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Research Article

Performance Evaluation Model of Public Resource Trading Platform Using Entropy-Based Gray Clustering Method

Jian Wang,[1,2] Jun Fang,[1] Ling Dai,[3] and Jun Hu[4]

[1]*College of Civil Engineering and Architecture, Wuhan University of Technology, Wuhan, Hubei 430070, China*
[2]*Department of Architecture, Huanggang Polytechnic College, Huanggang, Hubei 436102, China*
[3]*Department of Public Education, Huanggang Polytechnic College, Huanggang, Hubei 436102, China*
[4]*Ningxia Construction Investment Group Co. Ltd., Yinchuan, Ningxia 750004, China*

Correspondence should be addressed to Jun Hu; hu@whut.edu.cn

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In order to standardize public resource trading activities and improve the operating efficiency of public resource trading platforms, this paper conducts research on the performance of public resource trading platforms. A three-level and 28-dimension performance evaluation index system for public resource trading platform is established by considering the four levels of “input-process-output-effect.” Besides, entropy weight method, gray clustering, and fuzzy comprehensive evaluation are integrated on this basis. Entropy weight method is used to determine the index weight, and the degree value of membership for indexes on gray class is determined based on gray clustering method and converted into a matrix. Then, fuzzy comprehensive evaluation method is used to determine the evaluation value and finally carry out the platform performance evaluation, which provides theoretical support for academic researchers to conduct follow-up research on the performance evaluation of public resource trading platforms.

1. Introduction

The public resource trading platform is a public welfare platform system that is promoted by government departments and is independent of government agencies. It is based on public service functions with the goal of serving the public and benefiting people. According to data from the National Public Resource Trading Platform, there were 1,191 public resource trading platforms nationwide, and a total of 273,703 projects have been transacted as of end of April 2021. With the continuous development of market, market elements are active and social vitality continues to increase. The frequent transactions of public resources across the country have aroused the attention of government and all sectors of society. In recent years, all parts of country have made efforts to promote the construction of public resource trading markets and build a standardized trading platform in the region based on local conditions. Local governments at all levels actively promote the construction of public resource trading markets and public resource trading platforms. Besides, they use a series of relevant measures to standardize and improve the market environment for public resource transactions in order to realize the market-oriented allocation of public resources.

The construction of China’s public resource trading platform started relatively late and existing research results are relatively single. The academic circles have carried out a key discussion on the development of public resource transaction market, and part of literature analyzes the corruption of public resource transactions [1]. In terms of transaction supervision, Beigeng Xiao (2016) believed that because the legislative model in public resource transactions was decentralized legislation, this made the efficiency of resource allocation low and directly leads to the fragmentation of supervision [2]. Wenwen Zhang and Jiangyu Huang (2018) believed that it is necessary to strengthen the information construction of China’s public resource trading platform, share data, and strengthen transparency, so that public resource trading can be supervised by the public. This not only helped to reduce the frequency of corruption but also reduced the cost of supervisory labor [1]. Hu et al. (2020) believed that there were major problems in the standardization of public resource trading platforms. They suggested that the standardization work should be implemented from five aspects: market, service, electronic transaction, bid evaluation, and data [3]. At the national level, National Development and Reform Commission (2021) had summarized the typical practices of integrating public resource trading platforms in some provinces, regions, and cities including standardization construction, process construction, and information construction and analyzed their main effects [4]. In order to realize the standardized operation of public resource transactions, relevant scholars at home and abroad have also proposed that performance incentives are effective measures to promote public resource transactions in addition to strengthening supervision. It can be seen that the current research focuses on platform construction and platform supervision, and the research content mainly focuses on modern information technology application and management regulation design. The research on performance is mainly focused on theoretical level. Although the research on performance evaluation methods is involved, the number is relatively small.

The current research methods for performance evaluation mainly involve the combination of entropy weight method and analytic hierarchy process (AHP) combined with empowerment method [5], DEA-Malmquist index analysis method [6], AHP combined with fuzzy comprehensive evaluation method [7], gray clustering [8], and fuzzy comprehensive evaluation method. Different evaluation methods have their own advantages and disadvantages. Among them, fuzzy comprehensive evaluation method is more difficult to determine the degree of membership [9]. The combination of gray clustering and fuzzy comprehensive evaluation method can make up for this shortcoming.

The performance evaluation of public resource trading platform is of great significance to operation platform, the transformation of government functions, the effective allocation of resources, and the interests of public. However, the current research methods on platform performance are rarely used in public resource transactions. In existing research results, many useful explorations have been carried out on the application of gray clustering and fuzzy comprehensive evaluation in performance evaluation. This paper takes the performance evaluation of public resource trading platform as the starting point based on existing research results and uses literature analysis combined with expert consultation to establish performance evaluation index system. Entropy weight method is used to weight the index system, and gray clustering is used to determine the membership value of indexes on the gray class and convert it into a matrix. The performance evaluation model is established, and the performance evaluation method of existing public resource trading platform is researched and innovated with the help of fuzzy comprehensive evaluation method to determine the evaluation value.

2. Design for Performance Evaluation Index System of Public Resource Trading Platform

2.1. Construction Idea for Performance Evaluation Index System of Public Resource Trading Platform. There are many ways to construct performance evaluation indexes, and one of the most common construction methods is based on mathematical theory. There are four main steps: Firstly, determine the evaluation target, and then the evaluation objects are decomposed according to evaluation objectives and the evaluation element set is established. Secondly, establish the evaluation index set and determine the correlation between evaluation indexes and evaluation elements, and finally screen the evaluation indexes to determine the optimal evaluation index set. It can be seen from construction process that the relationship between the evaluation element set and evaluation index set established by this method is one-to-one, corresponding to each other. However, there is a many-to-many relationship between the index element set and evaluation index set in the performance evaluation index system of public resource trading platform. Therefore, this method is not suitable for performance evaluation index system construction of public resource trading platform. There is another method that is often used in performance evaluation index system construction, which is to divide the performance evaluation into four dimensions, input, process, output, and effect, according to input-output process. The index level is divided into three levels: basic index, index element set, and auxiliary index to build a set of multidimensional and multilevel performance evaluation index system. Comparing the two construction methods, it is obvious that the second method is more suitable. From the perspective of stage and time dimension of public resource trading platform, the platform performance can be analyzed from the four aspects of input, process, output, and effect.

