Research on evaluation of third-party governance operation services for environmental pollution

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Abstract. This paper focuses on the evaluation of third-party governance operation services for environmental pollution, and determines the evaluation indicator system composed of 5 primary indicators as the basic competence of enterprise, operation of equipment, technique economics, environmental benefit and management level, and 26 secondary indicators via policies and regulations, standards, literature research and expert consultation in combination with the composition elements, service value judgment factors and full-life cycle of the work, providing theoretical support for the effect evaluation of third-governance over the environmental pollution in China. Then, the hierarchical analytic matrix is formed by analyzing the environmental pollution governance evaluation indicator system via analytic hierarchy process and scoring the importance of various indicators by experts by applying the Delphi method. The feature vector of the matrix is then calculated to obtain the weight of each indicator and verify the effectiveness of the Delphi method and obtain the comprehensive weight by judging the consistency of the matrix, so as to finally determine the overall ordering level of the importance of secondary indicators.

1. Introduction
The existing pollution governance technology evaluation and engineering evaluation methods are defective. In terms of evaluation contents, the traditional project evaluation generally focuses on the economic analysis of the project with insufficient analysis on its profitability. However, the environmental pollution governance project involves the effectiveness of pollution control and corresponding legal responsibilities, so it is necessary to comprehensively consider the economic efficiency, effectiveness and environmental profits of the project [1].

In terms of evaluation methods, the traditional construction project evaluation is generally made by cost-benefit analysis with the focus placed on the overall improvement of social benefits, while insufficient analysis are made on the equity in allocation of costs and profits. In terms of evaluation processes, focus is placed on the evaluation of the overall economic feasibility of the project without clear analysis and evaluation on the applicability of the third-party governance mode in project. It can be seen from the above analysis that the traditional evaluation methods have certain limitations in evaluating the performance of the third-party pollution controller and cannot fully satisfy the requirements for evaluations. Therefore, it is of great significance in both theory and practice to establish an evaluation indicator system for third-party governance services over environmental pollution based on the analysis of the features of the mode of third-party governance over environmental pollution and establishment of the standard system for discussing the decisions [2-3].

The evaluation of the third-party governance over environmental pollution can improve the level of pollution controller, accelerate the application of the relevant technologies in pollution control projects, stimulate enterprises with higher service level to show out from the competition, select the superior
and eliminate the inferior in the environmental protection industry, so as to improve the pollution prevention and control efficiency. For the pollution controller and emitter, the evaluation of the third-party governance over environmental pollution can provide the technical basis for clarifying the responsibilities of pollution emitters and controllers, and solving the legal disputes, so as to avoid the off-standard emission of sewage disposal facilities and legal disputes between both parties due to the pollution control services provided by the pollution emitter [4-5].

In this paper, the research method for comprehensive indicators of the third-party governance over environmental pollution is determined based on the theoretical basis, which covers such important links involved in pollution control services as project financing, operation mode, responsibility definition, charging mechanism and effect monitoring from the typical third-party renovation projects of environmental pollution, so as to solve such problems in the third-party governance over environmental pollution as unclear responsibilities, imperfect modes, non-standard services and unreasonable assessment, define the important basis and standards for the responsibilities of both parties, promote the application and implementation of environmental performance contract management, improve the efficiency in pollution control, standardize the market order, create an open, equal and orderly competition atmosphere, and make contribution to the healthy and rapid development of environmental protection equipment and service industries.

2. Third-party Governance Evaluation Indicator System for Environmental Pollution and Methods for Indicator Research

2.1. Delphi Method
In Delphi Method, the suggestions of experts are solicited anonymously. First, expert consultation sheet is prepared, i.e. listing the name of indictors, weight of expert consultation and problems to be noted by layers and groups as per the evaluation indicator system, and forming a sheet. Then, the experts are consulted by rounds, generally 4 rounds of feedback and communication, to converge their suggestions, and the consultation is completed when the suggestions of majority of experts are unanimous.

2.2. Analytic Hierarchy Process
Analytic Hierarchy Process (AHP) integrates the quantitative analysis and qualitative analysis. The correlations, logic belongingness and importance levels of the analysis systems are arranged in hierarchy to form a hierarchical structure from top to down. AHP adopts multiple importance levels to represent the judgment results of people, and each expert participating in the consultation form a judgment matrix, i.e. a matrix sheet is distributed to each expert for judgment, comparison and analysis. Finally, the feature vector and maximum characteristic root of each judgment matrix are calculated.

