Research on management innovation and performance evaluation of municipal engineering projects under PPP mode

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Abstract: As an innovative financing and management model, public-private partnership (PPP) has been widely used in the field of municipal engineering. However, PPP model also faces challenges such as complex project management, uneven risk distribution and difficult performance evaluation. This paper discusses the path and strategy of municipal engineering project management innovation under PPP mode, and constructs a scientific and reasonable performance evaluation system. It is found that integrated life cycle management, risk sharing mechanism optimization, performance management system construction, multi-agent collaborative governance and intelligent and green integration practice are the innovative paths to promote PPP project management. Based on the life cycle characteristics of PPP municipal engineering projects and the needs of stakeholders, this paper constructs a performance evaluation system including four first-class indicators: financial performance, public service quality, project management efficiency and sustainability, and uses fuzzy comprehensive evaluation method to evaluate it. Through case analysis, this paper finds that PPP projects have outstanding performance in service quality, but there is still room for improvement in cost control, management efficiency and sustainability. According to the evaluation results, this paper puts forward some improvement suggestions, such as introducing dynamic cost monitoring system, establishing preventive maintenance system and promoting low-carbon transformation, in order to improve the management level and operational efficiency of PPP projects and promote the healthy development of PPP model.

1. Introduction

In recent years, with the acceleration of urbanization and the increasing demand for infrastructure construction, the traditional single government investment model has been difficult to meet the increasing demand for public services. In this context, the Public-Private Partnership (PPP) model, as an innovative financing and management model, has been widely used worldwide [1]. By introducing private capital to participate in the construction and operation of public infrastructure, PPP mode can not only alleviate the financial pressure of the government, but also improve the operational efficiency and service quality of the project. In the field of municipal engineering, PPP mode is widely used, covering roads, bridges, water supply, sewage treatment, garbage disposal and many other aspects [2]. However, PPP mode also faces many challenges in actual operation, such as complex project management, uneven risk distribution and difficult performance evaluation. Therefore, it is of great theoretical and practical significance to study the management innovation and performance evaluation of municipal engineering projects under PPP mode.

This study discusses the path and strategy of municipal engineering project management innovation under PPP mode, and constructs a scientific and reasonable performance evaluation system. This will not only help to improve the management level and operational efficiency of PPP municipal engineering projects, but also provide decision support for the government and social capitalists and promote the healthy development of PPP model. In addition, the results of this study can also provide reference for PPP projects in other fields, and promote the wide application of PPP model in China and even around the world.

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2. Research on innovation of municipal engineering project management under PPP mode

2.1 Driving factors of management innovation

The state vigorously promotes PPP mode to stimulate the vitality of private investment, and relevant policies such as Guiding Opinions on Promoting and Social Capital Cooperation Mode in Public Service Field and Franchising Law of Infrastructure and Public Utilities provide legal basis and operational framework for project implementation. Local governments also attract social capital through tax incentives, land supply and other ways to promote the reform of management model [3]. In addition, the State Council emphasized resolving local debt crisis and improving the management level of engineering construction industry through PPP, which further promoted the practical exploration of management innovation.

Traditional municipal engineering relies on government financial allocation and faces the bottleneck of fund shortage. PPP mode introduces social capital to share investment responsibility, broadens financing channels, reduces the risk of government debt and ensures the feasibility of the project. This diversified fund-raising mechanism forces managers to optimize resource allocation and improve the efficiency of fund use. Compared with the traditional model in which the government bears all risks, PPP clarifies the rights and responsibilities of all parties through contracts, and disperses the construction, operation and maintenance risks to the private sector with more professional capabilities. For example, social capitalists can effectively control cost overruns, construction delays and other issues by virtue of technology and management experience, and urge the government and market players to jointly seek more efficient ways of cooperation [4].

The Ministry of Finance and other departments require the establishment of a scientific performance evaluation system, the implementation of a pay-per-performance mechanism, and the introduction of third-party evaluation to ensure the quality of public services. This policy pressure pushes managers to change from extensive to refined, and pays attention to dynamic monitoring and result feedback in the whole life cycle. The application of new technologies such as big data and artificial intelligence provides new tools for project management. The construction of information platform realizes real-time tracking of project progress, intelligent allocation of resources and digital support of decision-making, which has become the key force driving the upgrading of management process [5].

