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# Construction of Bid Evaluation Index System in Government Public Project Green Procurement in China Based on D-S Evidence Theory

**Yi Zhang**

School of Economics and Management, Hubei University of Technology, Wuhan 430068, China; 20130031@hbut.edu.cn

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**Abstract:** It is of great theoretical and practical significance to construct a bid evaluation index system characterized by green for government public project green procurement. With the combination of sustainable development theory and system theory, and with the goal of government public project procurement as the guide, this paper uses the documentary research method, questionnaire survey method, and expert consultation method to analyze the influential factors of bid evaluation for government public project procurement with the perspective of green development from the aspects of qualification, economy, technology, management, and public welfare and to construct the bid evaluation index system for government public project green procurement; based on Dempster-Shafer evidence theory, using the D-S evidence synthesis method to construct a comprehensive judgment matrix for group decision-making (which effectively solves the problem of synthesizing expert opinions), and combined with the analytic hierarchy process, the index weights are determined. Ultimately, a bid evaluation index system for government public project green procurement is obtained, including 5 first-level indexes, 18 secondary indexes, and 56 tertiary indexes, providing theoretical guidance for the government to implement green procurement in the field of public projects.

**Keywords:** government public project; green procurement; bid evaluation index system; D-S evidence theory; analytic hierarchy process

## 1. Introduction

Government public engineering procurement projects are generally the construction of infrastructure in China. While creating huge economic and social benefits for society, they also consume a lot of natural resources and energy, causing irreversible serious pollution and destruction to the environment, which human beings depend on. According to statistics, more than 50% of the raw materials obtained by humans from nature are used to construct various types of buildings and their auxiliary equipment. During the construction and use of these buildings, about 50% of global energy is consumed; building-related air pollution, light pollution, and electromagnetic pollution account for 34% of the total environmental pollution; construction waste accounts for 40% of the total waste generated by human activities (*the "Green Building Evaluation Standards" of the Ministry of Construction of the People's Republic of China*). Therefore, how to save energy resources and protect the ecological environment while advancing the construction of public projects has become an important issue for realizing the green and sustainable development of our economy and society.

The report of the 19th national congress of the communist party of China emphasized that implementing the concept of green development and advancing the construction of ecological civilization is an inevitable requirement to break through the bottleneck restriction of resources and the environment, and an inevitable option to adjust the economic structure, change the development mode, and achieve sustainable development. As the leader and driver of public project construction, the government contributes more to the implementation of green procurement in the engineering field and inserts the concept of green development into the entire bid evaluation activity. The establishment of the bid evaluation index system for government public project green procurement is the prerequisite for the evaluation and selection of bidders. Only by establishing a comprehensive and reasonable bid evaluation index system can bidders be effectively and comprehensively evaluated. Therefore, this paper conducts systematic research on the bid evaluation index system for government public project green procurement, which will not only help save energy, protect the environment, and bring huge environmental benefits to the society, but will also help establish a social image and give full play to the role of the government's demonstration and leadership. The study has a very important practical significance for the government in terms of implementing green procurement in the engineering field, building and improving the government public project green procurement system, and establishing and enhancing an economic system of green low-carbon cycle development.

There are six sections in this article. The first section is the introduction, the second section is a literature review, the third section is the construction of a bid evaluation index system for government public project green procurement, the fourth section is the research method, the fifth section is the calculation results, and the sixth section is the conclusions and discussion.

## 2. Literature Review

Due to the fact that there is little research that focuses specifically on the bid evaluation index system for government public project green procurement, this section mainly sorts out the relevant literature on the bidding evaluation index system for engineering procurement.

Since the scholar Holt [1] proposed indicators to evaluate the capabilities of construction project contractors, many scholars at home and abroad have studied the evaluation index system. Hatush [2,3] pointed out that although the project is becoming more and more complex and the owners' requirements are getting higher and higher, the general evaluation indicators and evaluation methods have changed relatively little. He conducted survey interviews through an extensive literature research and the Delphi method and found that the most commonly used evaluation indicators include financial stability, technical ability, management ability, health and safety performance, and credibility. Alsugair [4] established a framework for the engineering bid evaluation, including a total of 36 factors which are divided into 9 categories: financial risk, bidding document understanding, bidding document integrity, project location, bidder qualification, bidders' experience and reputation, construction ability, alternatives, and the organization of the bidder. Fong [5] used the price, financial ability, past performance, past experience, resources, ongoing construction projects, past relationship with the owner, and safety performance as the evaluation indicators for the final selection of the contractors. Following this, foreign scholars Singh [6,7], Banaitiene [8], Watt [9,10], Padhi [11], Horta [12], Bochenek [13], and Taylan [14] have improved and developed the evaluation index system, which has enriched the theoretical and practical research of the bid evaluation index system for engineering procurement to a certain extent.

