on the above method, we can determine the weight of the index selection system of social capital partners in accordance with the steps and requirements of the AHP method.

The weight of x_{ij} in the social capital partners' selection index system is $w_{ij}(i = 1, 2, ..., m; j = 1, 2, ..., n)$, which is determined by the above, improved AHP method.

STEP3: Determine the single index characteristic matrix X

The evaluation value of a number of n alternative social capital partners is composed of a number of m evaluation indexes. The evaluation of each evaluation index to n alternative social capital partners can be expressed by an index characteristic value, namely,

$$X = \begin{pmatrix} x_{11} & \dots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \dots & x_{mn} \end{pmatrix} = (x_{ij})_{m \times n}$$
(2)

Here, x_{ij} (i = 1, 2, ..., m; j = 1, 2, ..., n) is the index characteristic value of the *i* evaluation factor of *j* alternative social capital partners.

(1) Determination of the characteristic value of a quantitative index

In the index selection system for social capital partners in a new profit PPP project, two of the second-level indexes belong to the quantitative indexes. These quantitative indexes are the non-subsidiary price level (X_{21}) and the comprehensive capital cost rate of financing the scheme (X_{33}).

i. The methods of determining the characteristic value of the non-subsidiary price level (X_{21}) are as follows:

According to the above definition, the non-subsidiary price level (X_{21}) is the scheme targeted at the alternative social capital partners, in order to calculate the non-subsidiary price and take the average mean of the non-subsidiary price as the basis upon which to calculate the non-subsidiary price level. The lower the non-subsidiary price of the social capital partners, the higher the non-subsidiary price level.

On this basis, assume that the non-subsidiary price of each social capital partner is p_i (i = 1, 2, ..., m), the average mean of the non-subsidiary price of social capital partners is p_0 , and the non-subsidiary price level of each social capital partner is q_i (i = 1, 2, ..., m), then:

$$\begin{cases} q_{i} = 1 - \frac{p_{i} - p_{0}}{p_{0}} \\ p_{0} = \frac{\sum_{i=1}^{m} p_{i}}{m} \end{cases}$$
(3)

ii. The methods of determining the characteristic value of the comprehensive capital cost rate of financing the scheme (X_{33}) are as follows:

Assume that the comprehensive capital cost rate of financing scheme is u, the capital source of each financing scheme is f, and the weight of each capital to all the capital is v_d (d = 1, 2, ..., f),

then:

$$u = \sum_{d=1}^{f} a_d \cdot v_d \tag{4}$$

(2) Determination of the characteristic value of qualitative indexes

In the index selection system of social capital partners in a new profit PPP project, 21 of the second-level indexes belong to qualitative indexes, namely, indexes other than the non-subsidiary price level (X_{21}) and the comprehensive capital cost rate of financing the scheme (X_{33}). The expert evaluation method is adopted to determine the characteristic value.

Each index evaluation interval value of the 21 second-level indexes in the index selection system for social capital partners in a new profit PPP project is given by the experts in the review team. Then, the method of determining the characteristic value of the qualitative indexes is as follows:

Assume that a total of K experts participate in the selection of social capital partners. The interval value of a certain qualitative index x_{ij} given by the k (k = 1, 2, ..., K) is $[v_{1h}^{(k)}, v_{2h}^{(k)}]$ ($v_{2h}^{(k)} \ge v_{1h}^{(k)}$), the weight of each expert is c_k (k = 1, 2, ..., K); then, the characteristic value of the qualitative index x_{ij} is

$$x_{ij} = \frac{1}{2} \cdot \frac{\sum_{k=1}^{K} \{ [v_{2h}^{(k)}]^2 - [v_{1h}^{(k)}]^2 \} \cdot c_k}{\sum_{k=1}^{K} [v_{2h}^{(k)} - v_{1h}^{(k)}] \cdot c_k}$$
(5)

According to Eq. (5), we determine the index characteristic value of each qualitative index in the selection of social capital partners in a new profit PPP project, respectively, and the interval value of the index characteristic value is [0, 100].