2.2 The path and strategy of management innovation

2.2.1 Whole life cycle integrated management

Break the limitation of traditional segmented management, and adopt the mode of "integration of consulting, investment and construction" to integrate the links of consulting, investment and construction, so as to form the synergistic effect of vertical industrial chain. Through the integration of PPP consulting business chain, the seamless connection from pre-planning to post-operation and maintenance can be realized, and the efficiency loss caused by information islands can be reduced [6]. BIM technology and Internet of Things equipment are used to digitally control the whole process of design, construction and operation, so as to improve the inter-stage coordination ability.

2.2.2 Optimization of risk sharing mechanism

Refine the risk list and establish a dynamic adjustment mechanism to flexibly allocate risks according to project characteristics. Bundle operational resources in livelihood projects with unstable income to balance the cash flow of non-profit and for-profit sub-projects; In view of the compliance risks caused by imperfect laws, dispute settlement clauses and bottom-up compensation schemes are set up to enhance the stability of cooperation

2.2.3 Construction of performance management system

Drawing on the concept of Balanced Scorecard (BSC), design an indicator system from four dimensions: finance, customers, internal processes, and learning and growth, and quantitatively evaluate the results using Key Event Method and Analytic Hierarchy Process. Through the

performance audit framework during the operation period, passenger satisfaction and equipment failure rate are included in the assessment and linked to financial payments to form a closed-loop incentive mechanism. Regularly conduct third-party independent evaluations and publicly disclose the results to enhance transparency and social supervision.

2.2.4 Multi-subject collaborative governance

Construct a triangular framework of government supervision, enterprise implementation and public participation. On the one hand, the role of the government has changed from direct intervention to rule-making and market supervision, and market behavior has been restrained through franchise agreements; On the other hand, residents are encouraged to express their demand preferences through hearings, questionnaires and other forms, so that the supply of public services is closer to the actual needs of people's livelihood [7].

2.2.5 Practice of integration of intelligence and greening

Using cloud computing platform to aggregate multi-source data and develop prediction models to assist decision-making; Promote low-carbon technologies such as prefabricated buildings and renewable energy applications to reduce the environmental footprint. The urban pilot "smart street lamp" system integrates functional modules such as lighting regulation and environmental monitoring to achieve the dual goals of energy saving and functional expansion.

3. Research on performance evaluation of municipal engineering projects under PPP mode

3.1 Construction of performance evaluation index system

Based on the life cycle characteristics of PPP municipal engineering projects (large investment, long cycle and public welfare) and the needs of stakeholders (government, social capital and public), an evaluation system including 4 first-level indicators and 20 second-level indicators is constructed (Table 1). Delphi method is used to solicit experts' opinions to determine the index weight, and factor analysis is used to verify the independence of the index.

Table 1 Performance evaluation index system

Primary index	Example of secondary indicators	Weight distribution
Financial performance (30%)	Return on capital and control rate of operating cost	Quantitative index
Quality of public services (35%)	Facility availability, public satisfaction, environmental compliance rate	Quantitative+qualitative
Project management efficiency (25%)	Time limit for a project compliance rate, safety accident rate, change response speed	Quantitative index
Sustainability (10%)	Low-carbon technology application rate and community impact index	Qualitative index

3.2 Performance evaluation method

After comparing various performance evaluation methods, it is found that different methods have their own advantages and disadvantages and scope of application. BSC emphasizes the multi-dimensional balance between financial and non-financial indicators and has strong strategic

orientation, but its weight setting is subjective and complicated. Key performance indicators (KPI) focus on the core objectives of the organization, which is easy to quantify and implement, but easy to ignore non-key performance factors; Data Envelopment Analysis (DEA) is accurate in efficiency evaluation, but it is only suitable for pure quantitative data, and its application scope is limited.

Considering comprehensively, the fuzzy comprehensive evaluation method was selected as the evaluation method of this project because of its outstanding ability in dealing with qualitative indicators [8]. PPP projects involve a large number of qualitative factors that are difficult to quantify, such as public satisfaction, service quality, etc. This method transforms qualitative information into computable data through membership function, and scientifically determines the index weight by combining with analytic hierarchy process (AHP) to improve the comprehensiveness and objectivity of evaluation, so it has the highest applicability and is the best choice.