Zhang et al. [15] proposed a set of evaluation index systems for selecting general contractors, including three categories of business indicators, technical indicators, and management indicators, covering five aspects of project quotation, project quality, construction period, project safety, and environmental protection. Tian et al. [16] constructed a bid evaluation index system for government procurement projects, including bid quotation, construction design, construction period, project construction capacity, quality assurance, environmental protection, social responsibility, and business operation status. Wei [17] established a bid evaluation index system for engineering government procurement, consisting of 42 individual indicators in total, related to three aspects: commercial bid, technical bid, and public welfare bid. Zheng [18] constructed a bid evaluation index system for engineering projects in the context of government procurement, which included five aspects: bid quotation, quality assurance, construction schedule, construction plan, and qualification and credibility, totaling 18 individual indicators. Meng [19] established a bid evaluation index system from five aspects: technical bid, commercial bid, economic bid, management bid, and public welfare bid. At present, there is very limited research on integrating the concept of green development into the construction of the bid evaluation index system for engineering procurement; only Li [20–22], Yang [23], Li [24], Zhang [25], etc. conducted research on the green bid evaluation system of engineering procurement. Li [20–22] first established a comprehensive bid evaluation system for green construction projects, including three major categories of indicators: qualification, technology, and economics; Yang [23] established an evaluation index system for selecting general contractors of EPC projects under the green concept, including four categories of indicators: design plan, construction plan, procurement plan, and management measures; Li [24] built an evaluation index system for building contractors under the green concept, including four categories: qualification indicators, green construction technical indicators, organizational management indicators, and economic indicators; Zhang [25] constructed a green bid evaluation index system for engineering projects from the four levels of qualification, technology, economy, and management.

Judging from the existing research, at present, a specific bid evaluation index system has been established for specific engineering procurement evaluation issues, and the evaluation indicators are also roughly the same, mainly including price, experience and performance, reputation, technical capability, management capacity, financial ability, organization and institution, HSE (*health, safety and environment*) performance, etc., but the research on integrating the green development concept into the construction of a bid evaluation index system for government public project procurement are scarce, and there is no systematic and complete theoretical system. There are four aspects to be improved: (1) Most of the existing research on the bid evaluation index system is included in the application of bid evaluation methods, and there is no separate and systematic research; (2) The existing literature focuses on the research of bidders and environmental issues, while neglecting the research of bidders and resource consumption, social development, and other issues; (3) Most of the existing literature considers environmental factors as one of the bid evaluation factors, and the evaluation factors have not been greened, so there is a lack of any green evaluation system that integrates the concept of green development throughout the bid evaluation activities; (4) Most scholars use the analytic hierarchy process to determine the index weights, but when constructing the judgment matrix, they simply use a linear weighted method to synthesize the judgment values of experts, and do not discuss in depth how to effectively synthesize expert opinions, which easily leads to information loss and results distortion. Therefore, a more rigorous approach to process expert opinions is needed. D-S evidence theory (*short for Dempster-Shafer evidence theory*) has the unique advantages of dealing with uncertain information and provides an effective fusion method for multi-source data. Based on this, this paper will combine sustainable development theory and system theory, take the goal of government public project procurement as a guide, and integrate the green development concept into the construction of a bid evaluation index system for government public project procurement. In this design, a comprehensive, reasonable, and operable bid evaluation index system for government public project green procurement is constructed; based on the D-S evidence theory, the D-S synthesis method is used to fuse the opinions of multiple experts, construct a comprehensive judgment matrix for group decision-making, and determine the index weights in combination with the analytic hierarchy process.

## 3. Construction of Bid Evaluation Index System for Government Public Project Green Procurement in China

### *3.1. Objective Analysis of Government Public Project Procurement*

The objective analysis of government public project procurement has a guiding role in the construction of a bid evaluation index system [17]. Government procurement is a procurement activity different from commercial procurement. The fundamental reason for this is that the main body of government procurement is the government, which uses public funds. In government procurement activities, the government is not only a subject of commercial activities, but also a representative and manager of social public interests, which determines that government procurement must not only pursue economically effective goals, but also consider public policy goals. The economically effective goal is the primary goal of government procurement. The starting point is to save procurement funds and improve procurement efficiency, which is the fundamental characteristic of government procurement as a commercial activity. Public policy goals are defined by the government through legislation, and they refer to the political, economic, social, or environmental policy objectives that embody the social and public interests. Public policy goals are not based on economic benefits, so they are also called non-economic goals, and they are the second largest objectives of government procurement. Public policy goals include achieving energy conservation, protecting the environment, supporting underdeveloped regions and ethnic minority areas, and promoting the development of SMEs (*small and medium-sized enterprises*) (*Implementation Regulations of the Government Procurement Law that came into effect on March 1, 2015*). In addition, the requirements of public project construction itself must be combined, so the objectives of government public project procurement include five aspects: qualification evaluation, economy evaluation, technology evaluation, management evaluation, and public welfare evaluation.

### 3.2. Analysis of Bid Evaluation Framework of Government Public Project Green Procurement

Drawing on the multi-level and multi-dimensional modeling ideas of complex systems, combining sustainable development theory and system theory, and guided by the goal of government public project procurement, this paper analyzes the influential factors of bid evaluation for government public project procurement from the perspective of green development using the five aspects of qualification, economy, technology, management, and public welfare, which are classified, divided, and studied to determine the controllable and uncontrollable factors. At the same time, the influential factors that can be used as bid evaluation indexes for government public project green procurement are extracted.