STEP4: Determine the index membership degree matrix R

After determining the characteristic value x_{ij} of each evaluation index, it is necessary to calculate the relative membership degree of each index. In the index system established in this study, there are "the larger the better" type indexes and "the smaller the better" type indexes.

(1) Index membership degree calculation of "the smaller the better" type indexes.

For the smaller the better type indexes, the formula for the index membership degree calculation is as follows:

$$r_{ij} = 1 - \frac{x_{ij}}{x_{imax} + x_{imin}} \quad (j = 1, 2, ..., n)$$
(6)

Here, r_{ij} refers to the optimum level of the *i* index of the *j* alternative social capital partner; $x_{imax} = \max \{x_{ij}\}, x_{imin} = \min \{x_{ij}\}$.

In the established index system, three indexes belong to the smaller the better type indexes, namely1) the comprehensive capital cost rate of financing scheme X_{33} , 2) the risk assessment of financing scheme X_{35} and, 3) the transfer project risk assessment program X_{62} .

(2) Index membership degree calculation of the larger the better type indexes

For the larger the better type indexes, the formula for the index membership degree calculation is as follows:

$$r_{ij} = \frac{x_{ij}}{x_{imax} + x_{imin}} \quad (j = 1, 2, ..., n)$$
(7)

Here, r_{ij} refers to the optimum level of the *i* index of the *j* alternative social capital partner; $x_{imax} = \max \{x_{ij}\}, x_{imin} = \min \{x_{ij}\}$.

In the established index system, other indexes are the larger the better type indexes, except for the smaller the better type indexes with a total number of four.

According to Eq. (6) and Eq. (7), the index characteristic value matrix will be converted to an index membership matrix, as follows:

$$R = \begin{pmatrix} r_{11} & \dots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \dots & r_{mn} \end{pmatrix} = (r_{ij})_{m \times n}$$
(8)

STEP5: Determine the most ideal social capital partners and the least ideal social capital partners.

The index membership rate of the ideal social capital partners is supposed to be the maximum value of the corresponding index membership degree of all alternative social capital partners, that is:

$$R = (r_1^* \quad r_2^* \quad \cdots \quad r_i^* \quad \cdots \quad r_n^*)_{1 \times n}$$
(9)

Here, $r_i^* = \max_i \{x_{ij}\}$ (i = 1, 2, ..., m).

The index membership rate of the negative social capital partners is supposed to be the minimum value of the corresponding index membership degree of all alternative social capital partners, that is:

$$R = (r_1 \quad r_2 \quad \cdots \quad r_i \quad \cdots \quad r_n)_{1 \times n}$$
(10)

Here, $\bar{r_i} = \min_i \{x_{ij}\} \ (i = 1, 2, ..., m).$

STEP6: Calculate the different degrees of the alternative social capital partners to the ideal social capital partners, as well as to the least ideal social capital partners.

Adopt the Weighted Euclidean Distance to measure the difference in the degree d_j^* and d_j^- of alternative social capital partners to the ideal social capital partners and the least ideal social capital partners, as follows:

$$d_{j}^{*} = \sqrt{\sum_{i=1}^{m} W_{i} (r_{ij} - r_{i}^{*})^{2}}$$
(11)

$$d_{j}^{-} = \sqrt{\sum_{i=1}^{m} W_{i} (r_{ij} - r_{i}^{-})^{2}}$$
(12)

Here, *j* = 1, 2, ..., *n*.

SETP7: Calculate the closeness degree of the alternative social capital partners to the ideal social capital partners.

Define the closeness degree of *j* alternative social capital partners to the ideal social capital partners as C_j , and then the expression is:

$$C_{j} = d_{j}^{-} / (d_{j}^{*} + d_{j}^{-})$$
(13)

Generally, in the $0 \le C_j \le 1$, the closer the C_j to 1, the higher the membership degree of the corresponding alternative social capital partners. According to the value of C_j , the order of the alternative social capital partners can be made, thus providing effective support for the selection of social capital partners in a new profit PPP project.