In addition to the four aspects of input, process, output, and effect, the performance of public resource trading platform also exhibits five dimensions: economy, efficiency, effectiveness, fairness, and sustainability. Economy, efficiency, and effectiveness are called 3E principles, which play an important guiding role in the performance evaluation index system construction of public resource trading platforms. In addition to 3E principle, fairness and sustainability are also two very important aspects. The fairness index examines from social level, while the ecological index examines the degree of impact on natural ecological environment. At the same time, the four aspects of input, process, output, and effect are closely related to the five dimensions of economy, efficiency, effectiveness, fairness, and sustainability. For example, the investment and process must be economically evaluated, so as to effectively control the financing cost and management cost. The output is evaluated for efficiency in order to improve the input-output ratio of platform. The construction and operation effects of platform should be comprehensively assessed from the three aspects of effectiveness, fairness, and sustainability. Based on the above analysis, the construction process of performance evaluation index system for public resource trading platform is shown in Figure 1.

2.2. Construction for Performance Evaluation Index System of Public Resource Trading Platform

2.2.1. Platform Construction. The construction of public resource trading platform is a concrete manifestation of platform investment, and it is also an important aspect of performance evaluation of public resource trading platform. The platform construction index elements are mainly divided into four categories: supporting infrastructure construction, expert database construction, talent team construction, and information construction.

(1) Supporting infrastructure construction:

The supporting infrastructure construction of public resource trading platform should follow the principle of economy in adapting measures to local conditions and avoiding repeated construction. The functional partitions of platform should also have clear boundaries and be clearly marked, and effective isolation between areas that affect fairness and justice must be carried out. The supporting infrastructure of trading platform mainly includes three aspects: public service facility configuration, environmental facility configuration, and safety facility configuration. The related facility configuration should meet the needs of various public resource trading activities such as bid opening, bid evaluation, auction, listing and bidding, and related on-site business handling. In the later operation and maintenance, it can also be unified coded management.

(2) Expert database construction:

The construction of bid evaluation expert database mainly includes two aspects: on the one hand, it is necessary to actively guide relevant experts to enter the database and guide and assist bid evaluation experts in completing personal identification, personal information collection, and information uploading and other related tasks. It can also integrate and collect expert resource information from the bid evaluation and evaluation expert database for the evaluation of public resource trading projects and realize expert resource sharing. The other is to enrich the types of experts in expert library. Bid evaluation experts should be compound talents and not just confined to a certain fixed field. The types of experts in expert library should be diversified, including not only technical experts but also economic experts and experts in other fields. A rich and diverse expert database can improve the efficiency of review.

(3) Talent team construction:

Talent team construction is an important foundation for public resource trading platform construction. It should be strengthened from three aspects: talent training system, talent team structure, and the talent incentive mechanism. The public resource trading platform should establish a complete and standardized personnel training system to improve the overall quality of platform employees. Secondly, we should optimize talent team structure and increase the proportion of high-level talents, focus on cultivating outstanding talents and leading talents in the industry, and establish an ideal talent group structure. The talent incentive mechanism is an important measure for talent team construction. Through a series of effective incentive measures, it is necessary to not only prevent the loss of existing outstanding talents but also introduce innovative talents to cultivate new talents in a timely manner. Only in this way can we continue to achieve the construction goal of public resource trading platform.

(4) Information construction:

The informatization construction of public resource trading platform includes three aspects: informatization software system construction, informatization organization system construction, and informatization security system construction. Information software system construction is to make full use of network technology to establish a public resource transaction electronic service system to realize information resource sharing. Information organization system construction is to realize the docking of provincial platform service system and national platform service system to realize the exchange and sharing of information resources and to disclose all transaction information and transaction processes to society in a timely manner except for the information that should be kept secret. Information security system construction is to establish a sound information security guarantee system to ensure the smooth operation of platform.

2.2.2. Platform Operation.

(1) Electronic trading system operation:

The establishment of a unified public resource transaction platform electronic transaction system can realize the entire electronic transaction of four major public resource transactions of government procurement, state-owned property rights, engineering construction, and land and mineral rights. In terms of government procurement, it is possible to realize information sharing among the three parties of bidding and bidding entities, supervisory entities, and trading venues and launch the construction of a public resource trading platform and remote bid evaluation. In terms of state-owned property rights, the trading platform can incorporate various links

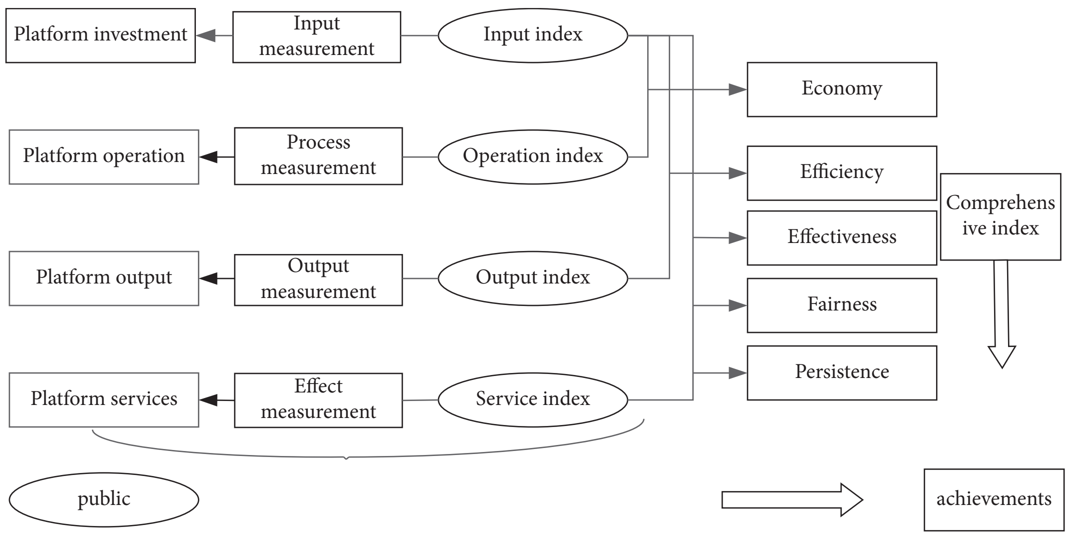

Figure 1: The construction process of performance evaluation index system for public resource trading platform.

such as project admission, information release, project registration, file downloading, deposit payment, and organization of transactions into the scope of electronic operation. In terms of engineering construction, the electronic operation of corresponding links such as registration, bid opening, and bid evaluation of construction projects can be realized. In terms of land and mineral rights, the entire electronic operation of corresponding links such as project entry, information release, project registration, downloading of listing documents, and payment of deposits can be realized.