Although there is a lack of research at home and abroad to integrate the concept of green development into the construction of a bid evaluation index system for government public project procurement, some scholars have evaluated green buildings and green construction, which provide a certain basis for extracting the influential factors of bid evaluation for government public project green procurement. By not only pursuing economically effective goals, but also considering public policy goals, this paper draws on the established indicator system [25], categorizes and analyzes the related literature, and uses frequency statistics and theoretical analysis methods to establish a framework for a bid evaluation index system for government public project green procurement from five aspects: qualification, economy, technology, management, and public welfare. A qualification bid review needs to consider not only the qualification, finance, credibility, performance, and other conditions of the bidder, but also whether it has green construction experience; in addition to the bid price, the economy bid review also needs to consider the green costs (such as environmental governance costs, green investment costs, and full life cycle operating costs). Tenders cannot simply determine the winning bidder based on the level of the project quotation, they should consider the specific construction plans and project quotation of bidders from the whole life cycle; the technology bid represents the technical strength possessed by the bidder to realize the construction of the project, and in addition to considering the construction period and project quality, it is mainly considered in view of four aspects: water saving, land saving, material saving, and energy saving; the management bid represents the bidder's planning, organization, control, coordination, and other management capabilities, considering not only the organizational management capabilities, but also the green management capabilities; the public welfare bid reflects the social responsibility of the bidders during the project construction, including healthy civilization, security assurance, environmental protection, etc. The framework of the bid evaluation for government public project green procurement is shown in Figure 1 below (Note: the shaded parts are green indicators).

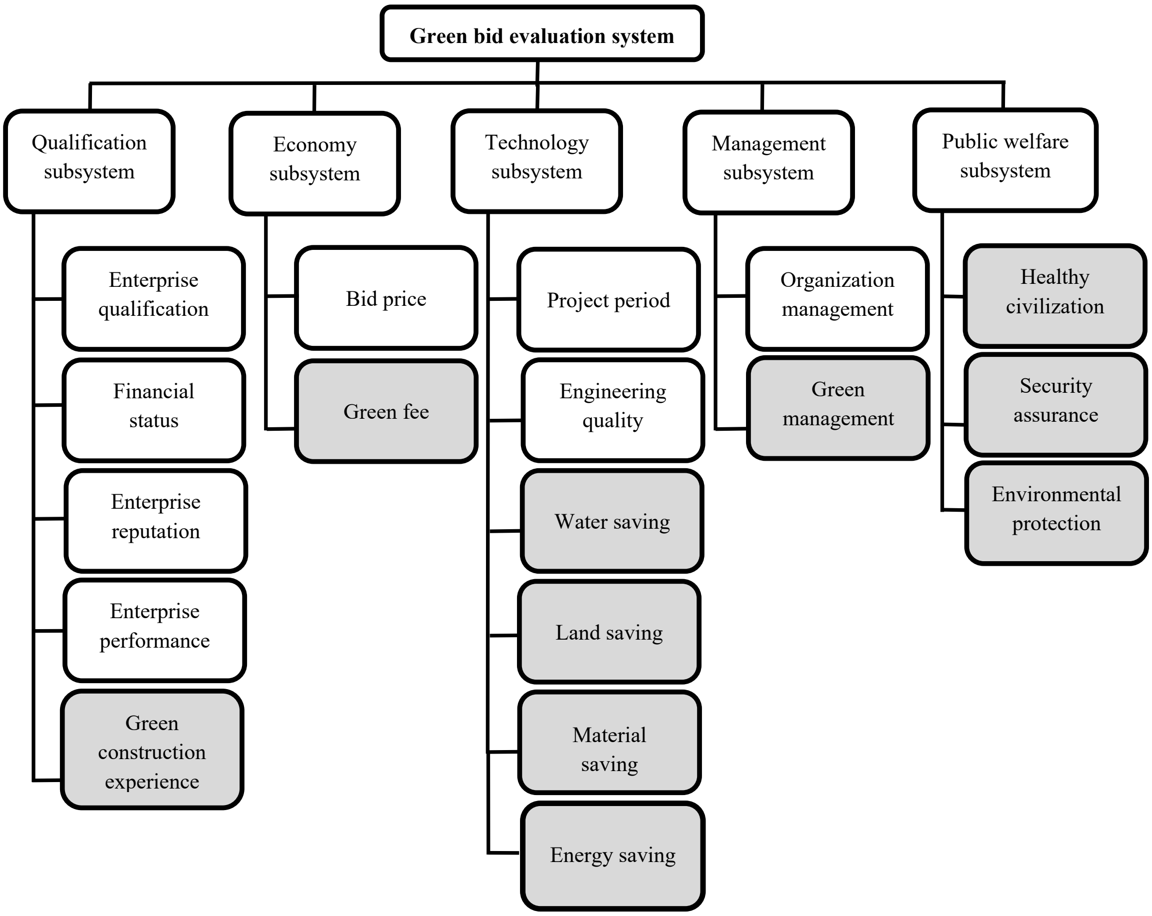


**Figure 1.** The framework structure of the bid evaluation for government public project green procurement.

*3.3. Establishment of Bid Evaluation Index System for Government Public Project Green Procurement*

