Research Article

Optimization of Benefit Allocation in Contracted Water-Saving Projects Based on the Shapley Value Method

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Contracted water-saving management (CWSM) has emerged as a powerful model for water-saving actions. In a CWSM project, whether the benefit allocation among the stakeholders is fair and reasonable will affect the enthusiasm of stakeholders for participating in the project, as well as the stability of the project’s operations. This study identifies core stakeholders in CWSM projects of colleges/universities. Then, a preliminary benefit allocation model is constructed through the Shapley value method, risks are identified, and a modified model is developed based on the COWA-gray fixed weight clustering method. Finally, a CWSM project launched by a Chinese university is studied to verify the applicability of the modified model.

1. Introduction

Water shortage has become a major environmental problem in the 21st century [1]. Guterres said that “without further efforts, between 3.5 and 4.4 billion people in the world will live with limited access to water, with more than 1 billion of them living in cities” [2]. Accordingly, water savings is the most direct and effective method to address water resource shortages, especially in emerging economics [3]. Among the water users, colleges/universities are well-known for high water consumption and great water-saving potential. In China, there were 3005 colleges/universities in 2020 [4]. According to statistics, the per capita domestic water consumption of students is 300–400 L/(person•d), which is more than twice that of residents [5]. Furthermore, with a history of a few decades, the colleges/universities have possessed old water facilities, backward water measurement and monitoring devices, and only few water-saving facilities and technologies. Water-saving actions cannot be implemented effectively because of a shortage of funds and the insufficient water-saving capacity of colleges/universities. Consequently, there is considerable potential for improving water-saving efficiency in colleges and universities.

The key to solving the water-saving issue lies in the continued investment of water users [6, 7]. However, colleges/universities do not have access to advanced water-saving technologies nor do they have financial support to update the facilities. Accordingly, the emergence of the contracted water-saving management (CWSM) project has provided an opportunity to solve these problems. CWSM is defined as follows: “a water-saving service mechanism for obtaining benefit in which water-saving service enterprises and water users provide advanced water-saving technologies in the form of contracts, thereby providing water users with water-saving reformation and management services” [8]. In CWSM projects, water users are the clients. Water-saving service enterprise (WSSE) raises capital to retrofit the project and provide technology and services, with the purpose of sharing benefit from water conservation. This model invites WSSEs and funding agents to provide advanced water-saving technology and financial support. It proposes a win–win approach to create benefits for all stakeholders [9, 10].
Thus, implementing CWSM projects would be a feasible choice to solve water-saving issues in colleges/university.

As for CWSM, research suggests that this mechanism was initiated in China in 2015 [6], and the standards were issued by the China Standardization Administration in 2018 (for example, General Principles of Water Saving Management Contract Technology (GB/T 37149–2017)). Earlier studies have noted that numerous stakeholders could be involved in CWSM projects, and questions have been raised about the benefit allocation among the involved parties [7, 9, 11]. For the characteristics of colleges/universities in China (most of which are public universities), a reasonable benefit allocation mechanism can attract high-quality water-saving service enterprise (WSSE) and lead to successful CWSM projects. However, there are few studies that have investigated the benefit allocation in CWSM projects, especially in CWSM projects of colleges/universities. For WSSE, the fund-raiser and technology provider, whether it can make profit as soon as possible would affect its enthusiasm to implement the CWSM projects. Therefore, it is necessary to explore and establish an equitable benefit allocation mechanism for the stakeholders. So, here come the issues:

1. Who are the core stakeholders of the CWSM projects in colleges/universities?
2. What are the risk factors undertaken by each core stakeholder in a CWSM project in colleges/universities?
3. How can the contracted water-saving benefit be allocated fairly and reasonably among the core stakeholders?

Based on the mentioned questions, this study aims to establish a benefit allocation model of CWSM projects in colleges/universities based on the Shapley value method and risk sharing of core stakeholders. The remaining part of the study proceeds as follows: Section 2 begins by laying out research on CWSM projects and looks at how the benefit can be allocated in other areas. Section 3 is concerned with the methodology used for this study, including identifying core stakeholders and risk factors, and proposing a modified model based on the expected Shapley value. Then, Section 4 presents a case study to verify the applicability of the proposed model. The final section gives a brief summary and critique of the findings, and policy implications are also presented.