(2) Platform operating environment:

The operating system environment of public resource trading platform mainly includes the legal and regulatory environment, market planning, and development and utilization planning. China's public resource transactions are based on original administrative distribution system. In the process of promoting the marketization for public resources and the efficiency of transaction utilization, all parties are aware of importance of promoting the progress of marketization of public resources. However, in the process of promoting public resource transactions and the financial benefits for public resource utilization, public resource transactions often occur at low prices. This brings rapid development to some public resource utilization enterprises, but it does not reflect the nature of social benefits that public resources should have. In the long run, it reduces the comprehensive benefits of public resource utilization.

2.2.3. Platform Service.

(1) Service quality:

With the help of electronic network system of public resource trading platform, the time limit is simplified. The concept of online appointment services is established, thereby greatly improving platform service efficiency. The main construction goal of public resource trading platform is to accelerate and improve the efficiency of public services.

(2) Monitoring channel:

The supervision channels include the planning of types, methods, quantities, and uses of public resource transactions, the development and utilization of public resources, and the guidance of flow of public resources. At present, the supervision institutions of public resource trading platforms in China are mainly national and regional public resource trading supervision institutions. A supervisory system combining multiple supervisory methods is also under construction.

2.2.4. Platform Output. The output index elements of platform are an important part of performance evaluation for public resource platform. According to the design of performance evaluation index system for public resource trading platform and the support of related theories, output index elements of platform are mainly divided into three categories: public resource marketization rate index, public resource classification protection index, and public resource allocation national economic contribution index.

(1) Marketization rate of public resources:

The marketization rate of public resources is mainly reflected in three aspects: property rights management, marketization degree, and the construction of public resources economic archives. To achieve efficient allocation of public resources, property rights management is the first-level task. The marketization process of public resources is actually a rational distribution process of public resource property rights and the marketization of property rights. The marketization of public resources is one of construction goals of a public resource trading platform, and the marketization degree of public resources is represented by marketization rate. It reflects the extent to which public resources are included in market-oriented transactions and the level of market-oriented public resource transactions. Marketization is an important tool for the efficiency of public resource utilization. Therefore, the output performance of public resource trading platform must be reflected by the degree of marketization. In addition, the construction of public resource economic archives is an important method to standardize the management of public resource transactions and evaluate the economic efficiency of public resources.

(2) Classified protection degree of public resources:

The degree of public resource classification protection includes two aspects: public resource classification management and public resource price system construction. The classified management of public resources is the prerequisite for classified management of public resources and the proposal of targeted transaction rules. The transaction price of public resources reflects resource value and is also based on public resource classification. The construction of public resource price system can clarify different type value of resources. At the same time, it also reflects the quantity of resources themselves, such as exhaustion compensation public resources, strategic public resources, and first-level public resources.

(3) National economic contribution rate of public resource transactions:

The national economic contribution rate of public resource transactions should be reflected in two aspects: accounting system construction and contribution accounting. The public resource trading platform is basically executed by administrative unit. Although there are industry service charges and operating service charges in the charging part, in general, the financial accounting of public resource trading platforms is more focused on national economic evaluation. Therefore, the financial accounting and financial performance accounting of public resource trading platform should be incorporated into the national economic accounting system to evaluate performance of public resource trading platform. The accounting system of public resources mainly reflects the contribution of public resource transactions to national economy. Contribution can be calculated using input-output method or the ratio of public resource transaction quota to regional economic total.

From the four aspects of analysis of platform construction, platform operation, platform service, and platform output, the performance evaluation index system of public resource trading platform is constructed combined with the methods of combining related reference documents and expert consultation. It contains a total of 28 evaluation dimensions at 3 levels. The performance evaluation index system of public resource trading platform is shown in Table 1.

A questionnaire survey was conducted on the above-mentioned index system. According to statistics, a total of 150 questionnaires were distributed and 115 valid questionnaires were retrieved; effective questionnaire rate was 77%. According to the survey results, 28 variables were analyzed in IBM SPSS Statistics software, and analysis results are shown in Table 2. The Cronbach's Alpha coefficient of questionnaire as a whole and each dimension exceeded 0.7, and the reliability of 3 dimensions reached 0.8. This shows that the proposed index system has good reliability, and the rationality of indexes system design has been verified.

2.3. Determine the Index Weight Based on Entropy Weight Method. In this paper, entropy weight method is used to assign index weight. Entropy weight method is essentially a mathematical method of objective weighting. The basic principle is based on the difference in variation degree of different indexes using information entropy to calculate weights and using entropy weights for weight correction and then obtain relatively scientific index weights. Different from subjective weighting methods such as analytic hierarchy process, expert scoring method, and Delphi method, the weighting process of entropy weight method is relatively objective. It uses the decision matrix to calculate index weights, which greatly reduces the influence of human subjective judgments, thereby making the evaluation results more objective. In entropy weight method, the size of entropy value represents variation degree of indexes. The greater the entropy value, the greater the index variation and the greater the amount of information contained. The greater the role it plays, the greater its weight is. The steps of entropy weighting method are as follows.