6. Applications

6.1 Overview of the Project and Implementation Steps of the Selection of Social Capital Partners

The main task of the people responsible for southern water resources allocation is based upon city life and the production of a water supply. Their job is to solve the problem of ecological water shortages and at the same time to realize the optimal allocation of regional water resources in the southern provinces. This group must also solve the problem of urban water shortages in the eastern region and to develop and implement a multi-water resources strategy in eastern cities. The urgency of the project's construction and the lack of government financial resources placed new requirements on the project's investment and financing model. The project managers and government departments are supposed to solve the problem of the shortage of funds needed for the project's implementation. The problem could be solved through innovation in terms of investment and financing mechanisms to overcome the lack of government funding support. Because of the lack of funding and urgency of the situation, the government decided to use the PPP model for this project. In the process of implementing the project by using the PPP model, one important task is to select the social capital partner(s).

As the southern water resources allocation project is complex and requires a large amount of investment, the demand for social capital is higher. In order to ensure the effectiveness of the selection of social capital partners for the southern water resources allocation project, the comprehensive evaluation method should be adopted throughout the course of the selection of the social capital partners.

In the process of selecting the social capital partners for the southern water resources allocation project, the evaluation team was organized by the water conservancy department. This department is composed of seven members and participates throughout the entire PPP implementation process.

6.2 Determination of Index Weight

In order to define the weight of each index in the evaluation criteria, a panel of experts determines the index weight according to the requirements of the improved GAHP method. These experts further determine the weight of the evaluation index system of the social capital partners in the southern water resources allocation project and combine the characteristics of the southern water resources allocation project and the requirements of the social capital partners.

In the process of determining the weight of index system, seven members in the evaluation group are responsible for determining the relative importance comparison values of the two indexes under each level. The detailed information about the seven experts are shown in Table 2.

The interval value of relative importance ranges between [0, 1], and the relative importance comparison values of the two indexes are calculated according to Eq. (1).

According to the above-described manner, we can calculate the relative importance of each level under the comparison value index system and perform data processing. This will enable us to form the weights of the evaluation index system of social capital partners in the southern water resources allocation project, according to the steps and requirements of the GAHP method (Table 3).

6.3 Implementation of Selection

After a series of links, three enterprises participated in bidding

Surname	Title	Work Unit	Qualification	Expertise
Tan	Vice Professor	Hohai University	Consulting Engineer; Cost Engineer	Project management
Yao	Professor	Yangzhou University	Consulting Engineer	Project Financing
Jian	Senior Engineer	Water Conservancy Bureau of Guangdong Province	Cost Engineer	Project management
Li	Senior Engineer	Water Conservancy Bureau of Guangdong Province	Consulting Engineer	Construction Technology of Water Conservancy Project
Wang	Senior Engineer	Water Conservancy Bureau of Guangdong Province	Consulting Engineer; Cost Engineer	Construction Technology of Water Conservancy Project
Liu	Senior Engineer	Engineering Consulting Center of Guangdong Province	Consulting Engineer	Construction Technology of Water Conservancy Project
He	Senior Engineer	Pearl River Water Resources Commission of the Ministry of Water Resources	Consulting Engineer; Cost Engineer	Project Financing