Guided by the goal of government public project procurement, according to the concept, connotation, and related evaluation system of green buildings and green construction, based on the framework of the bid evaluation for government public project green procurement, this paper integrates the green development concept into the construction of a bid evaluation index system for government public project procurement. In the design of the index system, with the documentary research method, questionnaire survey method, and expert consultation method, a set of comprehensive, reasonable, and operable bid evaluation indexes for government public project green procurement is established from the five aspects of qualification, economy, technology, management, and public welfare, including 5 first-level indexes, 18 secondary indexes and 56 tertiary indexes, as shown in Table 1 below.

**Table 1.** Bid evaluation index system for government public project green procurement.

| Target Layer | First-Level Indexes | Secondary Indexes | Tertiary Indexes |
|---|---|---|---|
| Bid evaluation index system for government public project green procurement | Qualification subsystem | Enterprise qualification | Qualification level<br>Enterprise size |
| | | Financial status | Registered capital<br>Working capital<br>Financial ability<br>Financial soundness |
| | | Enterprise reputation | Contract performance<br>Litigation or arbitration |
| | | Enterprise performance | Past excellent engineering performance<br>Construction in progress and new undertakings |
| | | Green construction experience | Construction experience of similar project<br>Green construction demonstration project |
| | Economy subsystem | Bid price | Total bid price<br>Unit price of major items<br>Quotation for sporadic project<br>Reasonability of quotation composition<br>Payment terms |
| | | Green fee | Environmental governance costs<br>Green investment costs<br>Full life cycle operating costs |
| | Technology subsystem | Project period | Construction period<br>Duration reasonability<br>Construction schedule and guarantee measures |
| | | Engineering quality | Quality management system and guarantee measures<br>Technical strength<br>Construction plan and technical measures<br>Quality and quantity of labor<br>Material quality<br>Mechanical equipment level |
| | | Water saving | Water saving and water resource utilization measures<br>New water-saving technology implementation plan<br>Safe water implementation plan |
| | | Land saving | Site utilization<br>Reasonability of construction layout<br>Land saving and land resource utilization measures |
| | | Material saving | Proportion of green materials use<br>Material saving and material resource utilization measures<br>Proportion of recyclable materials reuse<br>Proportion of local materials |
| | | Energy saving | Proportion of clean energy use<br>Energy saving and energy utilization measures<br>New energy-saving technology implementation plan |
| | Management subsystem | Organization management | Planning and control capacity<br>Organization and coordination capacity |
| | | Green management | Green construction management system<br>Green education and cultural construction |
| | Public welfare subsystem | Healthy civilization | Health protection for construction laborers<br>Wage protection for construction laborers<br>Humanistic care for construction laborers |
| | | Security assurance | Safety management system and measures<br>Safety measures for mechanical facilities<br>Personal safety measures |
| | | Environmental protection | Dust control measures<br>Sewage discharge control measures<br>Soil protection and construction waste control measures<br>Noise control and light pollution control measures |

## 4. Methodology

In this paper, a multi-level and multi-dimensional modeling approach is adopted to construct a bid evaluation index system for government public project green procurement. At present, most scholars use the analytic hierarchy process to determine the index weights. However, when constructing the judgment matrix, they simply use a linear weighted method to synthesize the judgment values of experts, and do not discuss in depth how to effectively synthesize expert opinions, which easily leads to information loss and results distortion; consequently, a more rigorous approach for processing expert opinions is needed. Based on the D-S evidence theory, this paper uses the D-S synthesis method to fuse the opinions of multiple experts, construct a comprehensive judgment matrix for group decision-making, and calculate the index weights in combination with the analytic hierarchy process.

### *4.1. D-S Evidence Theory*

D-S evidence theory originated from the research work of Dempster [26–28], at Harvard University in the 1960s, on the use of upper and lower probability to solve the multi-valued mapping problem; then, his student Shafer further developed it and formed a set of mathematical methods for dealing with uncertainty reasoning. The core of D-S evidence theory is to provide a synthesis algorithm that can fuse multi-source data, which can effectively solve the problem of uncertain information processing in the evaluation process.