2.3.1. Build and Standardize the Evaluation Matrix. Technical and economic experts were invited in public resource trading to use Delphi method to score the importance of each performance evaluation index for public resource trading platform. The initial evaluation matrix v of public resource trading platform is

$$v = \begin{bmatrix} v_{11} & v_{12} & \cdots & v_{1n} \\ v_{21} & v_{22} & \cdots & v_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ v_{m1} & v_{m2} & \cdots & v_{mn} \end{bmatrix}. \quad (1)$$

After constructing the initial evaluation matrix, it needs to be normalized to facilitate calculation. Generally speaking, formula (2) can be used for cost indexes. For benefit indexes, formula (3) can be used. Thus, the performance evaluation standard matrix R of public resource trading platform can be obtained (see formula (4)).

Table 1: Performance evaluation index system of public resource trading platform.

First-level index	Second-level index	Third-level index
Platform construction B	Supporting infrastructure construction B_1	Public service facility configuration B_{11} Environmental facility configuration B_{12} Safety facility configuration B_{13}
	Expert database construction B_2	Composition of technical experts B_{21} Composition of economic experts B_{22} Composition of other experts B_{23}
	Talent team construction B_3	Talent training system B_{31} Talent team structure B_{32} Talent incentive mechanism B_{33}
	Information construction B_4	Information software system construction B_{41} Information organization system construction B_{42} Information security system construction B_{43}
Platform operation C	Operation status of electronic trading system C_1	System operating efficiency C_{11} System operation monitoring C_{12} Abnormal frequency of system operation C_{13}
	Platform running environment C_2	Operating system environment C_{21} External cooperation C_{22}
Platform service D	Service quality D_1	Service staff's duty performance D_{11} Service process compliance D_{12}
	Supervision channel D_2	Government supervision D_{21} Social supervision D_{22}
Platform output E	Marketization rate of public resources E_1	Property management E_{11} Marketization degree E_{12} Economic file construction of public resources E_{13}
	Marketization rate of public resources E_2	Classification management of public resources E_{21} Price system construction of public resources E_{22}
	National economy contribution of public resource transaction E_3	Accounting system construction of public resources E_{31} Contribution and accounting E_{32}

Table 2: Reliability statistics of indexes system.

Index system name	Cronbach's Alpha	Cronbach's Alpha based on standardized items	Number of items
Overall questionnaire	0.858	0.859	28
Platform construction	0.801	0.804	12
Platform operation	0.812	0.815	5
Platform service	0.757	0.756	4
Platform output	0.825	0.827	7

$$r_{ij} = \frac{v_{ij} - \min(v_{ij})}{\max(v_{ij}) - \min(v_{ij})}, \tag{2}$$

$$r_{ij} = \frac{\max(v_{ij}) - v_{ij}}{\max(v_{ij}) - \min(v_{ij})}, \tag{3}$$

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{bmatrix}. \tag{4}$$

In formulas (1)~(4), v is the initial matrix for performance evaluation of public resource trading platform. v_{ij} is the initial score of the j-th expert on the i-th performance evaluation index. R is the performance evaluation standardized matrix of public resource trading platform, and r_{ij} is the standardized value scored by the j-th expert on the i-th performance evaluation index. i and j are evaluation indexes and evaluation experts, respectively.

2.3.2. Determine the Index Weight. Entropy weight method can fully consider variation degree of different indexes, while using expert experience to fully reflect the importance of indexes. Since entropy weight method is based on information entropy, it is necessary to obtain the information entropy and difference coefficient in turn. Finally the index weight is got; the following is detailed calculation formula:

$$w_i = \frac{1 - H_i}{m - \sum_{i=1}^{m} H_i}. \tag{5}$$

Here, $H = -1/\ln n \sum_{j=1}^{n} f_{ij} \ln f_{ij}$ is information entropy; $f_{ij} = r_{ij}/\sum_{j=1}^{n} r_{ij}$ is characteristic proportion.

3. Construction for Performance Evaluation Model of Public Resource Trading Platform

3.1. Construction Idea for Performance Evaluation Model. Public resources are the means of production or living shared by society, including social resources, natural resources, and administrative resources. It is a prerequisite for national economic and social development and is directly related to social public interests, people's quality of life, and sustainable economic and social development. Therefore, the performance evaluation of public resource trading platform is an overall concept, which should be investigated from many aspects. This paper establishes an evaluation system from four aspects: platform construction, platform operation, platform service, and platform output. Most of existing performance evaluation studies use single method for performance evaluation, such as analytic hierarchy process, fuzzy comprehensive evaluation method, structural equation model, and gray analysis. These single methods all have shortcomings such as strong subjectivity and insufficient rigor. Thus, this paper tries to integrate entropy weight method, gray clustering, and fuzzy comprehensive evaluation together to solve the above problems ingeniously. The specific modeling process is as follows:

(1) The evaluation indexes are divided into five "gray categories": bad, poor, medium, good, and very good. Gray clustering method is used to obtain the triangular whitenization weight function value and comprehensive clustering coefficient of performance indexes at all levels, so as to determine the maximum degree of membership matrix.

(2) According to the maximum membership degree matrix determined in step (1) and index weight determined by entropy weight method, fuzzy comprehensive evaluation method is used to obtain the comprehensive evaluation value of performance indexes at all levels, as shown in Figure 2.

3.2. Construction Process for Performance Evaluation Model

3.2.1. Determine the Degree of Membership Based on Gray Clustering. The public resource trading platform performance evaluation index system established in this paper has a total of 28 evaluation indexes, which can be divided into 5 gray categories, which are bad, poor, medium, good, and very good. The actual value of indexes corresponding to index j of evaluation sample is x_j, and the sample is analyzed with x_j. The detailed steps are as follows.

(1) According to predivided evaluation gray level, the actual value of each performance evaluation index is divided into the corresponding gray level. For example, the value range of indexes j can be divided into 5 intervals:

$$[b_1, b_2], \quad [b_2, b_3], \quad [b_3, b_4], \quad \ldots \quad [b_4, b_5]. \tag{6}$$

(2) The most likely point belonging to gray category k is taken as the center point and denoted as λ_n. Then, the value of triangular whitenization weight function belonging to n gray classes λ_n is taken as integer 1. Set the value interval of evaluation index j belonging to gray class n as $[\lambda_{n-1}, \lambda_{n+1}]$. Extend the left end point of first gray category and the right end point of s-th gray category to the left and right to obtain b_0 and b_{s+2}, respectively. At the same time, $n-1$ gray points $(\lambda_{n-1}, 0)$ and $n+1$ gray point $(\lambda_{n+1}, 0)$ on coordinate axis are, respectively, connected with the points on coordinate axis $(\lambda_n, 0)$. From this, the triangular whitenization weight function image of this paper is obtained ($j = 1, 2, \ldots, n$; $n = 1, 2, \ldots, 5$), as shown in Figure 3.

