Research on Performance Evaluation in PPPs in Sewage Treatment

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Abstract. Reasonable performance evaluation is one of the critical successful factors of PPP practices. For the sewage treatment PPP projects, the performance evaluation of "Emphasis on construction, neglect operation" has not been effectively improved. The value-for-money effect was lower than expected. Based on this background, this paper intends to take the XX Sewage Treatment PPP project as the research object, which will focuses on the analysis on the system of performance evaluation and summarize present problems of the system, then redesigns the performance evaluation system. At last, this paper measures the redesigned system, and provides some suggestions that contribute to the design performance evaluation system in PPP projects in sewage treatment.

1. Introduction
China’s water pollution is serious shortage of resources. In October 2016, Ministry of Finance (MOF) of China published Notice on Cooperation in Public Services between the Government and Private Sector, which clarified that wastewater treatment projects must adopt PPP mode. During the 13th Five-year Plan, China plans to invest more than 560 billion yuan in urban sewage treatment and recycling facilities. Until March 2018, the PPP projects in sewage treatment have reached 1004(number), 292.9 billion yuan (investment). Reasonable and effective performance evaluation system is essential for PPP projects’ success. Current performance evaluation research lacks for focusing on wastewater treatment and full life cycle. This paper takes a PPP project in sewage treatment in Sichuan Province as an example. This paper would construct a performance evaluation system from the perspective of the whole life cycle, and provide a reference for PPP project performance evaluation in sewage treatment.

2. literature review
Foreign studies seldom pay their attention to performance evaluation specifically in sewage treatment PPP projects. Peter E.D. Love (2015) pointed out that performance evaluation was essential for PPP project delivery and suggested the realization of effective evaluations through BIM [1]. Most of other researches focused on identifying and assessing critical successful factors for PPP projects, while there have been few typical works for performance evaluation framework. Although PPP performance evaluation started rather late in China, it has made significant progress. Based on KPI theory, Zhao...
Xinbo (2009) extracted general performance indicators according to project’s core process [2]. Zhang Wankuan, et al. (2010) adopted factor analysis method to get four first level indicators of performance evaluation [3]. Yuan Jingfeng (2010) established a performance evaluation system with four dimensions and twenty-six key indicators and applied it to the Hong Kong Disneyland [4]. Through the BSC theory, Yan Danliang (2014) established a performance evaluation from five dimensions: project environment, financial capability, internal control and management, satisfaction of stakeholders, and innovation and development [5]. In addition to BSC, KPI and AHP, Cheng Yanmei (2014) applied the DEA [6]. Wang Taigang (2017) designed the evaluation system using the matter-element extension model [7]. Other performance assessment intended for particular fields (e.g. sports, rail traffic) all follow the previously mentioned methods [8][9][10][11]. In summary, few researches focus sewage treatment industry. Besides, there have been plenty of qualitative researches but lack for typical empirical studies.

3. literature review
The main research methods used in this paper include: literature research, field research, case analysis. At present, the guidance or documents of national level on the PPP project’s performance evaluation is brewing in succession. In combination with the policy requirements and the relevant theories on performance evaluation, this article has combed the framework of the performance evaluation system for wastewater treatment projects in PPP mode. As shown in Figure 3.1.

4. Case Study
From the public perspective, the overall target is to ensure the comprehensive management level and investment return during different periods. Concrete targets are to monitor operational performance, and to improve the technical quality of the sewage disposal and works steadily as well as improves the management level in the XX county, and to improve scientific decision-making, and to realize the reasonable deployment of the resource, and to take most advantage of investment benefits.

4.1 Targets of Performance Evaluation
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4.2 Subject and Object of Performance Evaluation
According to the Interim Regulations on Financial Administration of PPP Project promulgated by the Ministry of Finance in September 2016, the XX Environmental Protection Bureau is suitable as the evaluation subject. The XX Environmental Protection Bureau should establish functional leadership groups with industry authorities and finance departments, and supervise private capital or special purpose company (Evaluation object) to perform contractual obligations according to law.
4.3 Cycle of Performance Evaluation

This paper holds that the time span of performance evaluation of the project should include the period of construction, operation and transfer. The evaluation frequency should include both regular evaluation and contemporary evaluation mechanisms and assess the results of both mechanisms comprehensively in the final evaluation. Regular evaluation will be conducted once a quarter while the frequency and time of contemporary evaluation will be decided by the implementing institutions (no less than twice a year).

4.4 Performance Evaluation Indicator and its Weight

This chapter determines the key performance indicators of XX Project based on the method of Critical Success Factor (CSF). This paper selects the "Sewage treatment" & "PPP Project" & "Critical success factors (CSF) & "Performance Evaluation" as key words in the Web of Science database and the CNKI database respectively, then screening 60 relevant literature (Chinese and English). After studying intensively, this paper finally selects 24 articles [2] ~ [25] for CSF analysis. Table 4.2 lists the key performance indicators for the XX PPP project. Based on practical feasibility, this paper takes both the methods of Delphi method and AHP to determine the index weight. The calculation steps are shown as follows.