2. Literature Review

The contracted water-saving management (CWSM) is originated from some prototypes. As early as the beginning of the twenty-first century, the Armenian Water and Wastewater Company signed a contract with the French company SAUR for a water-saving quantity guarantee mode. After four years of implementation, water efficiency was effectively improved [12]. In 2011, the Oman Public Hydropower Authority and the French water management company Veolia signed a five-year water-saving cost trusteeship contract, in which the water-saving effect is significant [13]. Countries such as India, Ukraine, Kazakhstan, Brazil, Tanzania, and Burkina Faso are also actively exploring new modes of water-saving management contracts according to their own national conditions, and there have been many successful cases [14]. Wang and Lu [15] used energy management contracts to make a preliminary exploration of the CWSM mode and its operating mechanism. Recently, topics about baseline adjustment [9], water rights trading [6], and risk assessment [7, 16] in CWSM projects have been studied.

Regarding benefit allocation in CWSM project, no largescale studies have been performed. Yin and Liu [17] used the Shapley model to conduct an empirical analysis of benefit allocation in water-saving management contracts. In their study, water users have been determined to be the largest beneficiaries, followed by water-saving service enterprises (WSSE). Game theory provides a quantitative decision-making framework for the benefit allocation of the project [18]. Applying the cooperative game can solve the problem of benefit allocation among multiple participants, since it focuses on the fairness and justice of team members. The Shapley value method of a cooperative game focuses on the marginal contributions of project stakeholders, and distributes benefits based on their contribution. This method is relatively scientific, fair, reasonable, and stable for benefit allocation. Boonen et al. [19] proposed a new method for allocating venture capital to various business departments of an enterprise based on the Aumann Shapley value. Huang et al. [18] used the fuzzy Shapley value method to reallocate the emission rights, distributed the benefits of cooperation to the participants of different alliances, and verified the model’s validity. From the perspective of stakeholders, Shang et al. [20] used the Shapley method to analyze the initial benefit allocation scheme of energy-saving guarantee contract energy management projects, and used the AHP method to determine the risk evaluation indicators and stakeholder weights. Wang et al. [21] used game theory and the Shapley value method to obtain the optimal emission reduction decision and profit distribution under the three cooperation modes of pure competition, cooperative competition, and pure cooperation. René et al. [22] discussed two solutions of cooperative transferable utility games, namely, Shapley value and intrinsic Shapley value, and proved that the requirement of equal residual distribution in the generalized joint venture game is a characteristic of the Shapley value. Lu [23] used the Shapley model, the modified Shapley model, and the fair entropy model to conduct a comparative study on the benefit allocation of a water-using enterprise, thereby providing a reference for the benefit allocation and promotion and application of contracted water-saving management. The Shapley value method in the cooperative game has been substantially applied in the research of benefit allocation, and has a certain reference value for research into the benefit allocation of CWSM projects in colleges/universities. Different methods and their application have been concluded as given in Table 1.

It can be seen from the above literature that although studies have recognized the importance of benefit allocation of CWSM projects, research has yet to systematically
investigate the appropriate mechanism. The Shapley value method is an effective way to deal with benefit allocation issues. However, it is not difficult to find that the existing method does not adequately reflect the risk sharing of the stakeholders. Therefore, this paper will improve the existing model based on the above point, and further apply the improved model to CWSM projects to check its availability.

### 3. Results and Discussion

This section presents the structure of the proposed methodology for benefit allocation in CWSM projects, as shown in Figure 1. The details are described in the following.

