Research Article

Identifying Key Influential Factors of Bid Evaluation in Government Public Project Green Procurement in China Using BP-DEMATEL Model

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Received 31 January 2022; Accepted 10 February 2022; Published 2 March 2022

Academic Editor: Filippo Cacace

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With the global resource and environment problems becoming increasingly prominent and the government procurement scale growing rapidly, the implementation of green procurement for government public project will have a significant impact on the protection of resources and environment. Identifying the key influential factors of bid evaluation in government public project green procurement is of great significance for promoting the construction of government public project green procurement system. Based on the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, Back Propagation (BP) neural network is introduced to determine the direct-relation matrix, optimizing the traditional DEMATEL method. This paper uses the BP-DEMATEL model to identify key influential factors of bid evaluation in government public project green procurement by algorithmic design. Among 56 indicators, which have formed a set of index system of bid evaluation in government public project green procurement, 20 key influential factors are identified, providing reference for the government to implement green procurement in the field of public project. The research results not only enrich and improve the theoretical and practical research in the field of government public project green procurement, but also solve the defects of traditional DEMATEL method that the method is too subjective and tedious when obtaining the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or expert scoring method, thus expanding the scope of the application of the DEMATEL method.

1. Introduction

With the global resource and environment problems becoming increasingly prominent and the government procurement scale growing rapidly, government green procurement has become a worldwide trend. Government green procurement refers to the economic behavior of legally using fiscal funds to purchase green products, projects, and services [1], which is the entire process that one or more qualified suppliers are selected through tendering or other methods to accomplish green products, projects, and services under the guidance of green development concept. Wang Ying, Director of the Government Procurement Management Office of the State Treasury Department of the Ministry of

Finance, pointed that the Chinese government green procurement system is still in its infancy and it is of relatively small coverage at present, which is mainly reflected in the policies of compulsory procurement and prior procurement of energy-saving and environment-friendly products; however, projects involve less green procurement. From the existing research, the Chinese government procurement systems lack systematic and comprehensive standards of bid evaluation for public project green procurement. Therefore, identification of key influential factors of bid evaluation in government public project green procurement can provide theoretical guidance and methodological basis for the government to promote and improve the construction of government public project green procurement system.

In China, government public project mainly focuses on infrastructure construction, while creating huge economic and social benefits for the society; they also consume a large number of natural resources and energy resources and cause irreversible serious pollution and damage to the environment, on which human beings depend. This paper is a systematic study on identifying the key influential factors of bid evaluation in government public project green procurement, which not only helps to save energy, protect environment, and bring great environmental benefits to society, but also helps to establish social image and give full play to government's leading role. It is of great practical significance for the government to carry out green procurement in the field of public project, construct and improve the green procurement system of government public project, and establish and improve the economic system of green and low-carbon circular development.

According to the website of the Ministry of Finance of the People's Republic of China released on September 3, 2021, the scale of Chinese government procurement in 2020 reached 3,697.06 billion yuan, which is 390.36 billion yuan more than the previous year, increasing by 11.8% and accounting for 10.2% of China's fiscal expenditure and 3.6% of Gross Domestic Product (GDP). The scale of project procurement was 1,749.24 billion yuan, accounting for 47.3% of Chinese government procurement scale, as shown in Figure 1. In addition, open tendering accounted for 79.3% of Chinese government procurement scale. It can be seen that the scale of project procurement will be in steady growth and still be in the dominate position in the short term. Open tendering will continue to be the main way of Chinese government procurement. To refine the research direction and clarify the research goals, this paper only conducts research on the bid evaluation in government public project green procurement that adopts open tendering.

This paper uses the BP-DEMATEL model to identify key influential factors of bid evaluation in government public project green procurement by algorithmic design. The key influential factors provide reference for the government to implement green procurement in the field of public project. The research results not only enrich and improve the theoretical and practical research in the field of government public project green procurement, but also solve the defects of traditional DEMATEL method that the method is too subjective and tedious when obtaining the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or expert scoring method, thus expanding the scope of the application of the DEMATEL method.

The following section is literature review. Section 3 is methodology. Section 4 is results and discussion. Finally, conclusions of this study are drawn.

2. Literature Review

As there are few studies specifically focused on the bid evaluation in government public project green procurement, this section mainly reviews the relevant literature from the following four aspects.