(3) Based on triangular whitenization weight function formula (7), substituting the actual score value of each index, whitening weight function value $f_j^n(x)$ can be obtained. Then substituting all indexes into formula (7) in turn, you can get all the membership values of each index on different gray classes, as shown in Table 3.

$$f_j^n(x) = \left\{ \begin{array}{l} 0, x \notin [\lambda_{n-1}, \lambda_{n+1}] \\ \\ \dfrac{x - \lambda_{n-1}}{\lambda_n - \lambda_{n-1}}, x \in [\lambda_{n-1}, \lambda_n] \\ \\ \dfrac{\lambda_{n+1} - x}{\lambda_{n+1} - \lambda_n}, x \in [\lambda_n, \lambda_{n+1}] \end{array} \right\}, n = (1, 2, 3, \ldots, s). \tag{7}$$

Transform the membership degree values of indexes in Table 3 on gray category into a matrix, and then the corresponding membership degree matrix can be obtained:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1k} & r_{1s} \\ r_{21} & r_{22} & \cdots & r_{2k} & r_{2s} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{m1} & r_{m2} & \cdots & r_{mk} & r_{ms} \end{bmatrix}. \tag{8}$$

3.2.2. Determine the Evaluation Value Based on Fuzzy Comprehensive Evaluation Method. The basic principle of fuzzy comprehensive evaluation method is to set the optimal evaluation index to 1. At the same time, based on it, the remaining indexes are divided into evaluation values according to corresponding poor-quality values. According to the characteristics of each index for research objects, methods such as F statistics and F distribution can be used to determine membership function relationship between the index factors and evaluation value of indexes. Fuzzy comprehensive evaluation method has the characteristics of

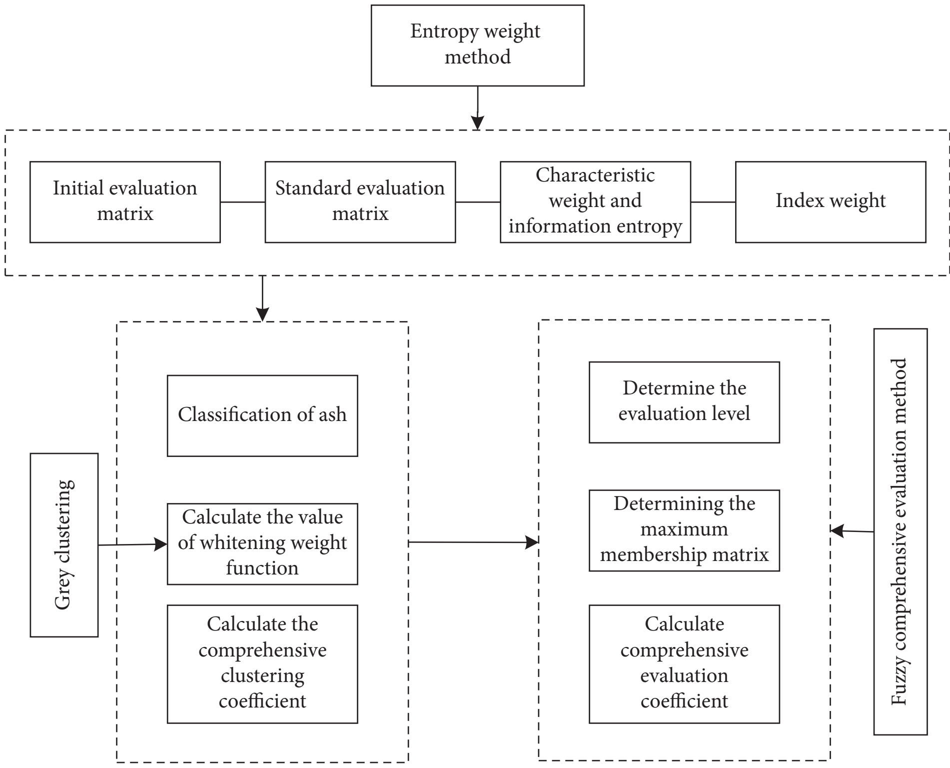

Figure 2: Schematic diagram of evaluation model construction process.

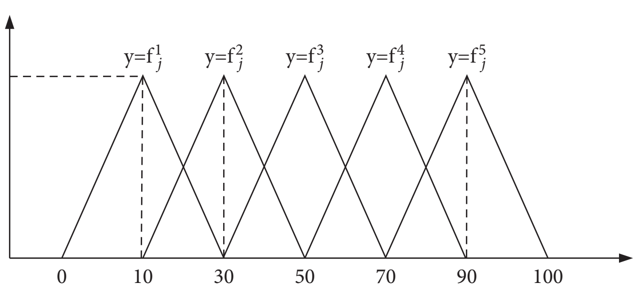

Figure 3: Schematic diagram of triangular whitenization weight function.

Table 3: Degree value table of membership for evaluation indexes.

Evaluation index	$f_j^1(x)$	$f_j^2(x)$	$f_j^3(x)$	$f_j^n(x)$	...	$f_j^s(x)$
x_{11}	r_{11}	r_{12}	...	r_{1k}	...	r_{1s}
x_{12}	r_{21}	r_{22}	...	r_{2k}	...	r_{2s}
⋮	⋮	⋮	⋮	⋮	⋮	⋮
x_{ms}	r_{m1}	r_{m2}	...	r_{mk}	...	r_{ms}

maneuverability, systemicity, and strong target. It can conduct comprehensive evaluation based on the relationship of influencing factors for complex objects. It is suitable for solving various complex problems with strong uncertainty and difficulty to quantify. Based on the weights and "subscription degree matrix" obtained by entropy weight method and gray clustering method, this paper intends to adopt fuzzy comprehensive evaluation method and use fuzzy transformation to get the evaluation results of each performance index.