3. Establishment of Indicator System for Evaluation of the Third-party Governance over Environmental Pollution

3.1. Definition of Boundary and Methods for Establishment
Combine with the professional features of environmental pollution control and adopt the concept of LCA: the overall frame for evaluation indicator system shall be determined from the whole life cycle of the third-party governance over environmental pollution from investment, financing, design, manufacturing, commissioning, operation, acceptance, maintenance to monitoring. The third-party governance over environmental pollution is a complete set of engineering solution that the pollution controller provided to the pollution emitters based on the governance equipment, thus it is not only necessary to evaluate the energy saving and environmental protection indicators, but also to pay close attention to indicators in quality, safety and economic efficiency. The evaluation indicators selected shall be comprehensive but concise, with prominent focuses and great operability.
In this paper, the quantitative and qualitative evaluation indicators are combined for the research of the evaluation system for the third-party governance over environmental pollution. The primary indicators of basic competence of enterprise, operation of equipment, technique economics, environmental benefit and management level are determined via project investigation and questionnaires, and an evaluation indicator system for the third-party governance over environmental pollution is formed in combination with several indicators hereunder, so as to optimize the model for evaluation of environmental protection projects by calculating the weight and analyzing the consistency of the above-mentioned indicators via Delphi method and AHP, and setting up the evaluation model through the gray correlation method.

3.2. Composition of Evaluation Indicator System

The composition elements of evaluation for the third-party governance over environmental pollution mainly include person, process, technology and resource. The aspects of life cycle include planning & design, implementing, operation, improvement and supervision [6]. James Heskett et. al from Harvard Business School established the service profit chain theory which demonstrates that the profits of environmental protection enterprises mainly come from the loyal customers, while the loyalty of customers mainly deepens on the value of services provided to the customer by the enterprise. As a matter of fact, value of service is the cost-performance ratio of the service purchased by the customer. It is in direct proportion to the quality of results and process obtained by the customer, and in inverse proportion to the currency price of and other costs paid for the services purchased. The value of service deepens on the service ability of the enterprise, while the latter deepens on such factors as the scale and level of hardware facilities in the service place, level and effectiveness of the service process, as well as the skills of employees.

The evaluation indicator system for environmental pollution governance operation services shall be established based on laws, regulations, rules, technical polices and plans of China regarding environmental protection and pollution control to promote the harmony of environmental, economic and social benefits. The establishment of evaluation indicator system and determination of main evaluation indicators involve such fields as energy-saving and emission reduction, environmental protection. Therefore, the capacities of the manufacturers and users’ interests shall be comprehensively considered, and indicators shall be selected from such aspects as technical performance, energy-saving and environmental protection, safety and reliability to fully represent the scientific, advancement and operability of the evaluation methods and technologies, which can provide guidance for the third-party governance over environmental pollution in China.

In the Project, preliminary researches are performed for tens of environmental protection control service companies. A lot of relevant technical literatures and documents at home and abroad are reviewed and analyzed. A lot of technical performance data, energy efficiency data and environmental protection data of pollution governance works are extensively collected by sampling and surveying the information regarding the basic competence of enterprises, various pollution governance technologies, energy consumption and pollutant emission, and sorting out the technical information, standards and policies for energy-saving and emission reduction monitoring and control in China, so as to preliminary determine the scope of evaluation indicators. As shown in Table.1, the above primary and secondary indicators are preliminary selected by comparing the product standards, analyzing practical engineering cases and analyzing faults commonly found in equipment certification and post-engineering evaluation cases.

This evaluation indicator system may be used for third-party evaluation, self-evaluation or evaluation from the superordinate over the performance of environmental pollution emitters, and is applicable to both the pre-evaluation and the post-evaluation processes for the environmental pollution governance projects.
Table 1. Evaluation Indicator System for the Third-party Governance over Environmental Pollution.

| S/N | Primary indicator          | Secondary indicators                                                                 |
|-----|----------------------------|---------------------------------------------------------------------------------------|
| 1   | Basic competence (B1)     | Number of staff (C1)  
|     |                            | Enterprise scale (C2)  
|     |                            | Market investment and financing capacity (C3)  
|     |                            | Social credit (C4)  
|     |                            | Financial conditions (C5)  
|     |                            | Proportion of professionals and technicians (C6)  
|     |                            | Technical innovation capacity of enterprise (C7)  
| 2   | Operation of equipment (B2) | Energy consumption of equipment (C8)  
|     |                            | Water consumption of equipment (C9)  
|     |                            | Availability ratio of equipment (C10)  
|     |                            | Operation ratio of equipment (C11)  
|     |                            | Service life of equipment (C12)  
| 3   | Technical economics (B3)  | Investment cost for control of unit pollution (C13)  
|     |                            | Annual maintenance fees (C14)  
|     |                            | Annual labor costs (C15)  
|     |                            | Floor area (C16)  
|     |                            | Use efficiency of by-products (C17)  
| 4   | Environmental benefit (B4) | Compliance of pollutant emissions (C18)  
|     |                            | Improvement of surrounding environment (C19)  
|     |                            | Pollutant removal rate (C20)  
|     |                            | Safety operation regulations (C21)  
|     |                            | Automatic on-line monitoring (C22)  
| 5   | Management level (B5)     | Measures for control of secondary pollution (C23)  
|     |                            | Timeliness of service (C24)  
|     |                            | Quality and compliance of service (C25)  
|     |                            | Service buyer satisfaction (C26)  