Table 2. Detailed Information of the Seven Experts

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	-		-
Target layer	First-level index	Second-level index	The weight of second-level index against target-level
		Corporate credit rating X ₁₁	0.0420
	Reputation and performance	Business results of similar projects X ₁₂	0.0388
	evaluation X ₁	Corporate qualification conditions X ₁₃	0.0320
		Corporate social influence X ₁₄	0.0331
	Price factor evaluation X ₂	Non-subsidy price level X_{21}	0.2850
		Financing schedule rationality X_{31}	0.0329
		Financing capability evaluation X ₃₂	0.0412
	Financing plan evaluation X ₃	Comprehensive capital cost rate of financing X_{33}	0.0380
		Financing channel evaluation X ₃₄	0.0357
		Risk evaluation of financing plan X ₃₅	0.0412
Social Capital Partners in the Southern Water Resources Allocation Project Evaluation and	Construction project evaluation X ₄	Project design organization project evaluation X_{41}	0.0373
		Project construction organization scheme evaluation X_{42}	0.0517
		Operations team ability assessment X_{51}	0.0234
Review (O)		Standard assessment of adopted techniques X52	0.0264
	Operation and maintenance program evaluation X ₅	Operational safety production scheme evaluation X_{53}	0.0252
		Operational environment protection scheme evaluation X54	0.0262
		Operational emergency response assessment X ₅₅	0.0232
		Operational specification document evaluation X ₅₆	0.0191
		Maintenance technica l scheme evaluation X_{57}	0.0243
		Maintenance team evaluation X ₅₈	0.0224
		Maintenance specification document evaluation X ₅₉	0.0247
	Transfer scheme evaluation V	Project transfer plan evaluation X_{61}	0.0397
	Transfer scheme evaluation Λ_6	Project transfer project risk assessmentX ₆₂	0.0363

Table 3. The Weights of Evaluation Index System of Social Capital Partners in the Southern Water Resources Allocation Project

Table 4. The Characteristic Value Results of the Social Capital Partners in the Southern Water Resources Allocation Project

First-level index	Second-level index	YGGS	ZGSW	WLY
	Corporate credit rating X ₁₁	1.10	0.99	0.92
Reputation and performance	Business results of similar projects X ₁₂	94.52	87.34	78.23
evaluation X_1	Corporate qualification conditions X ₁₃	98.23	84.21	84.52
	Corporate social influence X ₁₄	89.45	90.45	84.21
Price factor evaluation X ₂	Non-subsidy price level X_{21}	1.10	0.99	0.92
	Financing schedule rationality X_{31}	87.34	81.23	78.39
	Financing capability evaluation X ₃₂	89.21	78.45	82.34
Financing plan evaluation X ₃	Comprehensive capital cost rate of financing X ₃₃	5.67%	6.74%	7.23%
	Financing channel evaluation X ₃₄	84.21	89.45	78.45
	Risk evaluation of financing plan X ₃₅	25.67	35.32	45.21
Construction project evaluation X ₄	Project design organization project evaluation X ₄₁	93.45	90.23	83.12
	Project construction organization scheme evaluation X ₄₂	88.73	85.32	88.98
	Operations team ability assessment X_{51}	91.34	93.21	83.45
	Standard assessment of adopted techniques X52	83.21	80.34	81.23
	Operational safety production scheme evaluation X ₅₃	79.42	82.12	74.56
	Operational environment protection scheme evaluation X ₅₄	82.34	80.14	78.91
operation and maintenance program evaluation X.	Operational emergency response assessment X ₅₅	76.34	79.74	71.23
program evaluation X ₅	Operational specification document evaluation X ₅₆	83.45	81.23	79.81
	Maintenance technical scheme evaluation X ₅₇	82.34	80.34	78.04
	Maintenance team evaluation X ₅₈	80.32	81.21	74.56
	Maintenance specification document evaluation X ₅₉	85.21	87.69	82.12
Transfer scheme evaluation V	Project transfer plan evaluation X_{61}	78.93	80.34	77.37
Transfer scheme evaluation λ_6	Project transfer project risk assessmentX ₆₂	32.37	31.01	39.45

for the southern water resources allocation project as social capital partners. All three companies are already engaged in the operation of urban water schemes, such as YGGS, ZGSW and WLY.

The specific process of selecting the southern water resources allocation project social capital partners is as follows:

(1) Determination of characteristic value of index

Based on the information provided in the three companies' bidding documents, the experts in the evaluation panel determined the interval value of each bidder's index evaluation through the combination of evaluation criteria of social capital partners for the southern water resources allocation project. Based on the experts' findings, they determined the index characteristic value of the non-subsidiary price level (X_{21}) and the comprehensive capital cost rate of financing scheme (X_{33}), respectively, according to Eq. (3) and Eq. (4). It was then possible to calculate the index characteristic value of the other 21 qualitative indexes according to Eq. (5). The index characteristic value results of the social capital partners in the southern water resources allocation project are shown in Table 4.