#### 3.1. Identification of Core Stakeholders of CWSM Projects in Colleges/Universities

To get a whole picture of stakeholders in CWSM projects in colleges/universities, interviews and Delphi survey with professionals were conducted. First, ten experts who were familiar with the water-saving projects in colleges/universities were contacted. Five of them were from universities and others from water-saving service enterprises (Table 2 illustrates their profile). They were asked to list all stakeholders in CWSM projects in colleges/universities. Sixteen main stakeholders were identified after the first round. Then, interviewees were requested to rank those stakeholders considering three aspects: benefits gained from the project (profitability), impact on the project (importance), and the risks. The score range was set to [1, 10], which was divided into three levels: high [8, 10], medium [5, 8], and low [1, 4]. According to the scoring results, the sixteen stakeholders were divided into core stakeholders (with two high scores or more), dormant stakeholders, and marginal stakeholders (all with low scores). The ranked stakeholders of CWSM projects in colleges/universities are given in Table 3. It can be seen that the core stakeholders of the project are as follows: (1) water-saving service enterprises (WSSE), which provides water diagnosis, water-saving project design, investment, construction, operation management, and other services for the project; (2) colleges/universities (hereafter referred to as colleges), which provides the field of water-saving projects and closely cooperates with WSSEs based on the actual demands; and (3) financial institutions, which can provide financial support for the project to ensure the stability of the project funds.

#### 3.2. Preliminary Model of Benefit Allocation Based on Shapley Value

##### 3.2.1. Basic Assumptions

In a CWSM project, the project’s benefit should be given priority in the project loan. In this study, the benefit allocation refers to the benefit obtained by the stakeholders from the income available after deducting the project loan. Before modeling to allocate the benefit, we postulate the following assumptions:

1. In the process of benefit allocation, the core stakeholders of the project tend to maximize their benefit and will not withdraw from the game relationship. Eventually, we can reach a revenue distribution scheme that all parties are willing to accept.
2. All parties to the contract obey the rational hypothesis in economics and understand how to avoid their own shortcomings, and they will choose the optimal strategy through rational judgment and calculation so as to maximize their own interests.
3. The water-saving income after water-saving transformation by WSSE is not less than that by college itself and it can be fully effective.
The CWSM projects will not shorten or extend the life cycle, or change the function of campus buildings.

The remaining life of campus buildings or facilities that need transformation is longer than the duration of the water-saving transformation.

3.2.2. Principle of Benefit Allocation. It has been determined that the core stakeholders of CWSM projects in colleges/universities are WSSEs, colleges, and financial institutions. All participants in the project engage in rational thinking and bring certain marginal contributions to the table. Cooperative game is a cooperation mode in which the participants can produce cooperative surplus through alliance. The distribution of the cooperation surplus depends on the strength contrast and strategy combination of players.

The basic elements of a cooperative game are the players and the characteristic function, namely \([N, v]\), where \(N = \{1, 2, \ldots, n\}\) is the set of participants; the numbers in set \(N\) are positive integers, and \(n\) represents the number of players; \(v\) is the characteristic function of this alliance. \(K\) represents the alliance of players and \(K \subseteq N\); \(v(K)\) shows the benefit of the cooperation among players in alliance \(K\). Some definitions of the cooperative game are as follows:

\[
V(\emptyset) = 0, \\
V(K_1 \cup K_2) \geq V(K_1) + V(K_2), K_1 \cup K_2 = \emptyset. 
\]

Where \(V(K_1)\) is the characteristic function of participant \(K_1\); \(V(K_2)\) is the characteristic function of participant \(K_2\); and \(V(K_1 \cup K_2)\) is the characteristic function of the alliance after the cooperation between \(K_1\) and \(K_2\).

(2) For an income \([N, v]\), there should be a Pareto improved distribution rule, that is, when one player is assigned a higher income than its own payoff when it works alone, i.e., this player does not engage in cooperation, the income \((Y_1(V), Y_2(V), \ldots, Y_m(V))\),
where $K$ is all subsets of core stakeholders $m$ in $N$, $|K|$ is the number of core stakeholders in the cooperative alliance $K$, $V(K)$ is the income obtained by $K$, $V(K - m)$ is the income that can be obtained after removing the stakeholder $m$ from the set $K$, and $V(K) - V(K - m)$ is the marginal contribution value of the stakeholder $m$.

### 3.2.3. Preliminary Model Establishment of Benefit Allocation

In the cooperation game of the core stakeholders of CWSM projects in colleges/universities, we define the cooperation formed by WSSEs, colleges, and financial institutions as a cooperative strategy $(N, V)$, where $N = (WSSEs, colleges, financial institutions)$, any subset of $N$ corresponds to the way of forming a cooperative alliance, and $V$ is the characteristic function of the Shapley value, that is, the project benefit generated by any combination of core stakeholders in the alliance. Hereafter, WSSEs are referred to as $E$, colleges are $C$, and financial institutions are $F$. Let $K$ be a subset of $N$, and then, all the alliances of $K$ are given in Table 4.