This paper assumes that the recognition framework of importance ratio is $\Theta = \{\alpha_1, \alpha_2, \cdots, \alpha_f, \cdots, \alpha_g\}$ $(f = 1, 2, \cdots, g)$; let $k$ experts make pairwise comparisons independently, and then assume that the trust degree of the comparison result is $\theta$ $(0 < \theta < 1)$; according to the opinions of $k$ experts, the $k$ basic probability distribution functions *mass* on the power set $\Theta$ can be obtained:

$$\begin{cases} m_d(\alpha_f) = \theta \\ m_d(\Theta) = 1 - \theta \end{cases} (d = 1, 2, \cdots, k)\ (f = 1, 2, \cdots, g) \tag{1}$$

Assuming the comprehensive evaluation result of the importance ratio of the indicator $D_i$ with $D_j$ is $e_{ij}$ $(i = 1, 2, \cdots, n; j = 1, 2, \cdots, n)$, $e_{ij} \in \Theta$. By synthesizing the $k$ functions *mass* in sequence, the total basic probability distribution function of $e_{ij}$ on the power set $\Theta$ can be obtained:

$$\begin{cases} m(\alpha_f) \\ m(\Theta) \end{cases} (f = 1, 2, \cdots, g) \tag{2}$$

Among them, the D-S evidence synthesis rule is:

$$m(A) = [m_1 \oplus m_2 \oplus \cdots \oplus m_k](A) = \begin{cases} 0 (A = \varnothing) \\ \dfrac{\sum\limits_{A_1 \cap A_2 \cap \cdots \cap A_k = A} m_1(A_1) m_2(A_2) \cdots m_k(A_k)}{1 - \sum\limits_{A_1 \cap A_2 \cap \cdots \cap A_k = \varnothing} m_1(A_1) m_2(A_2) \cdots m_k(A_k)} (A \neq \varnothing) \end{cases} \tag{3}$$

Calculate the reliability and likelihood of $e_{ij}$ on every single point $\alpha_f$:

$$\begin{cases} Bel(\alpha_f) = m(\alpha_f) \\ Pl(\alpha_f) = \sum\limits_{H \cap \alpha_f \neq \varnothing} m(H) H \subset \Theta \end{cases} \tag{4}$$

Calculate ultimate trust level of $e_{ij}$ on every single point $\alpha_f$:

$$Cr(\alpha_f) = Bel(\alpha_f) + Pl(\alpha_f) \tag{5}$$

Order $e_{ij} = \{\alpha_f \big| Cr(\alpha_f) = \max\limits_f Cr(\alpha_f), f = 1, 2, \cdots, g\}$, and the comprehensive evaluation results of experts comparing all indicators in pairs can be obtained.

### 4.2. Use AHP to Determine Indicator Weights

Analytic Hierarchy Process (AHP) is a qualitative and quantitative multi-criteria decision-making method proposed by Professor T.L. Satty [29–31] of the University of Pittsburgh in the early 1970s. The basic idea is to decompose a complex problem into multiple elements, build a hierarchical structure, compare the importance of indicators in pairs for each layer through expert consultation, construct the judgment matrix, calculate the weight of each indicator, and check the consistency of the judgment matrix. The method is simple, practical, scientific, and effective, and can achieve a full ordering of various indicators. However, at present, most scholars simply use a linear weighted method to synthesize the judgment values of experts when constructing a judgment matrix. They do not discuss in depth how to effectively integrate expert opinions, which easily leads to information loss and results distortion; so a more rigorous approach to process expert opinions is needed. This paper uses the D-S evidence synthesis method above to fuse the opinions of multiple experts, construct a comprehensive judgment matrix for group decision-making, and calculate the index weights in conjunction with the AHP method. The specific steps are as follows:

Step 1: Construct a comprehensive judgment matrix for group decision-making.

As for each indicators of the upper layer, the judgment matrix indicates the relative importance comparison between indicators in pairs in this layer. In order to quantify the decision-making judgment, the [0,1,2] 3-scale method, 1.1–1.9 scale method, and 1–9 scale method can be generally used [32]. This paper uses the 1–9 scale method. Experts independently compare indicators in pairs of each layer and assign relative importance ratios. The specific meanings are shown in Table 2 below. Using the D-S evidence synthesis method above to synthesize the expert questionnaire data, the comprehensive judgment matrix for group decision-making is constructed. Order the comprehensive judgment matrix for group decision-making $A = [a_{ij}]_{n\times n}\ (i = 1, 2, \cdots n; j = 1, 2, \cdots n)$, $a_{ij}$ represents the comprehensive evaluation result of the relative importance ratio between the index $i$ and the index $j$.

**Table 2.** The 1–9 scale method.

| Scale | Meaning |
|---|---|
| 1 | Both are equally important. |
| 3 | The former is slightly more important than the latter. |
| 5 | The former is evidently more important than the latter. |
| 7 | The former is deeply more important than the latter. |
| 9 | The former is extremely more important than the latter. |
| 2,4,6,8 | Mid-value of adjacent judgment. |
| Reciprocal | If the comparison between the factors $i$ and $j$ is judged as $a_{ij}$, then the judgment of the comparison between the factors $j$ and $i$ is $1/a_{ij}$ |

Step 2: Calculating index weight.

The calculation of the index weight value can generally utilize the square root method, the sum product method, the characteristic root method, the least square method, etc. This paper uses the square root method for the calculation [33].