FIGURE 1: China's Government Procurement Structure in 2020 (data source: website of the Ministry of Finance of the People's Republic of China, September 3, 2021).

2.1. Research on Relevant Regulations of Government Public Project Procurement. "Regulations for the Implementation of the Government Procurement Law of the People's Republic of China" (hereinafter referred to as the "Regulations") came into effect on March 1, 2015. Paragraph 1 of Article 7 stipulates that the activity that government purchase project through tendering is subject to "Tendering and Bidding Law of the People's Republic of China" and its implementing regulations. Paragraph 2 of Article 7 of the "Regulations" stipulates that the project mentioned in Paragraph 1 refers to construction project, including the new-construction, reconstruction, expansion of buildings and structures, and their decoration, demolition, and repairment. Article 7 of the "Regulation" successfully achieved the cohesion and unification with the "Tendering and Bidding Law of the People's Republic of China" and its implementing regulations, maintaining the consistency of the law, avoiding disagreement in the application, and strengthening the legality of project procurement [2]. At present, rules and regulations on green procurement have not yet formed a system, and they are scattered in environmental protection and procurement-related laws and policies. "Government Procurement Law" and "Implementing Regulations of Government Procurement Law" govern Chinese government procurement activities, providing a policy and legal basis for the implementation of the public project green procurement system. However, only a few articles mention the issue of green procurement. There are no systemic green procurement regulations and there are structural and functional deficiencies as a whole [3]. For instance, Article 6 of the "Regulations" simply take the achievement of energy conservation and environment protection as the goal of public policy, there are no clear laws and specific measures on how to achieve energy saving, environmental protection, and green procurement promotion, and there is a lack of rules on measures to deal with non-green procurement behaviors [4].

2.2. Theoretical and Practical Research on Green Procurement of Government Public Project. Government green procurement refers to the economic behavior of legally using fiscal funds to purchase green products, projects, and services. In terms of theoretical research, most scholars mainly discuss the theoretical basis of government green procurement from the aspects of new institutional economics, environmental economics, environmental management, and sustainable development theory [5]. Specifically, government green procurement activities are mainly guided by externality theory, green supply chain management theory, sustainable development theory, and stakeholder theory [6–8]. At present, the theoretical research on green procurement in China is mainly for government procurement and manufacturing procurement; the research content mainly focuses on green supplier selection [9–15], green procurement management mode [16], restriction factor analysis [17–19], legal system [20–22], policy recommendations [23–26], etc., while the research on green supplier selection mainly focuses on goods [27], and research focuses on projects of government green procurement is rare. In terms of practical research, in recent years, some progress has been made in green procurement of government public project. Whether it is the construction of the Beijing's Olympic facilities or the Shanghai World Expo Hall, a new model of green procurement has been implemented from the designer to the constructor [28]. Some local governments are formulating green procurement regulations in the field of public project; for example, the Legal System Office of the People's Government of Changzhou City, Jiangsu Province, announced the “Guidelines on Accelerating Green Procurement of Government-Invested Projects in the Engineering Construction Field (Consultation Draft),” which is recognized as the first public project green procurement guideline by experts [29] (China Government Procurement News, July 24, 2015).

2.3. Research on Green Index System of Bidding Evaluation in Project Procurement. There is very limited research on green index system of bidding evaluation in project procurement; only Li [30–32], Yang [33], Li [34], Zhang [35, 36], etc. conducted research. It is Li [30–32] who first constructed an index system of bid evaluation for green construction, including three categories of indicators: qualification, technology, and economy; Yang [33] constructed an evaluation index system of contractor selection for EPC projects based on green concept, including four categories of indicators: design plan, construction plan, procurement plan, and management measures; Li [34] constructed an evaluation index system for building contractor green construction capacity, including four categories of indicators: qualification, green construction technology, organizational management, and economy; Zhang [35] constructed a green index system of bid evaluation for engineering projects from four aspects of qualification, technology, economy, and management; Zhang [36] constructed a bid evaluation index system for government public project green procurement from five aspects of qualification, economy, technology, management, and public welfare.

2.4. Research on Identification Methods of Key Influential Factors. Most scholars used DEMATEL model for research [37–42], and some experts and scholars also combined two or more mathematical models based on previous studies, such as AHP-DEMATEL model [43], Fuzzy-DEMATEL model [44, 45], Grey-DEMATEL model [46, 47], DEMATEL-ANP model [48], COWA-DEMATEL model [49], DEMATEL-TOPSIS model [50], DEMATEL-COPRAS model [51], DEMATEL-ISM model [52–55], and DEMATEL-ISM-MICMAC model [56]. To a certain extent, they have enriched the theoretical and practical research on the identification methods of key influential factors.