(2) Determination of index membership degree matrix R

After the determination of the three bidders' index characteristic values (using the evaluation index system for social capital partners in the southern water resources allocation project), the index membership degree of each index was identified according to Eq. (5) and Eq. (6), in order to form the index membership degree matrix R.

The results of the selection of index membership degree matrix for the southern water resources allocation project are shown in Table 5.

Determination of the most ideal social capital partners and the least ideal social capital partners

We determine the most ideal social capital partners and the least ideal social capital partners according to Eq. (9) and Eq. (10).

The results of determining the most ideal social capital partners and the least ideal social capital partners for the southern water resources allocation project are shown in Table 6.

(4) Calculation of the difference in the degrees of the alternative social capital partners to the most ideal social capital partners and the least ideal social capital partners, according to Eq. (11) and Eq. (12)

The differences in the degree of bidders d_j^* to the most ideal social capital partners and the least ideal social capital partners d_j^- for the southern water resources allocation project social capital partner evaluation process is shown in Table 7.

(5) Closeness degree calculation of alternative social capital partners to the most ideal social capital partners

We calculate the closeness degree of bidders to the most ideal social capital partners according to Eq. (13).

The results of the closeness degree of alternative social capital partners to the most ideal social capital partners and the least ideal social capital partners for the southern water resources allocation project social capital partner evaluation process are shown in Table 8.

(6) The ranking and negotiation of alternative social capital partners

According to the evaluation results, the ranking of the three

				•
First-level index	Second-level index	YGGS	ZGSW	WLY
	Corporate credit rating X ₁₁	0.54	0.49	0.46
Reputation and performance	Business results of similar projects X ₁₂	0.55	0.51	0.45
evaluation X ₁	Corporate qualification conditions X ₁₃	0.54	0.46	0.46
	Corporate social influence X ₁₄	0.51	0.52	0.48
Price factor evaluation X ₂	Non-subsidy price level X ₂₁	0.54	0.49	0.46
	Financing schedule rationality X_{31}	0.53	0.49	0.47
	Financing capability evaluation X ₃₂	0.53	0.47	0.49
Financing plan evaluation X ₃	Comprehensive capital cost rate of financing X ₃₃	0.56	0.48	0.44
	Financing channel evaluation X ₃₄	0.50	0.53	0.47
	Risk evaluation of financing plan X ₃₅	0.64	0.50	0.36
Construction project evaluation X ₄	Project design organization project evaluation X_{41}	0.53	0.51	0.47
	Project construction organization scheme evaluation X_{42}	0.51	0.49	0.51
	Operations team ability assessment X_{51}	0.52	0.53	0.47
	Standard assessment of adopted techniques X52	0.51	0.49	0.50
	Operational safety production scheme evaluation X ₅₃	0.51	0.52	0.48
	Operational environment protection scheme evaluation X_{54}	0.51	0.50	0.49
operation and maintenance program evaluation X.	Operational emergency response assessment X55	0.51	0.53	0.47
program evaluation <i>x</i> ₅	Operational specification document evaluation X ₅₆	0.51	0.50	0.49
	Maintenance technical scheme evaluation X_{57}	0.51	0.50	0.49
	Maintenance team evaluation X ₅₈	0.52	0.52	0.48
	Maintenance specification document evaluation X ₅₉	0.50	0.52	0.48
Transfer scheme evaluation V	Project transfer plan evaluation X_{61}	0.50	0.51	0.49
Transfer scheme evaluation Λ_6	Project transfer project risk assessmentX ₆₂	0.54	0.56	0.44