4.4.1 Constructing a comparison matrix. During the three periods of construction, operation and transfer, experts judged the relative importance of indicators on each level pairwise through the method of nine scales and got 18 indicators comparison matrixes of different period and levels. The nine scales are shown as in Table 4.1 [26]. In comparison matrix A, \( a_{ij} \) means the comparative importance of Row i indicators and Column j indicators, obviously \( a_{ij} > 0, a_{ij} = 1/a_{ji} \).

| Indicators 1/ J | Extremely more important | Much more important | More important | Slightly more important | Equally important |
|-----------------|--------------------------|---------------------|---------------|------------------------|------------------|
| Evaluation value| 9                        | 7                   | 5             | 3                      | 1                |

Notes: 8, 6, 4, 2, 1/2, 1/4, 1/6, 1/8 are the medians of the judgment figures above

The calculation of weight.

Continued products of elements on each row of comparison matrix A can be calculated by:

\[
M_i = \prod_{j=1}^{n} a_{ij}, i=1,2,3.....n
\]

Equation (4-1)

The \( n^{th} \) root of \( M_i \) can be calculated by:

\[
\bar{W}_i = \sqrt[n]{M_i}
\]

Equation (4 – 2)

The geometric mean of vector \( u = (\bar{W}_1, \bar{W}_2, \bar{W}_3, ..., \bar{W}_n) \) can be calculated by:
The maximum eigenvalues $\lambda_{\text{max}}$ of the comparison matrix can be calculated by:

$$\lambda_{\text{max}} = \frac{1}{n} \sum_{i=1}^{n} (AW)_i$$

Equation (4-4)

Consistency test of comparison matrix. The relative importance of indicators in the comparison matrix is gained based on the subjective judgment of experts. When it is applied into particular practice, it should meet a certain objective consistency. The key Consistency Index (CI) is.

$$CI = \frac{\lambda_{\text{max}} - n}{n-1}$$

Equation (4-5)

Along with the change of n, the judging standard of CI changes. Here Random Consistency Index (RI) is introduced in the comparison matrix. When n is more than 2, if the Consistency Ratio (CR) = CI/RI<0.10, the comparison matrix will pass the consistency test. Table 4.2 shows the value of RI.

Table 4.2. Random Consistency Index (RI).

| N  | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|----|---|---|---|---|---|---|---|
| RI | 0 | 0 | 0.52 | 0.89 | 1.12 | 1.26 | 1.36 |

The weight of indicators on each level in each period can be determined by using the aforementioned method, as is shown in Table 4.3.

4.5 Implementation path of Performance evaluation

4.5.1 Construction period: Quarterly assessment during the construction period, 90 points or above is the standard level. If the score is below 90, the EPA can deduct a portion of the return on investment. Total investment adjustment value = original investment value × assessment score / 100.

4.5.2 Operation period: If the score is lower than 90 points, the government pays = availability payment amount * (70% + 30% * assessment result / 100) + operation and maintenance service fee*assessment result / 100 - user payment. If the assessment score is between 90 and 95, the government pays = availability payment amount + operation and maintenance service fee * assessment result / 100 - user payment. If the assessment score is above 95, the government payment = availability payment amount * (75% + 30% * assessment result / 100) + operation and maintenance service fee * (assessment result / 100 + 5%) - user payment.

4.5.3 Transfer period: The scores need to be above 80 points. If the conditions are not met, the project company shall update, renovate or reset the facilities and equipment to meet the government transfer requirements. If the transfer requirements are not met within the specified time limit, the XX County Environmental Protection Bureau can withdraw the corresponding amount in the transfer guarantee.
4.6 Results and Suggestions

4.6.1 Results of the Performance Evaluation: this section evaluates the performance of the target project based on the author's research on XX wastewater treatment PPP project. As 2017 is the first operation year of XX project, this section only evaluates the construction period and operation period. The comprehensive evaluation result scores 88.011 in the construction period and 87.103 in the operation period. As shown in Table 4.3. The general condition of construction and operation is good. According to the payment formula in the project implementation plan and the evaluation result, the government payment amount is 19,918,300 yuan under the fixed evaluation standard in 2017.

Table 4.3. Performance Evaluation Indicators and Results of the XX PPP Project.