In summary, there are three aspects to be further improved. (1) The current research on green procurement is mainly for government procurement and manufacturing procurement, and the research on green supplier selection mainly focuses on goods, while research focuses on projects of government green procurement is rare; (2) in the green procurement management of public project, the selection of green bidders is the key to improve the government green procurement performance and public project green performance. However, the Chinese government procurement system lacks systematic and complete standards of bid evaluation in public project green procurement; (3) identification of the key influential factors is less scientific. Most scholars use the traditional DEMATEL method to identify the key influential factors. However, as for many complex problems with lots of influential factors, it is difficult to obtain data of the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or experts scoring method, which greatly limits the application scope of the DEMATEL method. In addition, the use of questionnaire surveys or expert scoring method to obtain the influence degree between each pair of factors is highly dependent on the knowledge and experience of the survey participants, which relatively affects the objectivity and reliability of the research conclusions. By summarizing related research [57–61], based on the DEMATEL method, BP neural network is introduced to determine the direct-relation matrix, optimizing the traditional DEMATEL method. This paper uses the BP-DEMATEL model to identify key influential factors of bid evaluation in government public project green procurement by algorithmic design, so as to promote the theoretical and practical research of the government public project green procurement system.

3. Methodology

3.1. BP-DEMATEL Model. DEMATEL [62] is a method to analyze the cause-effect relationship between factors in complex systems and identify key factors. In this method, the direct-relation matrix is established based on the influence degree between each pair of factors in the system, the comprehensive influence matrix is calculated, the affecting degree and affected degree of each factor are calculated, and then the center degree and cause degree of each factor are determined. However, the direct-relation matrix in the DEMATEL method is mainly determined through

questionnaire surveys or expert scoring method, which depends on the knowledge and experience of the survey participants, thus relatively reducing the objectivity and reliability of the research conclusions. In addition, it is difficult and tedious to analyze the complex research objects with lots of influential factors. By introducing the BP neural network [63] to the DEMATEL method, the direct-relation matrix can be calculated by the BP neural network; then the influential factors can be analyzed and identified through the DEMATEL method. As for processing complex research objects with lots of influential factors, BP-DEMATEL model possesses convenience and operational feasibility. And the method overcomes subjectivity when using questionnaire surveys or expert scoring method as well. Therefore, the analysis of influential factors is more objective and reliable.

The BP neural network is used to establish a nonlinear mapping relationship from the input layer to the output layer, the neural network is trained by the momentum adaptive learning rate gradient descent method, the weights and thresholds of the network are continuously adjusted to minimize the error function, the weight matrix between the input layer and the hidden layer and the weight vector between the hidden layer and the output layer are obtained, and the overall weight vector between the input layer and the output layer is calculated, from which the direct-relation matrix is obtained. Through the DEMATEL method, the comprehensive influence matrix can be determined based on the direct-relation matrix, the affecting degree and affected degree of each factor are calculated, and then the center degree and cause degree of each factor are calculated. The Cartesian coordinate system is established based on the center degree and cause degree of each factor, the cause-effect diagram is drawn with the center degree as the abscissa and the cause degree as the ordinate, and the position of each factor is marked on the coordinate system. With the help of the cause-effect diagram, the factors can be separated into a cause group and an effect group. Additionally, the key factors of a complex system can be identified.

3.2. Calculation Steps of BP-DEMATEL. The flow diagram of the BP-DEMATEL model is shown in Figure 2.

The specific calculation steps of the BP-DEMATEL model are as follows.

Step 1. Construct the influential factor matrix x and the target factor matrix y :

$$\begin{aligned} x &= (x_{ik})_{m \times p} (i = 1, 2, \dots, m; k = 1, 2, \dots, p) \\ y &= (y_{1k})_{1 \times p} (k = 1, 2, \dots, p). \end{aligned} \quad (1)$$

Among them, m represents the number of influential factors, p represents the number of statistical samples, and there is only one target factor.

x_{ik} is the rating value of the i -th influential factor for the k -th sample, and y_{1k} is the rating value of the target factor for the k -th sample, i.e., the comprehensive evaluation result for the k -th sample. 1, 2, 3, 4, and 5 represent very poor, poor, fair, good, and excellent, respectively.