4. Determination of Weights of Evaluation Indicators for the Third-party Governance over Environmental Pollution

4.1. Building of Judgment Matrix

In this paper, it is proposed to determine the weight coefficient of the evaluation indicators for the third-party governance over environmental pollution by applying the Delphi Method and AHP. This method takes the 9-class scaling method in subjective weight method as the basis, mainly including defining the problem, establishing hierarchical structure, establishing the judgment matrix to calculate the weight vector with Delphi Method, single ordering and consistency check of hierarchy, overall ordering of hierarchy, and finally determining the weight of each indicator to the target layer.

After the hierarchical analysis model including the target layer, criterion layer and indicator layer is established, the judgment matrix is set up by comparing any two elements within each layer. There judgments are marked with figures by referring to proper scale. The judgment matrix is the basis information about AHP, and is also an important basis for the calculation of relative importance. Assuming that element Bk of the previous layer is used as the criterion, it has the dominance relation with elements C1, C2, ⋯, Cn of the next layer, so that the corresponding weights for C1, C2, ⋯, Cn can be determined as per their relative importance under the criterion of Bk. The basis or source for assignment of values may be provided by the decision maker directly, negotiated by the decision maker and analyzer, or obtained by the analyzer via a certain kind of technical consultation. Generally, the judgment matrix shall be given by experts who are familiar with the problems independently.
To make the evaluation indicator weighted values scientific, representative and highly reliable, the technical staff, environmental engineering designers, environmental scientific researchers and experts in this field are invited to make independent judgment without any interference, and 1-9 scale method is introduced to form the matrix judgment.

As for this research, the judgment matrix of the criterion layer (primary indicators) against the target layer A is shown in Table 2 below. After consulting the experts, it can be determined that the environmental profit has the most prominent importance among the primary indicators, followed by operation of equipment, technical economics and management level.

| Target layer (A) | Basic competence of enterprise (B1) | Operation of equipment (B2) | Technical economics (B3) | Environmental profits (B4) | Management level (B5) |
|------------------|-------------------------------------|-----------------------------|--------------------------|---------------------------|------------------------|
| Basic competence of enterprise (B1) | 1 | 1/3 | 1/3 | 1/5 | 1/3 |
| Operation of equipment (B2) | 3 | 1 | 1 | 1/3 | 1 |
| Technical economics (B3) | 3 | 1 | 1 | 1/3 | 1 |
| Environmental profits (B4) | 5 | 3 | 3 | 1 | 3 |
| Management level (B5) | 3 | 1 | 1 | 1/3 | 1 |

The judgment matrix of the criterion layer (primary indicators) against the target layer A is shown in Table 2 below. After consulting the experts, it can be determined that the environmental profit has the most prominent importance among the primary indicators, followed by operation of equipment, technical economics and management level.

4.2. Inspection on Consistency of Judgment Matrix

The negative average value of other characteristic roots of AHP other than the maximum characteristics root of judgment matrix is introduced as the indicator to determine the consistency of deviation of judgment matrix, i.e.

$$CI = (\lambda_{\text{max}} - n) / (n-1)$$

is applied to check the consistency of the judgment of decision maker. The larger the CI value is, the greater the degree of deviation of judgment matrix from the complete consistency is. Otherwise, the smaller the CI value is, the better the consistency is.

Obviously, when the judgment matrix is of complete consistency, CI=0, vice versa. Thus, it can be known that when CI=0, $\lambda=\lambda_{\text{max}}= n$, the judgment matrix is of complete consistency. Moreover, when matrix A is of satisfied consistency, $\lambda_{\text{max}}$ is slightly larger than n, and other characteristic values are close to zero.

To measure whether judgment matrixes for different orders are of satisfied consistency, it is necessary to introduce the average random consistency index of judgment matrix RI. When number of order is larger than 2, the ratio of consistency index CI of the judgment matrix to the average random consistency index RI of the same order refers to random consistency ratio, recorded as CR.
When CR = CI/RI < 0.10, it is deemed that the judgment matrix is of satisfied consistency, or the judgment matrix shall be adjusted to make it have satisfied consistency.

4.3. Single Hierarchical Ordering

The relative importance of factor in certain layer to a certain factor in previous layer is calculated, which is known as single hierarchical ordering. To be specific, single hierarchical ordering refers to calculating the weighted value of order of importance of factors in the current layer related to certain factor in previous layer as per the judgment matrix.