① Calculate the product of the elements of each row of the judgment matrix:

$$M_i = \prod_{j=1}^{n} a_{ij} \tag{6}$$

② Calculate n-th root of $M_i$:

$$V_i = \sqrt[n]{M_i} \tag{7}$$

③ Normalize $V = [V_1, V_2, \cdots, V_n]^T$:

$$W_i = \frac{V_i}{\sum\limits_{i=1}^{n} V_i} \tag{8}$$

Then, $W = [W_1, W_2, \cdots, W_n]^T$ is the requested weight vector.

Step 3: Consistency test of the comprehensive judgment matrix for group decision-making.

① Calculate the maximum characteristic root:

$$\lambda_{\max} = \frac{1}{n}\sum_{i=1}^{n} \frac{(AW)_i}{W_i} \tag{9}$$

② Calculate consistency index:

$$CI = \frac{\lambda_{\max} - n}{n - 1} \tag{10}$$

③ Calculate random consistency ratio:

$$CR = \frac{CI}{RI} \tag{11}$$

When $CR < 0.1$, it is considered that the comprehensive judgment matrix for group decision-making has a satisfactory consistency; otherwise, it needs to be adjusted. In the formula, $RI$ is the average random consistency index, and the required value of $RI$ is shown in Table 3 below.

**Table 3.** Average random consistency index *RI*.

| n | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|
| RI | 0.00 | 0.58 | 0.90 | 1.12 | 1.24 |

## 5. Calculation Result

Based on the D-S evidence theory, this paper uses the D-S evidence synthesis method to fuse the opinions of multiple experts, construct a comprehensive judgment matrix for group decision-making, and calculate the index weights in combination with the AHP method; then, it uses the Delphi method to make appropriate adjustments. The calculation results are shown in Table 4 below.

**Table 4.** The index weights and comprehensive weights of the bid evaluation index system for government public project green procurement.

| First-level Indexes | Weights | Secondary Indexes | Weights | Tertiary indexes | Weights | Comprehensive Weights |
|---|---|---|---|---|---|---|
| Qualification subsystem (B1) | 0.15 | Enterprise qualification (C1) | 0.1 | Qualification level (D1) | 0.8 | 0.012 |
| | | | | Enterprise size (D2) | 0.2 | 0.003 |
| | | Financial status (C2) | 0.3 | Registered capital (D3) | 0.1 | 0.0045 |
| | | | | Working capital (D4) | 0.1 | 0.0045 |
| | | | | Financial ability (D5) | 0.7 | 0.0315 |
| | | | | Financial soundness (D6) | 0.1 | 0.0045 |
| | | Enterprise reputation (C3) | 0.1 | Contract performance (D7) | 0.8 | 0.012 |
| | | | | Litigation or arbitration (D8) | 0.2 | 0.003 |
| | | Enterprise performance (C4) | 0.1 | Past excellent engineering performance (D9) | 0.8 | 0.012 |
| | | | | Construction in progress and new undertakings (D10) | 0.2 | 0.003 |
| | | Green construction experience (C5) | 0.4 | Construction experience of similar project (D11) | 0.4 | 0.024 |
| | | | | Green construction demonstration project (D12) | 0.6 | 0.036 |
| Economy subsystem (B2) | 0.25 | Bid price (C6) | 0.7 | Total bid price (D13) | 0.6 | 0.105 |
| | | | | Unit price of main items (D14) | 0.05 | 0.00875 |
| | | | | Quotation for sporadic project (D15) | 0.05 | 0.00875 |
| | | | | Reasonability of quotation composition (D16) | 0.15 | 0.02625 |
| | | | | Payment terms (D17) | 0.15 | 0.02625 |
| | | Green fee (C7) | 0.3 | Environmental governance costs (D18) | 0.35 | 0.02625 |
| | | | | Green investment costs (D19) | 0.35 | 0.02625 |
| | | | | Full life cycle operating costs (D20) | 0.3 | 0.0225 |
| Technology subsystem (B3) | 0.35 | Project period (C8) | 0.2 | Construction period (D21) | 0.6 | 0.042 |
| | | | | Duration reasonability (D22) | 0.05 | 0.0035 |
| | | | | Construction schedule and guarantee measures (D23) | 0.35 | 0.0245 |
| | | Engineering quality (C9) | 0.2 | Quality management system and assurance measures (D24) | 0.3 | 0.021 |
| | | | | Technical strength (D25) | 0.2 | 0.014 |
| | | | | Construction plan and technical measures (D26) | 0.35 | 0.0245 |
| | | | | Quality and quantity of labor (D27) | 0.05 | 0.0035 |
| | | | | Material quality (D28) | 0.05 | 0.0035 |
| | | | | Mechanical equipment level (D29) | 0.05 | 0.0035 |
| | | Water saving (C10) | 0.15 | Water saving and water resource utilization measures (D30) | 0.6 | 0.0315 |
| | | | | New water-saving technology implementation plan (D31) | 0.2 | 0.0105 |
| | | | | Safe water implementation plan (D32) | 0.2 | 0.0105 |