Step 2. Standardize the influential factor matrix x and the target factor matrix y :

$$x, y \Rightarrow \bar{x}, \bar{y}, \bar{x}_{ik} = \frac{x_{ik} - \mu_{ix}}{\sigma_{ix}}, \bar{y}_{1k} = \frac{y_{1k} - \mu_y}{\sigma_y}. \quad (2)$$

In the equation, $\bar{x} = (\bar{x}_{ik})_{m \times p}$ ($i = 1, 2, \dots, m; k = 1, 2, \dots, p$) represents standardized matrix of the influential factor matrix x , $\bar{y} = (\bar{y}_{1k})_{1 \times p}$ ($k = 1, 2, \dots, p$) represents standardized matrix of the target factor matrix y , μ_{ix} represents the sample mean of the i -th influential factor, σ_{ix} represents the sample standard deviation of the i -th influential factor, μ_y represents the sample mean of the target factor, and σ_y is the sample standard deviation of the target factor. The standardization process not only converts the raw data into standardized values without differences in dimensions or orders of magnitude, eliminating the influence of different factors due to different attributes, thus facilitating the comprehensive analysis and comparison of influential factors of different dimensions or orders of magnitude, but also accelerates the convergence speed of the algorithm.

Step 3. Calculate the weight matrix.

Let $\bar{x}$ be the input matrix of the BP neural network and $\bar{y}$ be the output vector of the BP neural network. Use the momentum adaptive learning rate gradient descent method to train the BP neural network. Calculate the weight matrix $W_{m \times g}$ between the input layer and the hidden layer, and the weight vector $w_{g \times 1}$ between the hidden layer and the output layer. Among them, g represents the number of hidden layer neurons.

Step 4. Calculate the overall weight vector:

$$\omega = |W_{m \times g}| \cdot |w_{g \times 1}| = (\omega_1, \omega_2, \dots, \omega_m)^T. \quad (3)$$

Among them, ω represents the overall weight vector between the input layer and the output layer and $|W_{m \times g}|, |w_{g \times 1}|$ means taking the absolute value for each element in the weight matrix.

Step 5. Construct the direct-relation matrix A :

$$A = (a_{ij})_{m \times m} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mm} \end{pmatrix}. \quad (4)$$

Among them, $a_{ii} = 0, a_{ij} = (\omega_i / \omega_j)$ (if $\omega_j = 0$, then $a_{ij} = 0$). The element a_{ij} in direct-relation matrix represents the direct influence degree of factor i on factor j , expressed by the ratio of the weight of factor i ω_i to the weight of factor j ω_j . There is not only a direct influence relationship between factors, but also an indirect influence relationship. In order to analyze the indirect influence between the factors, a comprehensive influence matrix requires to be calculated.

FIGURE 2: The flow diagram of the BP-DEMATEL model.

Step 6. Normalize the direct-relation matrix A to obtain the matrix B :

$$B = (b_{ij})_{m \times m} = \frac{1}{\max_{1 \leq i \leq m} \sum_{j=1}^m a_{ij}} \cdot A. \quad (5)$$

Step 7. Calculate the comprehensive influence matrix T :

$$T = (t_{ij})_{m \times m} = B(E - B)^{-1}. \quad (6)$$

Among them, $(E - B)^{-1}$ is the inverse matrix of $(E - B)$ and E is the unit matrix.

The element t_{ij} in the comprehensive influence matrix indicates the degree of direct and indirect influence of factor i on factor j , or the comprehensive influence degree to which factor j is affected by factor i .

Step 8. Calculate the affecting degree and affected degree of each factor.

Calculate the sum of each row and each column of T . D is the sum of the rows of T , which is defined as the affecting degree. R is the sum of the columns of T , which is defined as the affected degree. D and R can be calculated as follows.

Step 9. Calculate the center degree and cause degree of each factor.

u is the sum of the affecting degree D and affected degree R , which is defined as the center degree. v is the difference between the affecting degree D and affected degree R , which is defined as the cause degree.

$$\begin{aligned} u_i &= D_i + R_i, \\ v_i &= D_i - R_i. \end{aligned} \quad (7)$$

The center degree indicates the importance of the factor; the larger the value, the greater the importance of the factor. The cause degree can be used to distinguish whether the type of factor is a cause factor or an effect factor. If the cause degree is positive ($v_i > 0$), the factor falls under the cause group; if the cause degree is negative ($v_i < 0$), the factor will be grouped into the effect group.