Based on the Shapley value method, the benefit allocation scheme of the core stakeholders can be calculated and deduced. Tables 5–7 provide all the alliances that water-saving service enterprises, colleges, and financial institutions can participate in and the water-saving benefit that can be shared. The Shapley value with which the water-saving benefit can be shared by each core stakeholder can be expressed as in equations (5)–(7).

Increasing the accuracy of calculation. The specific process is as follows:

1. Invite $n$ experts $(n = 1, 2, . . . , 6)$ to score, according to their importance, the indicators at the same level (0–10 scoring method); the initial score dataset of $n$ experts for each indicator is $(a_1, a_2, . . . , a_j, . . . , a_n)$. The scoring data are sorted from largest to smallest and numbered from 0; the result is $b_0 \geq b_1 \geq b_2 \geq \cdots \geq b_{j-1} \geq \cdots \geq b_{n-1}$.

   The weight $\theta_{j+1}$ of data $b_j$ can be calculated by equation (9), where $\sum_{j=0}^{n-1} \theta_{j+1} = 1$.

\[
\theta_{j+1} = \frac{C_{n-1}^j}{\sum_{k=1}^{n-1} k^{n-1}} \frac{2^{n-1}}{C_{n-1}^j}, \quad j = 0, 1, 2, . . . , n - 1. \tag{9}
\]
The weight of the influencing factors, the greater the impact by equations (9)–(11) are given in Table 7 as well. The greater the decision data to get the absolute weight \( \bar{w}_i \) of the index factor using equation (10):

\[
\bar{w}_i = \sum_{j=1}^{n} \theta_{ji} b_{ij}, \quad i = 1, 2, \ldots, m, \tag{10}
\]

where \( m \) represents the number of index factors.

Calculate the relative weight \( w_i \) of index factors by equation (11):

\[
w_i = \frac{\bar{w}_i}{\sum_{i=1}^{m} \bar{w}_i}, \quad i = 1, 2, \ldots, m. \tag{11}
\]

The risk and weight of each core stakeholder calculated by equations (9)–(11) are given in Table 7 as well. The greater the weight of the influencing factors, the greater the impact of its changes on the benefit allocation. As given in Table 8, the risk sharing among the core stakeholders of the project is identified and the risk factors of each subject in the project are determined. Among them, the WSSEs provide the lifecycle service for colleges, which is a “high risk and high return” method. Colleges only need to cooperate with WSSEs to implement the project, without making a direct investment, so they are “zero risk, zero investment” beneficiaries of the project. Financial institutions face the risks of selecting WSSEs, assessing water-saving status, verifying water-saving volume, sharing benefit, project financing, and so on. It can be seen that the risk factors and proportion undertaken by all stakeholders are different.

### 3.3.2. Establishing a Modified Model of Benefit Allocation

Since the whole life cycle of CWSM projects in colleges/universities involves many human interference factors, high risks, and complex relationships, this paper chooses the gray clustering method [16, 38, 39] to determine the risks of each stakeholder and adjust the proportion of benefit allocation.
by the risk size. According to the different influence degree of each risk factor on the total risk in the scheme layer, six experts are invited to quantify the risk using the five-level scale method [40, 41]. We set the risk measurement value range as $[0, 10]$, which is divided into five levels: very high [8, 10], high [6, 8], normal [4, 6], low [2, 4], and very low [0, 2]. Among them, each risk evaluation index is considered from three aspects: the possibility of risk occurrence, risk controllability, and the harmfulness to energy-saving income. Details are as follows:

1. The determination of the gray category and the establishment of corresponding whitening weight function. Five gray categories of very large, large, average, small, and very small are determined, where the center point vector is $U = (9, 7, 5, 3, 1)$. Then, the whitening weight function corresponding to each gray category according to the risk sharing of CWSM projects in colleges/universities are determined, as given in Table 9.

2. Establishment of an evaluation matrix. According to the risk measurement, $P (P = 6)$ experts are invited to assign values to the index $A_{ij}$ to establish an evaluation matrix:

$$D_i = [d_{ijk}]_{s \times p},$$

where $d_{ijk}$ is the value assigned by the $k$-th expert to the $j$-th sub-index under the $i$-th index; $k = 1, 2, 3, \ldots, n$; and $s$ is the number of evaluation indexes of the matrix.