Theoretically, calculation of single hierarchical ordering can be summarized as calculating the maximum characteristic root and vector of the judgment matrix. During calculation, it is unnecessary to pursue higher accuracy, as the judgment matrix falls within a certain error scope itself. Moreover, the priority ordering weight values of all factors in layer given via AHP express a certain qualitative concepts in essence. Therefore, iteration method is generally applied to calculate the approximate maximum characteristic value and corresponding characteristic vector.

\( \lambda_{\text{max}} = \sum (AW) / nW_i \) (3)

Where, \( i \) is the factor of vector \( AW \).

The calculation results of judgment matrix \( A \) are as follows: \( M_1 = 1/135 \), \( M_2 = 1 \), \( M_3 = 1 \), \( M_4 = 135 \), \( M_5 = 1 \). After the normalization processing, the characteristic vector obtained via MATLAB is as follows:

\[
W_1 = \begin{pmatrix} 0.063 \\ 0.165 \\ 0.444 \\ 0.165 \end{pmatrix}, \quad W_2 = \begin{pmatrix} 0.031 \\ 0.059 \\ 0.156 \\ 0.062 \end{pmatrix}, \quad W_3 = \begin{pmatrix} 0.343 \\ 0.343 \\ 0.129 \\ 0.055 \end{pmatrix}, \quad W_4 = \begin{pmatrix} 0.444 \\ 0.164 \\ 0.129 \\ 0.063 \end{pmatrix}, \quad W_5 = \begin{pmatrix} 0.730 \\ 0.188 \\ 0.164 \\ 0.081 \end{pmatrix}, \quad W_6 = \begin{pmatrix} 0.308 \\ 0.113 \\ 0.113 \\ 0.113 \end{pmatrix}
\]

Thus, it can be obtained that \( \lambda_{\text{max}} = 5.042 \), \( CI = 0.011 \), \( RI=1.12 \), \( CR< 0.10 \), i.e. the judgment matrix is of satisfied consistency. The same results can be obtained by calculating consistency of the other five judgment matrix (B1, B2, B3, B4, B5).

4.4. Overall Hierarchical Ordering

Calculate from top to down layer by layer successively along the step hierarchical structure to finally obtain the relative importance or relative advantage ordering value of factors in the lowest layer against the highest layer (overall goal), i.e. the overall hierarchical ordering.

As for the overall hierarchical ordering, it is necessary to check the consistency from top to down. However, in practical operation in AHP, the consistency check of overall hierarchical ordering can be generally ignored. After calculation, the overall ordering of evaluation indicators against the third-party governance over environmental pollution is shown by Table 3.
Table 3. Overall Hierarchical Ordering of Evaluation Indicators of Environmental Pollution Control

| S/N | Primary indicator | weight | Secondary indicators | weight | Total weight |
|-----|-------------------|--------|----------------------|--------|--------------|
| 1   | B1                | 0.063  | C1                   | 0.031  | 0.002        |
|     |                   |        | C2                   | 0.059  | 0.004        |
|     |                   |        | C3                   | 0.381  | 0.024        |
|     |                   |        | C4                   | 0.156  | 0.010        |
|     |                   |        | C5                   | 0.156  | 0.010        |
|     |                   |        | C6                   | 0.062  | 0.004        |
|     |                   |        | C7                   | 0.156  | 0.010        |
|     |                   |        | C8                   | 0.343  | 0.057        |
|     |                   |        | C9                   | 0.343  | 0.057        |
| 2   | B2                | 0.165  | C10                  | 0.129  | 0.021        |
|     |                   |        | C11                  | 0.129  | 0.021        |
|     |                   |        | C12                  | 0.055  | 0.009        |
|     |                   |        | C13                  | 0.444  | 0.073        |
|     |                   |        | C14                  | 0.164  | 0.027        |
| 3   | B3                | 0.165  | C15                  | 0.164  | 0.027        |
|     |                   |        | C16                  | 0.164  | 0.027        |
|     |                   |        | C17                  | 0.063  | 0.010        |
|     |                   |        | C18                  | 0.730  | 0.324        |
|     |                   |        | C19                  | 0.188  | 0.084        |
|     |                   |        | C20                  | 0.081  | 0.036        |
| 4   | B4                | 0.444  | C21                  | 0.308  | 0.051        |
|     |                   |        | C22                  | 0.113  | 0.019        |
|     |                   |        | C23                  | 0.308  | 0.051        |
|     |                   |        | C24                  | 0.047  | 0.008        |
|     |                   |        | C25                  | 0.113  | 0.019        |
|     |                   |        | C26                  | 0.113  | 0.019        |

5. Conclusion
The weighted value of the relative advantage-disadvantage ordering of each indicator can be obtained. It can be found that such indicators as compliance of pollutant emissions, investment cost for control of unit pollution, safety operation regulations and measures for control of secondary pollution are relatively important for environmental pollution governance.

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