4. Results and Discussion

4.1. Construction of Index System of Influential Factors. The research of this paper is to continue and deepen the existing research results. The authors have constructed a set of index systems of bid evaluation in government public project green procurement, including 56 indicators [32]. Bid evaluation in government public project green procurement is a complex organic system. This paper uses the BP-DEMATEL model to systematically analyze the cause-effect relationship between factors and identify key influential factors, further optimizing the structure of the bid evaluation system.

4.2. Data Collection and Calculation Results. Select 150 valid questionnaires, and use MATLAB 2018a to calculate the center degree and cause degree of each factor. The specific results are shown in Table 1.

TABLE 1: Center degree and cause degree of each factor.

Code	Factors	Center degree	Cause degree
1	Qualification level	2.78256	-0.40013
2	Enterprise size	2.75536	0.09738
3	Registered capital	2.75887	0.16971
4	Working capital	2.75878	-0.16838
5	Financial ability	3.03586	-1.27824
6	Financial soundness	2.75795	-0.15403
7	Contract performance	2.78029	-0.38400
8	Litigation or arbitration	2.75460	0.07262
9	Past excellent engineering performance	2.77743	-0.36277
10	Construction in progress and new undertakings	2.75448	-0.06794
11	Construction experience of similar project	2.90030	0.91062
12	Green construction demonstration project	3.07292	1.36394
13	Total bid price	3.14606	-1.52156
14	Unit price of main items	2.76202	-0.21503
15	Quotation for sporadic project	2.76029	0.19142
16	Reasonability of quotation composition	2.97614	1.12909
17	Payment terms	2.97293	-1.12063
18	Environmental governance costs	2.95176	1.06318
19	Green investment costs	2.94286	1.03822
20	Full life cycle operating costs	2.85907	0.76924
21	Construction period	3.10734	1.43981
22	Duration reasonability	2.75786	-0.15248
23	Construction schedule and guarantee measures	2.91643	0.96075
24	Quality management system and assurance measures	2.80960	-0.55794
25	Technical strength	2.78457	0.41391
26	Construction plan and technical measures	2.91003	-0.94114
27	Quality and quantity of labor	2.75783	0.15195
28	Material quality	2.75631	0.12137
29	Mechanical equipment level	2.75537	0.09758
30	Water saving and water resource utilization measures	3.00386	-1.20028
31	New water-saving technology implementation plan	2.76936	-0.29462
32	Safe water implementation plan	2.76641	-0.26550
33	Site utilization	2.76542	0.25502
34	Reasonability of construction layout	2.76402	0.23933
35	Land saving and land resource utilization measures	2.99154	-1.16909
36	Proportion of green materials use	2.78787	-0.43555
37	Material saving and material resource utilization measures	2.97797	-1.13391
38	Proportion of recyclable materials reuse	2.75376	-0.02605
39	Proportion of local materials	2.75366	0.01088
40	Proportion of clean energy use	2.78499	0.41667
41	Energy saving and energy utilization measures	2.97706	-1.13153
42	New energy-saving technology implementation plan	2.75993	-0.18627
43	Planning and control capacity	2.85073	0.73765
44	Organization and coordination capacity	2.81496	-0.58433
45	Green construction management system	3.03599	1.27856
46	Green education and cultural construction	2.81383	-0.57888
47	Health protection for construction laborers	2.80398	-0.52895
48	Wage protection for construction laborers	2.79741	0.49290
49	Humanistic care for construction laborers	2.89285	-0.88661
50	Safety management system and measures	2.85937	0.77036
51	Safety measures for mechanical facilities	2.75385	-0.03404
52	Personal safety measures	2.75381	0.03022
53	Dust control measures	2.77434	0.33831
54	Sewage discharge control measures	2.79607	0.48526
55	Soil protection and construction waste control measures	2.78800	0.43639
56	Noise control and light pollution control measures	2.76967	0.29750

Draw the cause-effect relationship diagram with the center degree as the abscissa and the cause degree as the ordinate, as shown in Figure 3.