3. Establishment of a gray clustering weight matrix. The clustering coefficient of $A_{ij}$ belonging to the e-gray class is $X_{i j} = \sum_{k=1}^{p} f_k [d_{ijk}]$, the total evaluation coefficient is $X_{ij} = \sum_{i=1}^{3} X_{ij}$, the calculated gray clustering weight vector is $r_{ijk} = X_{i j} / X_{ij}$, and the gray clustering weight matrix is established as follows:

$$R_i = \begin{bmatrix} r_{i11} & r_{i12} & r_{i13} & r_{i14} & r_{i15} \\ r_{i21} & r_{i22} & r_{i23} & r_{i24} & r_{i25} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ r_{i11} & r_{i12} & r_{i13} & r_{i14} & r_{i15} \end{bmatrix}.$$

4. A clustering evaluation matrix is constructed. The cluster evaluation of each factor index is $Z_i = u_i \times R_i$. A comprehensive evaluation matrix for factor index is constructed as $Z_0 = [Z_1, Z_2, \ldots, Z_n]^T$, and comprehensive aggregation of upper-level indexes is expressed as:

$$M = w_0 \times z_0 = [M_1, M_2, \ldots, M_n].$$

The determination of the risk adjustment value is to synthesize the comprehensive evaluation vector and the measurement threshold value. The single value treatment is set as $W = M \times U$ to obtain the risk adjustment value of the three core stakeholders of the CWSM projects in colleges/universities. After normalization, it is transformed into a risk adjustment coefficient. By multiplying the project’s shareable benefit by the risk adjustment coefficient, the benefit allocation of each participant based on risk sharing can be obtained. The actual benefit that each stakeholder of the project should get after the modification is

$$Y_i(V) = Y_i(V) + \left( W_i - \frac{1}{n} \right) \times V(S).$$

### 4. Case Study

#### 4.1. Project Overview

In 2018, the total water consumption of University A reached 480,000 m$^3$, the annual water fee was 2.7 million yuan, and the per capita water consumption was 209 L/(person-d), which was far more than the per capita water consumption of major colleges stipulated in the “The quota of industry water in G province” by 120 L/(person-d). University A signed a contract with Y water-saving service enterprise in 2019 to transform water-saving technology through the water-saving benefit sharing contracted water-saving management mode. The water-saving benefits were distributed in a 3:7 ratio between the two parties, and the contract was 12 years. To support the successful implementation of CWSM, Water-saving service enterprise Y actively led and guided securities company D to set up a special fund of 9.63 million yuan, with contract water-saving management as the object of fund-raising and investment. The highlight of the project was the wastewater reuse system. The first stage of water-saving technical transformation of the project has been completed. The per capita comprehensive water quota of students in the school decreased from 209.3 L/(person-d) to 126.4 L/(person-d). The water-saving rate was 39.8%, and the water-saving effect was significant. Based on a contract of 12 years, it is expected to save 3.53 million m$^3$ of water. It is estimated that the total benefit available for distribution is about 19.56 million yuan when the contract expires.
4.2. Preliminary Benefit Allocation Based on the Shapley Value Method. In this case, water-saving company Y has sufficient water-saving technology to complete the water-saving contract. Therefore, University A, water-saving company Y, and securities company D are the main participants. Through the water-saving calculation of the CWSM project of University A and combined with the existing research [17, 42], benefit allocation assumptions for the seven situations given in Table 10 were made. It can be seen that when colleges reform the facilities by themselves, cooperate with water-saving companies, and adopt cooperation with water-saving companies and financial institutions, the benefit value is 30%, 80%, and 100% of the total water-saving benefit, respectively, while colleges that cooperate with financial institutions only generate 50% of the income.