**Table 4.** *Cont.*

| First-level Indexes | Weights | Secondary Indexes | Weights | Tertiary indexes | Weights | Comprehensive Weights |
|---|---|---|---|---|---|---|
| Technology subsystem (B3) | 0.35 | Land saving (C11) | 0.15 | Site utilization (D33) | 0.2 | 0.0105 |
| | | | | Reasonability of construction layout (D34) | 0.2 | 0.0105 |
| | | | | Land saving and land resource utilization measures (D35) | 0.6 | 0.0315 |
| | | Material saving (C12) | 0.15 | Proportion of green materials use (D36) | 0.3 | 0.01575 |
| | | | | Material saving and material resource utilization measures (D37) | 0.6 | 0.0315 |
| | | | | Proportion of recyclable materials reuse (D38) | 0.05 | 0.002625 |
| | | | | Proportion of local materials (D39) | 0.05 | 0.002625 |
| | | Energy saving (C13) | 0.15 | Proportion of clean energy use (D40) | 0.3 | 0.01575 |
| | | | | Energy saving and energy utilization measures (D41) | 0.6 | 0.0315 |
| | | | | New energy-saving technology implementation plan (D42) | 0.1 | 0.00525 |
| Management subsystem (B4) | 0.1 | Organization management (C14) | 0.45 | Planning and control capacity (D43) | 0.5 | 0.0225 |
| | | | | Organization and coordination capacity (D44) | 0.5 | 0.0225 |
| | | Green management (C15) | 0.55 | Green construction management system (D45) | 0.6 | 0.033 |
| | | | | Green education and cultural construction (D46) | 0.4 | 0.022 |
| Public welfare subsystem (B5) | 0.15 | Healthy civilization (C16) | 0.4 | Health protection for construction laborers (D47) | 0.3 | 0.018 |
| | | | | Wage protection for construction laborers (D48) | 0.3 | 0.018 |
| | | | | Humanistic care for construction laborers (D49) | 0.4 | 0.024 |
| | | Security assurance (C17) | 0.2 | Safety management system and measures (D50) | 0.8 | 0.024 |
| | | | | Safety measures for mechanical facilities (D51) | 0.1 | 0.003 |
| | | | | Personal safety measures (D52) | 0.1 | 0.003 |
| | | Environmental protection (C18) | 0.4 | Dust control measures (D53) | 0.2 | 0.012 |
| | | | | Sewage discharge control measures (D54) | 0.3 | 0.018 |
| | | | | Soil protection and construction waste control measures (D55) | 0.3 | 0.018 |
| | | | | Noise control and light pollution control measures (D56) | 0.2 | 0.012 |

From the calculation results of Table 4, it can be found that there are 27 indexes which are above the average value of the index weight 0.0178571. They are the most important indexes in relation to the government making a decision for public project green procurement. All tertiary indexes are shown in Table 5 below, in descending order of importance.

**Table 5.** Tertiary indexes in descending order of importance.

| Order | Tertiary Indexes | Comprehensive Weights |
|---|---|---|
| 1 | Total bid price (D13) | 0.105 |
| 2 | Construction period (D21) | 0.042 |
| 3 | Green construction demonstration project (D12) | 0.036 |
| 4 | Green construction management system (D45) | 0.033 |
| 5 | Financial ability (D5) | 0.0315 |
| 6 | Water saving and water resource utilization measures (D30) | 0.0315 |
| 7 | Land saving and land resource utilization measures (D35) | 0.0315 |
| 8 | Material saving and material resource utilization measures (D37) | 0.0315 |
| 9 | Energy saving and energy utilization measures (D41) | 0.0315 |
| 10 | Reasonability of quotation composition (D16) | 0.02625 |
| 11 | Payment terms (D17) | 0.02625 |
| 12 | Environmental governance costs (D18) | 0.02625 |
| 13 | Green investment costs (D19) | 0.02625 |
| 14 | Construction schedule and guarantee measures (D23) | 0.0245 |
| 15 | Construction plan and technical measures (D26) | 0.0245 |
| 16 | Construction experience of similar project (D11) | 0.024 |
| 17 | Humanistic care for construction laborers (D49) | 0.024 |
| 18 | Safety management system and measures (D50) | 0.024 |
| 19 | Full life cycle operating costs (D20) | 0.0225 |
| 20 | Planning and control capacity (D43) | 0.0225 |
| 21 | Organization and coordination capacity (D44) | 0.0225 |
| 22 | Green education and cultural construction (D46) | 0.022 |
| 23 | Quality management system and assurance measures (D24) | 0.021 |
| 24 | Health protection for construction laborers (D47) | 0.018 |
| 25 | Wage protection for construction laborers (D48) | 0.018 |
| 26 | Sewage discharge control measures (D54) | 0.018 |
| 27 | Soil protection and construction waste control measures (D55) | 0.018 |
| 28 | Proportion of green materials use (D36) | 0.01575 |
| 29 | Proportion of clean energy use (D40) | 0.01575 |
| 30 | Technical strength (D25) | 0.014 |
| 31 | Qualification level (D1) | 0.012 |
| 32 | Contract performance (D7) | 0.012 |
| 33 | Past excellent engineering performance (D9) | 0.012 |
| 34 | Dust control measures (D53) | 0.012 |
| 35 | Noise control and light pollution control measures (D56) | 0.012 |
| 36 | New water-saving technology implementation plan (D31) | 0.0105 |
| 37 | Safe water implementation plan (D32) | 0.0105 |
| 38 | Site utilization (D33) | 0.0105 |
| 39 | Reasonability of construction layout (D34) | 0.0105 |
| 40 | Unit price of main items (D14) | 0.00875 |
| 41 | Quotation for sporadic project (D15) | 0.00875 |
| 42 | New energy-saving technology implementation plan (D42) | 0.00525 |
| 43 | Registered capital (D3) | 0.0045 |
| 44 | Working capital (D4) | 0.0045 |
| 45 | Financial soundness (D6) | 0.0045 |
| 46 | Duration reasonability (D22) | 0.0035 |
| 47 | Quality and quantity of labor (D27) | 0.0035 |
| 48 | Material quality (D28) | 0.0035 |
| 49 | Mechanical equipment level (D29) | 0.0035 |