Figure 3 shows the cause-effect relationship diagram of 56 influential factors of bid evaluation in government public project green procurement, with the center degree as the

FIGURE 3: Cause-effect relationship diagram.

abscissa and the cause degree as the ordinate. In terms of cause degree, points with vertical coordinate above 0 are cause factors; the sequence numbers of the 11 factors with the largest cause degree (cause degree > 0.7) are 21, 12, 45, 16, 18, 19, 23, 11, 50, 20, and 43. The points with vertical coordinate below 0 are the effect factors; the serial numbers of the 9 factors with the largest absolute value of cause degree (cause degree < -0.7) are 13, 5, 30, 35, 37, 41, 17, 26, and 49. In terms of center degree, the serial numbers of the 20 factors with the largest value of center degree (center degree > 2.85) are 13, 21, 12, 45, 5, 30, 35, 37, 41, 16, 17, 18, 19, 23, 26, 11, 49, 50, 20, and 43.

4.3. Result Analysis and Discussion

4.3.1. Identification of Cause Factors. From Table 1 and Figure 3, there are 29 cause factors among the 56 influential factors, since their cause degree is greater than zero (cause degree > 0). As shown in Table 2, the sequence numbers of cause degree in descending order are 21, 12, 45, 16, 18, 19, 23, 11, 50, 20, 43, 48, 54, 55, 40, 25, 53, 56, 33, 34, 15, 3, 27, 28, 29, 2, 8, 52, and 39. It can be illustrated that they are more inclined to affect other factors. Among them, the sequence numbers of the 11 factors with the largest cause degree (cause degree > 0.7) are 21 (construction period), 12 (green construction demonstration project), 45 (green construction management system), 16 (reasonability of quotation composition), 18 (environmental governance costs), 19 (green investment costs), 23 (construction schedule and guarantee measures), 11 (construction experience of similar project), 50 (safety management system and measures), 20 (full life cycle operating costs), and 43 (planning and control capacity). It can be explained that these 11 cause factors have more intensive impact on other factors.

4.3.2. Identification of Effect Factors. From Table 1 and Figure 3, there are 27 effect factors among the 56 influential factors, since their cause degree is lower than zero (cause degree < 0). As shown in Table 3, the sequence numbers of the absolute value of cause degree in descending order are 13, 5, 30, 35, 37, 41, 17, 26, 49, 44, 46, 24, 47, 36, 1, 7, 9, 31, 32, 14, 42, 4, 6, 22, 10, 51, and 38. It can be illustrated that they are more inclined to be affected by other factors. Among them, the

sequence numbers of the 9 factors with the largest absolute value of cause degree (cause degree < -0.7) are 13 (total bid price), 5 (financial ability), 30 (water saving and water resource utilization measures), 35 (land saving and land resource utilization measures), 37 (material saving and material resource utilization measures), 41 (energy saving and energy utilization measures), 17 (payment terms), 26 (construction plan and technical measures), and 49 (humanistic care for construction laborers). It can be explained that other factors have more intensive impact on these 9 effect factors.

4.3.3. Identification of Key Influential Factors. Take the center degree as the basis for judging the importance of factors. According to Table 1, sort the factors in the descending order of center degree. Select 20 factors with center degree greater than the average 2.84244 as the key influential factors; the serial numbers of the importance degree in descending order are 13 (total bid price), 21 (construction period), 12 (green construction demonstration project), 45 (green construction management system), 5 (financial ability), 30 (water saving and water resource utilization measures), 35 (land saving and land resource utilization measures), 37 (material saving and material resource utilization measures), 41 (energy saving and energy utilization measures), 16 (reasonability of quotation composition), 17 (payment terms), 18 (environmental governance costs), 19 (green investment costs), 23 (construction schedule and guarantee measures), 26 (construction plan and technical measures), 11 (construction experience of similar project), 49 (humanistic care for construction laborers), 50 (safety management system and measures), 20 (full life cycle operating costs), and 43 (planning and control capacity), as shown in Table 4.

According to the research results, the 20 key influential factors of bid evaluation in government public project green procurement and their importance ranking (in order of centrality degree) are largely in line with the actual situation, proving the validity of this paper's methodology.

4.3.4. Comparative Analysis of BP-DEMATEL Model and Traditional DEMATEL Method. The traditional DEMATEL method depends on questionnaire surveys or expert scoring

TABLE 2: Cause factors.