Take "public service facility allocation B_1" in the performance evaluation index system of public resource trading platform constructed in this paper as an example. Perform performance evaluation according to evaluation set (i.e., gray category): V = bad, poor, medium, good, and very good, and get the value r of index "public service facility configuration B_{11}" for each evaluation level. Then the membership vector of B_{11} can be obtained:

$$R_{B11} = (r_{11}, r_{12}, r_{13}, r_{14}, r_{15}). \tag{9}$$

Specific steps are as follows:

(1) According to the above principles, the membership vector R_{B1}, R_{B2}, R_{B3},. . .,R_{Bn} of multiple performance evaluation indexes can be obtained, and the corresponding membership matrix R can be obtained:

$$R = \begin{bmatrix} R_{B1} \\ R_{B2} \\ \cdots \\ R_{Bn} \end{bmatrix}. \tag{10}$$

(2) If it is a comprehensive evaluation of a certain level of performance indexes, such as "supporting infrastructure construction B_1," it can be calculated according to the following formula:

$$B = A \times R = (b_1, b_2, b_3, \cdots, b_n) \times \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1m} \\ r_{21} & r_{22} & \cdots & r_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ r_{n1} & r_{n1} & \cdots & r_{nm} \end{bmatrix}. \tag{11}$$

(3) If it is a comprehensive evaluation of multilevel performance indexes, it can be calculated according to formula (12). Taking the target "platform construction B" as an example, based on the above analysis, the weights of four second-level indexes B_1, B_2, B_3, and B_4 relative to the first-level index B are $W = (W_{B1}, W_{B2}, W_{B3}, W_{B4})$. The membership vector of four second-level indexes is $R = (R_{B1}, R_{B2}, R_{B3}, R_{B4})\ T$, from which the membership vector M of first-level index B is obtained:

$$M = W \times \begin{bmatrix} R_{B1} \\ R_{B2} \\ R_{B3} \\ R_{B4} \end{bmatrix}. \tag{12}$$

4. Empirical Analysis for Performance Evaluation of Public Resource Trading Platform

City A is a second-tier city with a high level of urbanization, which is rich in public resources such as land, municipal administration, and transportation. In order to effectively regulate and manage public resources, while improving the efficiency of public resource transactions and integrating and optimizing the distribution of public resources, it built a comprehensive public resource trading platform in 2016. In order to build a large-scale public resource trading platform with comprehensive functions and strong service capabilities, City A invested funds to establish a relatively complete supporting infrastructure. It hired a professional talent team and established a corresponding talent training system and talent incentive mechanism. At the same time, a considerable part of funds were spent on informatization construction, and a large number of informatization and other software programs were purchased to ensure that the informatization level matches the management of public resource transactions. After 3 years of operation (i.e., by 2019), while achieving good results in the public resource transaction management of City A, it has also discovered some problems in its application of information software and resource management. Now use Delphi method to invite relevant experts to comprehensively score and evaluate the performance of city's public resource trading platform in terms of operation, service, and output. We obtained the scores of the first level, second level, and third level of platform construction, platform operation, platform services, and platform output.

4.1. Determine the Index Weight Based on Entropy Weight Method

4.1.1. Weight Determination of First-Level Indexes. Using Delphi method, 10 experts were invited to score the construction, operation, service, and output of first-level performance indexes of public resource trading platform. That is, the initial matrix V of first-level performance index evaluation of public resource trading platform is obtained:

$$V = \begin{bmatrix} 8 & 9 & 7 & 8 & 6 & 7 & 7 & 6 & 7 & 7 \\ 7 & 8 & 6 & 7 & 7 & 7 & 7 & 7 & 6 & 7 \\ 6 & 6 & 6 & 6 & 5 & 6 & 6 & 6 & 7 & 6 \\ 6 & 7 & 6 & 6 & 6 & 6 & 7 & 6 & 5 & 6 \end{bmatrix}. \tag{13}$$

According to whether the index belongs to "cost type" or "benefit type," the initial matrix of first-level performance index evaluation is standardized according to formula (2) and formula (3) to obtain standardized matrix R:

$$R = \begin{bmatrix} 0.667 & 1.000 & 0.333 & 0.667 & 0.000 & 0.333 & 0.333 & 0.000 & 0.333 & 0.333 \\ 0.500 & 1.000 & 0.000 & 0.500 & 0.500 & 0.500 & 0.500 & 0.500 & 0.000 & 0.500 \\ 0.500 & 0.500 & 0.500 & 0.500 & 0.000 & 0.500 & 0.500 & 0.500 & 1.000 & 0.500 \\ 0.500 & 1.000 & 0.500 & 0.500 & 0.500 & 0.500 & 1.000 & 0.500 & 0.000 & 0.500 \end{bmatrix}. \tag{14}$$

Table 4: Weights of first-level index.

First-level index	Platform construction	Platform operation	Platform service	Platform output
Weight	0.368	0.295	0.158	0.178

Table 5: Weights of second-level and third-level indexes.

Second-level index	Weight	Third-level index	Weight
Supporting infrastructure construction B_1	0.185	Public service facility configuration B_{11}	0.428
		Environmental facility configuration B_{12}	0.180
		Safety facility configuration B_{13}	0.392
Expert database construction B_2	0.128	Composition of technical experts B_{21}	0.361
		Composition of economic experts B_{22}	0.426
		Composition of other experts B_{23}	0.212
Talent team construction B_3	0.350	Talent training system B_{31}	0.331
		Talent team structure B_{32}	0.305
		Talent incentive mechanism B_{33}	0.364
Information construction B_4	0.337	Information software system construction B_{41}	0.410
		Information organization system construction B_{42}	0.328
		Information security system construction B_{43}	0.262
Operation status of electronic trading system C_1	0.373	System operating efficiency C_{11}	0.527
		System operation monitoring C_{12}	0.314
		Abnormal frequency C_{13} of system operation	0.159
Platform running environment C_2	0.627	Operating system environment C_{21}	0.509
		External cooperation C_{22}	0.491
Service quality D_1	0.648	Service staff's duty performance D_{11}	0.735
		Service process compliance D_{12}	0.365
Supervision channel D_2	0.352	Government supervision D_{21}	0.688
		Social supervision D_{22}	0.312
Marketization rate of public resources E_1	0.439	Property management E_{11}	0.343
		Marketization degree E_{12}	0.490
		Economic file construction of public resources E_{13}	0.167
Marketization rate of public resources E_2	0.158	Classification management of public resources E_{21}	0.371
		Price system construction of public resources E_{22}	0.629
National economy contribution of public resource transaction E_3	0.403	Accounting system construction of public resources E_{31}	0.736
		Contribution and accounting E_{32}	0.264

According to formula (5), the characteristic proportion and information entropy of first-level performance index of public resource trading platform can be obtained, and first-level index weight can be obtained. The calculation results are shown in Table 4.