3.3 Analysis of performance evaluation results and suggestions for improvement

The performance evaluation data of a sewage treatment PPP project shows that the project is outstanding in service quality, with a score of 92 (rating: excellent), a water quality compliance rate of 98% and a good financial performance (85), but there is a problem that the initial investment is overspent by 20%. In contrast, the management efficiency (70 points, qualified) and sustainability (65 points, to be improved) are relatively weak, mainly manifested in the delay of equipment maintenance response for more than 48 hours and the carbon footprint higher than that of traditional projects by 15%, indicating that there is still much room for improvement in operation management and environmental impact of the project. See Table 2. The radar chart is used to show multi-dimensional performance contrast, and the shortcomings are exposed intuitively (as shown in Figure 1, the sustainability dimension is obviously depressed).

Table 2 Evaluation data

Evaluation data dimension	Score (percentage system)	Grade	The key to the question
Financial performance	85	Good	Initial investment overspent by 20%
Quality of service	92	Excellent	The water quality compliance rate is 98%
Managerial effectiveness	70	Qualified	Equipment maintenance response delay ≥48 hours
Sustainability	65	To be improved	The carbon footprint is 15% higher than traditional projects

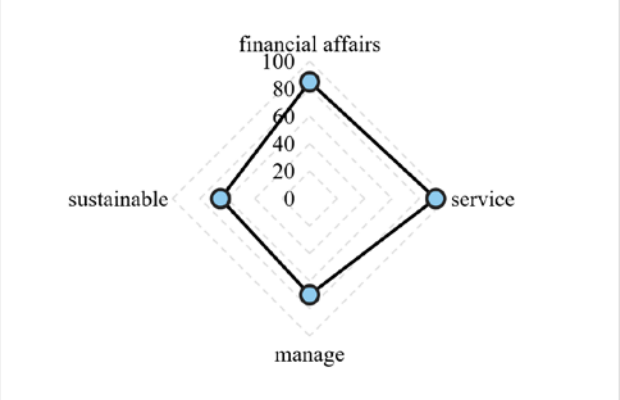

Figure 1 Multi-dimensional performance contrast radar chart

In view of the problems found in performance evaluation, it is suggested to improve from three aspects. In the aspect of cost control, the dynamic cost monitoring system such as BIM 5D model is introduced to improve the investment management accuracy and deal with the initial cost overrun problem; In operation and maintenance management, a preventive maintenance system is established, and the equipment response time target is set to no more than 24 hours to improve management efficiency; In terms of sustainable development, we will promote low-carbon transformation, effectively reduce the carbon footprint of the project and improve the environmental performance level by applying for green financial subsidies and purchasing clean energy equipment such as photovoltaic.

4. Conclusion

This study focuses on the management innovation and performance evaluation of municipal engineering projects under PPP mode, and has achieved the following important results:

(1) It is clear that national policies, financial pressure and the application of new technologies are the main driving factors. Through integrated life cycle management, optimizing risk sharing mechanism, constructing performance management system, realizing multi-agent collaborative governance and promoting the integration of intelligence and greening, the project management level and operational efficiency have been effectively improved. For example, the "integration of consulting, investment and construction" model integrates the industrial chain, and BIM technology and the Internet of Things realize the digital control of the whole process; Dynamic adjustment of risk list enhances the stability of cooperation; The index system and third-party evaluation designed by the balanced scorecard concept strengthen transparency and motivation.

(2) An evaluation system including four first-level indicators and 20 second-level indicators of financial performance, public service quality, project management efficiency and sustainability is constructed, and the weight and independence are determined by Delphi method and factor analysis. By contrast, the fuzzy comprehensive evaluation method is selected, because it can deal with qualitative indicators and determine the weight with AHP, and evaluate the project performance comprehensively and objectively. Taking a sewage treatment PPP project as an example, its service quality is excellent and its financial performance is good, but its management efficiency and sustainability need to be improved. Aiming at the problems, this paper puts forward some improvement suggestions, such as introducing BIM 5D model to control costs, establishing preventive maintenance system to improve efficiency, promoting low-carbon transformation and reducing carbon footprint.

To sum up, this study provides innovative strategies and scientific performance evaluation methods for municipal engineering project management under PPP mode, which is helpful to improve the project management level and promote the healthy development of PPP mode, and also has reference significance for PPP projects in other fields.

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