| Period | First-degree Weight | Second-degree Weight | Combination weight | Independent Score | Weight score |
|--------|---------------------|----------------------|-------------------|------------------|-------------|
| C1 Comprehensive capability of the contractor | 0.125 | C11 Managerial staff | 0.109 | 0.014 | 80 | 1.095 |
| C12 Construction equipment | 0.309 | 0.039 | 100 | 3.862 |
| C13 Subcontract management | 0.582 | 0.073 | 85 | 6.179 |
| C2 Design management | 0.250 | C21 Design quality | 1.000 | 0.250 | 75 | 18.750 |
| C3 Quality control | 0.125 | C31 System construction | 0.105 | 0.013 | 90 | 1.178 |
| C32 Program execution | 0.258 | 0.032 | 97 | 3.132 |
| C4 Schedule management | 0.125 | C41 Completion rate | 1.000 | 0.125 | 100 | 12.500 |
| C5 Cost control | 0.250 | C51 Standard degree uses of funds | 0.667 | 0.167 | 100 | 16.667 |
| C52 Overpend rate | 0.333 | 0.083 | 90 | 7.500 |
| C6 Safety, environmental protection and civilized construction management | 0.125 | C61 Safety in interior work | 0.482 | 0.060 | 83 | 5.001 |
| C62 Safety in exterior work | 0.117 | 0.015 | 87 | 1.273 |
| C63 Civilized construction management | 0.218 | 0.027 | 94 | 2.559 |
| C64 Environment protection | 0.183 | 0.023 | 85 | 1.946 |
| O1 Quality of products or services | 0.060 | O11 Quantity of sewage treatment | 0.073 | 0.004 | 100 | 0.436 |
| O12 Quality of sewage treatment | 0.554 | 0.033 | 92 | 3.057 |
| O13 Quantity of treated sludge | 0.248 | 0.015 | 83 | 1.233 |
| O14 Quality of sludge treatment | 0.126 | 0.008 | 100 | 0.755 |
| O2 Operational technique management | 0.340 | O21 Standard of production and management | 0.250 | 0.085 | 82 | 6.970 |
| O22 Account Management | 0.250 | 0.085 | 85 | 7.225 |
| O23 Water quality inspection | 0.500 | 0.170 | 75 | 12.750 |
| O3 Operational cost control | 0.160 | O31 Energy consumption for sewage treatment | 0.500 | 0.080 | 70 | 5.600 |
| O32 Cost for sewage treatment | 0.500 | 0.080 | 100 | 8.000 |
| O4 Health management and safety control | 0.290 | O41 Regulation of safety control | 0.333 | 0.097 | 86 | 8.313 |
| O42 Frequency of accidents | 0.667 | 0.193 | 100 | 19.333 |
| O5 Pricing mechanism | 0.050 | O51 Reasonable price | 1.000 | 0.050 | 90 | 4.500 |
| O6 Uses of funds | 0.020 | O61 Rational use of funds | 0.250 | 0.005 | 100 | 0.500 |
| O62 Reasonable management of funds | 0.750 | 0.015 | 90 | 1.350 |
| O7 Environmental and social benefits | 0.080 | O71 Satisfaction survey of the users | 0.500 | 0.040 | 92 | 3.680 |
| O72 Evaluation of environmental effects | 0.500 | 0.040 | 85 | 3.400 |

Total score during the construction period: 88.011
Total score during the operation period 87.103

| Indicator                                      | Score Rank | Score | Indicator                                      | Score Rank | Score |
|-----------------------------------------------|------------|-------|-----------------------------------------------|------------|-------|
| T1 Limits and procedures in the transfer      | 1          | 0.062 | T11 Clarity of standards for transfer          | 1          | 1.000 |
| T2 Transfer of technology and intellectual property | 2          | 0.123 | T21 Transfer of operation technology           | 2          | 0.800 |
| T22 Transfer of intellectual property         |            |       |                                               |            | 0.098 |
| T3 Operation condition                        |            | 0.275 | T31 Sustainable profitability                 | 3          | 0.750 |
| T32 Management and operation mechanism        |            |       |                                               |            | 0.206 |
| T4 Condition of assets                        |            | 0.540 | T41 Integrity of fixed assets                 | 5          | 0.500 |
| T42 Asset service life                        |            |       |                                               |            | 0.270 |

4.6.2 Suggestions Based on the Evaluation Results: This paper sorted the independent scores of the first level indicators, as shown in table 4.4.

Table 4.4: Score Rankings of Performance Evaluation Indicators of the Project.

According to the independent score of indicators, XX County Environmental Protection Bureau should provide the SPV with viability gap fund based on the evaluation results, and with relevant suggestions for improvement.

- **Improving operational techniques**

  As shown in table 4.3, the operation technology index has greatly affected the comprehensive operation level of the project. The core of the wastewater treatment process is the biochemical treatment part. The project is advised to take the A2/O+MBR technology which not only can meet the water quality requirements, but also lower the disposal cost. The water after treatment is generally able to reach the Water Quality Grade IV and above.

- **Lower operational cost**

  The score of operation cost is relatively low, which not only affects the score of performance appraisal, but also affects the project profit. Due to the long-term wet environment around the sewage treatment plant, the damage rate of many equipment is high, and then the maintenance cost is increased. In addition to improving operational technology, this paper proposes to strengthen equipment management and increase the frequency of daily maintenance, thereby reducing the frequency and cost of major repairs. In addition, SPV should implement peak load regulation and control the key technology of sludge reduction, so as to reduce the energy consumption of electricity consumption.

5. Conclusion

The implementation of sewage treatment projects with PPP model has become an inevitable requirement for infrastructure and public sector reform. However, in practice, the current situation of "heavy construction and light operation" has seriously affected the efficient management. In this context, this paper takes the PPP project of sewage treatment as the research object, and redesigns the performance evaluation system, including evaluation objective, evaluation subject and object, evaluation period, evaluation index and weight, evaluation method and implementation path. Then it puts forward some suggestions for improving the operation technology and reducing the project cost, and provides some reference for the performance evaluation of the sewage treatment PPP projects.
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