4.1.2. Weight Determination of Second-Level and Third-Level Indexes. In the same way, Delphi method is used to score the experts, and, at the same time, the weights of second-level and third-level performance indexes of public resource trading platform can be obtained according to formulas (2)–(4). The calculation results are shown in Table 5.

4.2. Determine the Degree of Membership Based on Gray Clustering.

(1) According to gray clustering classification standard determined in Section 3.2.1 and at the same time referring to the relevant research on performance evaluation index classification of public resource trading platform, combined with the specific research situation, the public resource trading platform is divided into five levels: bad, poor, medium, good, and very good. See Table 6 for the specific classification.

(2) Comprehensively determine the actual value of each index based on expert opinions; see Table 7.

(3) Determine the whitening weight function and comprehensive clustering coefficient of all levels of indexes according to formula (7); see Table 8.

4.2.1. Result Analysis. From the perspective of first-level performance indexes of public resource trading platform, the city's public resource trading platform construction performance, platform operating performance, platform service performance, and platform output performance belong to "very good," "medium," "medium," and "good" categories, respectively. From the perspective of second-level performance indexes of public resource trading platform, supporting infrastructure construction, talent team construction, and informatization construction belong to "very good" gray category. The marketization rate of public resources belongs to "good" gray category, and expert database

Table 6: The value range for performance indexes of public resource trading platform.

First-level	Second-level	Third-level	Bad (1-2)	Poor (2-3)	Medium (3-4)	Good (4-5)	Very good (5-6)
B	B_1	B_{11}	< 40	40–60	60–85	85–95	> 95
		B_{12}	< 60	60–70	70–80	80–85	> 85
		B_{13}	< 50	50–60	60–80	80–90	> 90
	B_2	B_{21}	< 50	50–60	60–80	80–90	> 90
		B_{22}	< 40	40–60	60–85	85–95	> 95
		B_{23}	< 60	60–70	70–80	80–85	> 85
	B_3	B_{31}	< 50	50–60	60–80	80–90	> 90
		B_{32}	< 60	60–70	70–80	80–85	> 85
		B_{33}	< 40	40–60	60–85	85–95	> 95
	B_4	B_{41}	< 40	40–60	60–85	85–95	> 95
		B_{42}	< 50	50–60	60–80	80–90	> 90
		B_{43}	< 60	60–70	70–80	80–85	> 85
C	C_1	C_{11}	< 40	40–60	60–85	85–95	> 95
		C_{12}	< 50	50–60	60–80	80–90	> 90
		C_{13}	< 60	60–70	70–80	80–85	> 85
	C_2	C_{21}	< 40	40–60	60–85	85–95	> 95
		C_{22}	< 50	50–60	60–80	80–90	> 90
D	D_1	D_{11}	< 40	40–60	60–85	85–95	> 95
		D_{12}	< 50	50–60	60–80	80–90	> 90
	D_2	D_{21}	< 40	40–60	60–85	85–95	> 95
		D_{22}	< 50	50–60	60–80	80–90	> 90
E	E_1	E_{11}	< 50	50–60	60–80	80–90	> 90
		E_{12}	< 40	40–60	60–85	85–95	> 95
		E_{13}	< 60	60–70	70–80	80–85	> 85
	E_2	E_{21}	< 40	40–60	60–85	85–95	> 95
		E_{22}	< 50	50–60	60–80	80–90	> 90
	E_3	E_{31}	< 50	50–60	60–80	80–90	> 90
		E_{32}	< 40	40–60	60–85	85–95	> 95

Table 7: The actual value of performance indexes of public resource trading platform.

Index	B_{11}	B_{12}	B_{13}	B_{21}	B_{22}	B_{23}	B_{31}	B_{32}	B_{33}	B_{41}	B_{42}	B_{43}	C_{11}	C_{12}
Actual value	96	88	91	65	73	78	86	81	93	97	93	86	66	69
Index	C_{13}	C_{21}	C_{22}	D_{11}	D_{12}	D_{21}	D_{22}	E_{11}	E_{12}	E_{13}	E_{21}	E_{22}	E_{31}	E_{32}
Actual value	78	72	64	89	81	53	58	53	48	69	36	49	87	93

construction, platform operating environment, service quality, and supervision channels belong to "medium" gray category. The operation of electronic trading systems and protection degree of public resources are classified as "poor" gray category.

4.3. Determine the Evaluation Value Based on Fuzzy Comprehensive Evaluation. In Section 3.2, gray clustering is used to evaluate performance of first-level and second-level indexes of public resource trading platform, and the degree of membership of each performance evaluation index is obtained. The fuzzy comprehensive evaluation can now be used to calculate the comprehensive evaluation results of performance for public resource trading platform and then put forward specific suggestions for improvement. The process is as follows:

(1) the "gray class" classification method similar to gray clustering model, the evaluation set of fuzzy comprehensive evaluation is set as $V = \{\text{bad, poor, medium, good, very good}\}$.
(2) Using triangular whitenization weight function formula in gray clustering, calculate the whitening weight function and gray clustering coefficient of performance evaluation index of public resource trading platform; see Table 8 for details.
(3) Calculate the comprehensive evaluation value according to fuzzy comprehensive evaluation formula (12), taking the weight of second-level index as an example, as shown below:

Table 8: The whitening weight function for performance indexes of public resource trading platform.