Code	Cause factors	Cause degree (>0)
21	Construction period	1.43981
12	Green construction demonstration project	1.36394
45	Green construction management system	1.27856
16	Reasonability of quotation composition	1.12909
18	Environmental governance costs	1.06318
19	Green investment costs	1.03822
23	Construction schedule and guarantee measures	0.96075
11	Construction experience of similar project	0.91062
50	Safety management system and measures	0.77036
20	Full life cycle operating costs	0.76924
43	Planning and control capacity	0.73765
48	Wage protection for construction laborers	0.49290
54	Sewage discharge control measures	0.48526
55	Soil protection and construction waste control measures	0.43639
40	Proportion of clean energy use	0.41667
25	Technical strength	0.41391
53	Dust control measures	0.33831
56	Noise control and light pollution control measures	0.29750
33	Site utilization	0.25502
34	Reasonability of construction layout	0.23933
15	Quotation for sporadic project	0.19142
3	Registered capital	0.16971
27	Quality and quantity of labor	0.15195
28	Material quality	0.12137
29	Mechanical equipment level	0.09758
2	Enterprise size	0.09738
8	Litigation or arbitration	0.07262
52	Personal safety measures	0.03022
39	Proportion of local materials	0.01088

TABLE 3: Effect factors.

Code	Effect factors	Cause degree (<0)
13	Total bid price	-1.52156
5	Financial ability	-1.27824
30	Water saving and water resource utilization measures	-1.20028
35	Land saving and land resource utilization measures	-1.16909
37	Material saving and material resource utilization measures	-1.13391
41	Energy saving and energy utilization measures	-1.13153
17	Payment terms	-1.12063
26	Construction plan and technical measures	-0.94114
49	Humanistic care for construction laborers	-0.88661
44	Organization and coordination capacity	-0.58433
46	Green education and cultural construction	-0.57888
24	Quality management system and assurance measures	-0.55794
47	Health protection for construction laborers	-0.52895
36	Proportion of green materials use	-0.43555
1	Qualification level	-0.40013
7	Contract performance	-0.38400
9	Past excellent engineering performance	-0.36277
31	New water-saving technology implementation plan	-0.29462
32	Safe water implementation plan	-0.26550
14	Unit price of main items	-0.21503
42	New energy-saving technology implementation plan	-0.18627
4	Working capital	-0.16838
6	Financial soundness	-0.15403
22	Duration reasonability	-0.15248
10	Construction in progress and new undertakings	-0.06794
51	Safety measures for mechanical facilities	-0.03404
38	Proportion of recyclable materials reuse	-0.02605

TABLE 4: Key influential factors.

Code	Key influential factors	Center degree
13	Total bid price	3.14606
21	Construction period	3.10734
12	Green construction demonstration project	3.07292
45	Green construction management system	3.03599
5	Financial ability	3.03586
30	Water saving and water resource utilization measures	3.00386
35	Land saving and land resource utilization measures	2.99154
37	Material saving and material resource utilization measures	2.97797
41	Energy saving and energy utilization measures	2.97706
16	Reasonability of quotation composition	2.97614
17	Payment terms	2.97293
18	Environmental governance costs	2.95176
19	Green investment costs	2.94286
23	Construction schedule and guarantee measures	2.91643
26	Construction plan and technical measures	2.91003
11	Construction experience of similar project	2.90030
49	Humanistic care for construction laborers	2.89285
50	Safety management system and measures	2.85937
20	Full life cycle operating costs	2.85907
43	Planning and control capacity	2.85073
	Average value of center degrees of 56 factors	2.84244

method to obtain research data of the influence degree between each pair of factors to construct direct-relation matrix. However, as for many complex problems with lots of influential factors, it is difficult to obtain data of the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or experts scoring method, which greatly limits the application scope of the DEMATEL method. In addition, the use of questionnaire surveys or expert scoring method to obtain the influence degree between each pair of factors is highly dependent on the knowledge and experience of the survey participants, which relatively affects the objectivity and reliability of the research conclusions. Based on the DEMATEL method, BP neural network is introduced to determine the direct-relation matrix, optimizing the traditional DEMATEL method. This paper uses the BP-DEMATEL model to systematically analyze the cause-effect relationship between factors and identify key influential factors, further optimizing the structure of the bid evaluation system. BP-DEMATEL model replaces the traditional DEMATEL method of using questionnaire surveys or expert scoring methods to obtain research data of the influence degree between each pair of factors, expanding the application scope of the traditional DEMATEL method. BP-DEMATEL model maintains the advantages of the traditional DEMATEL method and uses BP neural network to determine direct-relation matrix. This model makes the research conclusions more objective and reliable and provides a reference for the government to implement green procurement in the field of public project.