First-level index	Second-level index	The most ideal social capital partners	The east ideal social capital partners
	Corporate credit rating X ₁₁	0.54	0.46
Reputation and performance	Business results of similar projects X ₁₂	0.55	0.45
evaluation X_1	Corporate qualification conditions X_{13}	0.54	0.46
	Corporate social influence X ₁₄	0.52	0.48
Price factor evaluation X ₂	Non-subsidy price level X ₂₁	0.54	0.46
	Financing schedule rationality X ₃₁	0.53	0.47
	Financing capability evaluation X ₃₂	0.53	0.47
Financing plan evaluation X ₃	Comprehensive capital cost rate of financing X ₃₃	0.56	0.44
	Financing channel evaluation X ₃₄	0.53	0.47
	Risk evaluation of financing plan X ₃₅	0.64	0.36
Construction project evaluation V	Project design organization project evaluation X_{41}	0.53	0.47
Construction project evaluation X_4	Project construction organization scheme evaluation X_{42}	0.51	0.49
	Operations team ability assessment X_{51}	0.53	0.47
	Standard assessment of adopted techniques X_{52}	0.51	0.49
	Operational safety production scheme evaluation X ₅₃	0.52	0.48
	Operational environment protection scheme evaluation X_{54}	0.51	0.49
program evaluation X.	Operational emergency response assessment X55	0.53	0.47
program evaluation 715	Operational specification document evaluation X ₅₆	0.51	0.49
	Maintenance technical scheme evaluation X_{57}	0.51	0.49
	Maintenance team evaluation X ₅₈	0.52	0.48
	Maintenance specification document evaluation X ₅₉	0.52	0.48
Transfer scheme evaluation V	Project transfer plan evaluation X_{61}	0.51	0.49
Transfer scheme evaluation Λ_6	Project transfer project risk assessmentX ₆₂	0.56	0.44

Table 6. The Result of Selecting the Most Ideal Social Capital Partner and the Least Ideal Social Capital Partner for the Southern Water Resources Allocation Project

Table 7.	Differences in the Degrees of the Alternative Social Capi-
	tal Partners Compared to the Most Ideal Social Capital
	Partners and the Least Ideal Social Capital Partners

Bidders	d_j^*	d_j^-
YGGS	0.0001	0.0079
ZGSW	0.0025	0.0024
WLY	0.0081	0.0000

Table 8. The Closeness Degree of the Alternative Social Capital Partners to the Most Ideal Social Capital Partners

Bidders	d_j^*	d_j^-	C_j
YGGS	0.0001	0.0079	0.9875
ZGSW	0.0025	0.0024	0.4898
WLY	0.0081	0.0000	0.0000

bidders for the social capital partners is as follows: YGGS ranks first, ZGSW ranks second, and WLY ranks last.

The panel of judges and YGGS confirmed all the issues related to contract negotiations and reached a consensus. Accordingly, after the confirmation of the signing of the negotiation, publication and approval of the relevant documents, the water conservancy department and YGGS signed the PPP contracts.

7. Conclusions

In the context of China's economy entering into the "New

Normal", the capital cooperation between government and social capital investors has become an important means to ease financial pressure and improve the efficiency of government management. For profit PPP projects, the adoption of a PPP model is not only the general trend. The use of a PPP model is also an important measure by which the government's public services can be improved. In a PPP model, social capital partners play an important role. Thus, scientific methods should be adopted to select the most suitable social capital partners.

Based on the identification of an effective public bidding selection method, as well as a comprehensive evaluation method process, we have constructed an index system for social capital partner selection in a new profit PPP project. Selection will be made, among other factors, based on reputation and performance evaluation, price factor evaluation, financing plan evaluation, construction project evaluation, operation and maintenance program evaluation, and transfer scheme evaluation. We set up a model to evaluate social capital partners on the basis of an improved TOPSIS method. Our model provides effective support for the implementation of the evaluation process when seeking social capital partners for the new profit PPP project.

For a period of time, the Chinese government will continue to promote the PPP model, so it is extremely important to ensure that the selection of social capital partners is standardized. This study has established an index system that contains too many qualitative indexes, and so, the result can be easily influenced by subjective intentions. Therefore, the direction of future research should be toward the construction of an index system that contains more quantitative indexes.

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