Index	Comprehensive weight	Bad (1-2)	Poor (2-3)	Medium (3-4)	Good (4-5)	Very good (5-6)
B_{11}	0.029	0	0	0	0.200	0.800
B_{12}	0.012	0	0	0	0.450	0.550
B_{13}	0.027	0	0	0	0.400	0.600
B_1	0.068	0	0	0	0.323	0.677
B_{21}	0.017	0	0	0.667	0.330	0
B_{22}	0.020	0	0	0.971	0.086	0
B_{23}	0.010	0	0	0.600	0.400	0
B_2	0.047	0	0	0.782	0.218	0
B_{31}	0.043	0	0	0	0.100	0.900
B_{32}	0.039	0	0	0	0.200	0.800
B_{33}	0.047	0	0	0	0.600	0.400
B_3	0.129	0	0	0	0.313	0.687
B_{41}	0.051	0	0	0	0.071	0.929
B_{42}	0.041	0	0	0	0.200	0.800
B_{43}	0.032	0	0	0	0.650	0.350
B_4	0.124	0	0	0	0.265	0.735
C_{11}	0.058	0.289	0.711	0	0	0
C_{12}	0.035	0.213	0.787	0	0	0
C_{13}	0.018	0	0.319	0.681	0	0
C_1	0.110	0.219	0.673	0.108	0	0
C_{21}	0.094	0	0.319	0.681	0	0
C_{22}	0.091	0.589	0.411	0	0	0
C_2	0.185	0.207	0.258	0.441	0	0
D_{11}	0.075	0	0	0.521	0.479	0
D_{12}	0.037	0	0	0.614	0.386	0
D_1	0.102	0	0	0.614	0.386	0
D_{21}	0.038	0	0	0.782	0.218	0
D_{22}	0.017	0	0	0.481	0.519	0
D_2	0.056	0	0	0.688	0.312	0
E_{11}	0.027	0	0	0.427	0.573	0
E_{12}	0.038	0	0	0.285	0.715	0
E_{13}	0.013	0	0	0.492	0.508	0
E_1	0.078	0	0	0.222	0.778	0
E_{21}	0.010	0	0.694	0.306	0	0
E_{22}	0.018	0	0.820	0.180	0	0
E_2	0.028	0	0.773	0.227	0	0
E_{31}	0.053	0	0.381	0.619	0	0
E_{32}	0.019	0	0.429	0.571	0	0
E_3	0.072	0	0.394	0.606	0	0

$$B = A \times R = \begin{bmatrix} 0.029 \\ 0.012 \\ 0.027 \\ 0.017 \\ 0.020 \\ 0.010 \\ 0.043 \\ 0.039 \\ 0.047 \\ 0.051 \\ 0.041 \\ 0.032 \\ 0.058 \\ 0.035 \\ 0.018 \\ 0.094 \\ 0.091 \\ 0.075 \\ 0.037 \\ 0.038 \\ 0.017 \\ 0.027 \\ 0.038 \\ 0.013 \\ 0.010 \\ 0.018 \\ 0.053 \\ 0.019 \end{bmatrix}^T \times \begin{bmatrix} 0 & 0 & 0 & 0.200 & 0.800 \\ 0 & 0 & 0 & 0.450 & 0.550 \\ 0 & 0 & 0 & 0.400 & 0.600 \\ 0 & 0 & 0.667 & 0.333 & 0 \\ 0 & 0 & 0.914 & 0.086 & 0 \\ 0 & 0 & 0.600 & 0.400 & 0 \\ 0 & 0 & 0 & 0.100 & 0.900 \\ 0 & 0 & 0 & 0.200 & 0.800 \\ 0 & 0 & 0 & 0.600 & 0.400 \\ 0 & 0 & 0 & 0.071 & 0.929 \\ 0 & 0 & 0 & 0.200 & 0.800 \\ 0 & 0 & 0 & 0.650 & 0.350 \\ 0.289 & 0.711 & 0 & 0 & 0 \\ 0.213 & 0.787 & 0 & 0 & 0 \\ 0 & 0.319 & 0.681 & 0 & 0 \\ 0 & 0.319 & 0.681 & 0 & 0 \\ 0.589 & 0.411 & 0 & 0 & 0 \\ 0 & 0 & 0.521 & 0.479 & 0 \\ 0 & 0 & 0.614 & 0.386 & 0 \\ 0 & 0 & 0.782 & 0.218 & 0 \\ 0 & 0 & 0.481 & 0.519 & 0 \\ 0 & 0 & 0.427 & 0.573 & 0 \\ 0 & 0 & 0.285 & 0.715 & 0 \\ 0 & 0 & 0.492 & 0.508 & 0 \\ 0 & 0.694 & 0.306 & 0 & 0 \\ 0 & 0.820 & 0.180 & 0 & 0 \\ 0 & 0.381 & 0.619 & 0 & 0 \\ 0 & 0.394 & 0.606 & 0 & 0 \end{bmatrix} = (0.078, 0.191, 0.292, 0.224, 0.226). \quad (15)$$

According to the maximum degree principle of membership in fuzzy comprehensive evaluation, it can be obtained that the overall performance of city's public resource trading platform is at a medium level. This conclusion is basically consistent with the result obtained in above fuzzy comprehensive evaluation. Therefore, the comprehensive model of performance evaluation and improvement proposed in this paper is scientific and feasible and has a reliable guarantee of results.

5. Conclusion

(1) Considering the public welfare and operational characteristics of public resource trading platform, this paper proposes public resource performance evaluation indexes and analyzes them in detail from the four levels of platform construction, platform service, platform operation, and platform output.

(2) Innovatively propose a comprehensive model of public resource performance evaluation based on entropy weight method, gray clustering method, and fuzzy comprehensive evaluation method. Then use the clustering coefficient obtained by gray clustering analysis as the degree of membership in fuzzy comprehensive evaluation. It not only solves the problem that the degree of membership is difficult to determine but also avoids the subjective influence in determination process and at the same time avoids the problem of experts scoring indexes multiple times in evaluation process.

(3) Evaluate the performance of a public resource trading platform based on the established index system and evaluation method. Experiments show that the comprehensive performance evaluation model is scientific, reliable, and comprehensive.

Data Availability

The data included in this paper are available without any restriction.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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