5. Conclusions

5.1. Theoretical Contribution

- (1) The 20 key influential factors of bid evaluation in government public project green procurement

identified in this paper have enriched and perfected the theoretical and practical research in the field of government public project green procurement.

The current research on green procurement is mainly for government procurement and manufacturing procurement, and the research on green supplier selection mainly focuses on goods, while research focusing on projects of government green procurement is rare. In the green procurement management of public project, the selection of green bidders is the key to improve the government green procurement performance and public project green performance. However, the Chinese government procurement system lacks systematic and complete standards of bid evaluation in public project green procurement. Therefore, identifying the key influential factors of bid evaluation in government public project green procurement is of great significance for promoting the construction of government public project green procurement system. This paper uses BP-DEMATEL model to identify key influential factors base on the index system of influential factors of bid evaluation in government public project green procurement, further optimizing the structure of the bid evaluation system. Eventually, 20 key influential factors of bid evaluation in government public project green procurement identified are total bid price, construction period, green construction demonstration project, green construction management system, financial ability, water saving and water resource utilization measures, land saving and land resource utilization measures, material saving and material resource utilization measures, energy saving and energy utilization measures, reasonability of quotation composition, payment terms, environmental governance costs, green investment costs, construction schedule and guarantee measures, construction plan and technical measures, construction experience of similar project, humanistic care for construction laborers, safety

management system and measures, full life cycle operating costs, and planning and control capacity. The research results have enriched and perfected the theoretical and practical research in the field of government public project green procurement.

- (2) The BP-DEMATEL model established in this paper is effectively solving the defects of traditional DEMATEL method that the method is too subjective and tedious when obtaining the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or expert scoring method, thus expanding the scope of the application of the DEMATEL method.

The traditional DEMATEL method depends on questionnaire surveys or expert scoring method to obtain research data of the influence degree between each pair of factors to construct direct-relation matrix. However, as for many complex problems with lots of influential factors, it is difficult to obtain data of the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or experts scoring method, which greatly limits the application scope of the DEMATEL method. In addition, the use of questionnaire surveys or expert scoring method to obtain the influence degree between each pair of factors is highly dependent on the knowledge and experience of the survey participants, which relatively affects the objectivity and reliability of the research conclusions. Based on the DEMATEL method, BP neural network is introduced to determine the direct-relation matrix, optimizing the traditional DEMATEL method. This paper uses the BP-DEMATEL model to systematically analyze the cause-effect relationship between factors and identify key influential factors, further optimizing the structure of the bid evaluation system and providing new methods and ideas for identifying key influential factors of bid evaluation in government public project green procurement. The BP-DEMATEL model effectively solves the defects of traditional DEMATEL method that the method is too subjective and tedious when obtaining the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or expert scoring method, thus expanding the scope of the application of the DEMATEL method.

5.2. Limitations and Future Research

- (1) The key influential factors of bid evaluation in government public project green procurement need further improvement.

The key influential factors identified in this paper are scientific and systematic. With the rapid green development of economy and society, new indicators can be added based on the index system of influential factors of bid evaluation in government public project green procurement in the future. Under continuous revision and improvement, more comprehensive and systematic key influential factors can be identified.

- (2) Research on relation map can be introduced in the future.

The DEMATEL method is an important method for system factor analysis and identification; however it is too subjective and tedious when obtaining the influence degree between each pair of factors to construct direct-relation matrix through questionnaire surveys or expert scoring method. To solve this defect, the BP-DEMATEL model is constructed in this paper. But there remains certain limitation that the BP-DEMATEL model is only suitable for the case where the output is known. It is worth mentioning that the relation map (RM) can be introduced to BP-DEMATEL model in future research. The relation map is a directed graph composed of points, directed edges, and weights, points represent influential factors, directed edges represent the influence of one influential factor on another influential factor, and weights of the directed edges represent the strength of the influence. With the assistance of RM, the RM-BP-DEMATEL can be constructed; thus the direct-relation matrix of the factors can be obtained through the actual data of the system factors.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

This work was supported by the National Natural Science Foundation of China (Grant no. 71904046).

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