**Table 5.** *Cont.*

| Order | Tertiary Indexes | Comprehensive Weights |
|---|---|---|
| 50 | Enterprise size (D2) | 0.003 |
| 51 | Litigation or arbitration (D8) | 0.003 |
| 52 | Construction in progress and new undertakings (D10) | 0.003 |
| 53 | Safety measures for mechanical facilities (D51) | 0.003 |
| 54 | Personal safety measures (D52) | 0.003 |
| 55 | Proportion of recyclable materials reuse (D38) | 0.002625 |
| 56 | Proportion of local materials (D39) | 0.002625 |
| | **average value of index weight** | **0.0178571** |

## 6. Discussion and Conclusions

### 6.1. Discussion

The bid evaluation index system for government public project green procurement has a very important practical significance for the government in terms of implementing green procurement in the engineering field, building and improving the government public project green procurement system, and establishing and enhancing an economic system of green low-carbon cycle development. With the combination of sustainable development theory and system theory, and with the goal of government public project procurement as a guide, using the documentary research method, questionnaire survey method, and expert consultation method, this paper has constructed a set of bid evaluation indexes for government public project green procurement from the perspective of green development in the five aspects of qualification, economy, technology, management, and public welfare, including 5 first-level indexes, 18 secondary indexes, and 56 tertiary indexes, which is one of the innovative points of this study; based on D-S evidence theory, using the D-S evidence synthesis method to construct a comprehensive judgment matrix for group decision-making (effectively solving the problem of synthesizing expert opinions), and combined with the analytic hierarchy process, the index weights are determined, which is another innovative point of this study. From the calculation results, it can be found that there are 27 indexes that are above the average value of the index weight 0.0178571. They are the most important indexes for the government in terms of making a decision for public project green procurement. In descending order of importance, they are: total bid price (D13), construction period (D21), green construction demonstration project (D12), green construction management system (D45), financial ability (D5), water saving and water resource utilization measures (D30), land saving and land resource utilization measures (D35), material saving and material resource utilization measures (D37), energy saving and energy utilization measures (D41), reasonability of quotation composition (D16), payment terms (D17), environmental governance costs (D18), green investment costs (D19), construction schedule and guarantee measures (D23), construction plan and technical measures (D26), construction experience of similar project (D11), humanistic care for construction laborers (D49), safety management system and measures (D50), Full life cycle operating costs (D20), planning and control capacity (D43), organization and coordination capacity (D44), green education and cultural construction (D46), quality management system and assurance measures (D24), health protection for construction laborers (D47), wage protection for construction laborers (D48), sewage discharge control measures (D54), and soil protection and construction (D55). In future research, this index system is expected to be further refined and applied in order to verify the scientificity and applicability of the index system, and to further expand the scope of application of the index system.

### 6.2. Conclusions

On the basis of discussing the research results in the previous section, this paper puts forward some view points about the bid evaluation for government public project green procurement in theory and practice, and makes some suggestions for the future research direction.

(1) Judging from the existing research, the studies on integrating the green development concept into the construction of a bid evaluation index system for government public project procurement are scarce, and there is no systematic and complete theoretical system. In future research, it will be very important, urgent, and innovative to integrate the concept of green development into the construction of the bid evaluation index system of government public projects procurement, to which more and more attention will be paid.

(2) In the actual bid evaluation activities, a large number of expert judgments are the basis of the bid evaluation results. Therefore, how to effectively synthesize expert opinions has become a core problem to be solved, and the aggregation mode of multi-expert opinions still needs to be improved. Due to the preference differences of experts and the imperfection of information, there are possible conflicts and inconsistencies in expert opinions, which need to be further solved in the future.

(3) Scale is a tool for decision-makers to transform qualitative subjective judgment into quantitative judgment, so whether the selected scale can objectively reflect people's subjective judgment is the basis for making a correct decision. At present, there is a lack of in-depth studies on the mechanism of the scale system, which needs further research in the future.

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