According to the benefit allocation of each core stakeholder alliance and the preliminary benefit allocation model based on the Shapley value (as shown in Section 3.2), the respective benefit values were calculated as follows. The benefit of Water-saving company Y, University A, and Securities company D is 4.890 million yuan, 12.714 million yuan, and 1.956 million yuan, respectively:

\[
Y_Y(V) = \frac{V(Y, A) - V(A)}{6} + \frac{V(Y, A, D) - V(A, D)}{3} = 4.890 \text{ million yuan},
\]

\[
Y_A(V) = \frac{V(A)}{3} + \frac{V(Y, A)}{6} + \frac{V(A, D)}{6} + \frac{V(Y, A, D)}{3} = 12.714 \text{ million yuan},
\]

\[
Y_D(V) = \frac{V(A, D) - V(A)}{6} + \frac{V(Y, A, D) - V(Y, A)}{3} = 1.956 \text{ million yuan}.
\]
4.3. Modified Benefit Allocation Based on Risk Sharing.

The water-saving benefit of university \( A \) is the largest, followed by water-saving company \( Y \) according to the calculation results of the water-saving benefit by the initial Shapley value. This is obviously different from the actual situation, so the above results are modified to reflect the risk sharing of all stakeholders in the project. Five experts in relevant fields were invited to assign values to the three levels of the Water-saving company \( Y \), in combination with the actual situation and risk sharing table of each core stakeholder (Table 7) to construct a gray clustering evaluation matrix. According to the whitening weight function corresponding to each gray class given in Table 8, we calculated a gray clustering weight matrix and synthesized each clustering matrix and corresponding weight vector to obtain a total gray clustering evaluation matrix \( Z \) as follows:

\[
Z = u \times R,
\]

\[
x = \begin{bmatrix}
0.302 & 0.281 & 0.164 & 0.010 & 0.000 \\
0.397 & 0.334 & 0.210 & 0.059 & 0.000 \\
0.461 & 0.345 & 0.143 & 0.051 & 0.000 \\
0.367 & 0.411 & 0.222 & 0.000 & 0.000 \\
0.104 & 0.134 & 0.136 & 0.022 & 0.000
\end{bmatrix}, \quad (17)
\]

The comprehensive clustering evaluation vector calculated by equation (15) is \( M = u \), \( Z = [0.397, 0.282, 0.165, 0.051, 0.000] \). The comprehensive evaluation vector \( M \) and the central point vector \( U = [9, 7, 5, 3, 1] \) are combined to calculate the risk evaluation value \( W = M \times U = 6.498 \) of the water-saving company \( Y \). Similarly, the risk evaluation values of university \( A \) and securities company \( D \) during the whole process of the CWSM project are 0.045 and 2.445, respectively. By normalizing each risk evaluation value, we can see that water-saving company \( Y \), university \( A \), and securities company \( D \) have a risk of 0.723, 0.005, and 0.272, respectively. We can also see that, in this project, water-saving company \( Y \), university \( A \), and securities company \( D \) can get 12.518 million yuan, 6.299 million yuan, and 0.743 million yuan, respectively. The details are given in Table 11.

4.4. Result Analysis.

According to the contract that states that the water-saving benefit ratio of University \( A \) to Water-saving company \( Y \) stands at \( 3:7 \), the benefit of Water-saving company \( Y \) is 13.692 million yuan. According to the modified Shapley model developed in this study, the water-saving benefit ratio of universities to water-saving service enterprises is about \( 3:2:6:8 \). Thus, water-saving company \( Y \) can earn a total of 13.261 million yuan with an error of 3%, which is basically consistent with the actual situation.

Under the calculation principle of the Shapley model, colleges will share the largest benefit, which is obviously not realistic and not conducive to motivating water-saving service enterprises to participate in the project. Under the calculation principle of the modified Shapley model, the core stakeholders’ benefit allocation has the following flows: part of the water-saving benefit flows to water-saving service enterprise and increases the benefit of the water-saving service enterprise. The water-saving service enterprises invest more resources and take higher risks, so the corresponding correction coefficient is larger; therefore, water-saving benefit flows to water-saving service enterprises, which conforms to the contracted water-saving management market mechanism. The university’s benefit decreases after the risk correction. Colleges share the water-saving benefit in the project, but they are almost “zero investment and zero risk,” so the risk coefficient of colleges is very small; the benefit allocation will be decreased and lower than that of water-saving service enterprises after correction. The benefit of financial institutions has decreased. The financial institutions provide funds for projects and take greater capital risks in participating projects. This study considers that the water-saving income after the water-saving transformation for colleges is not less than the net income of the water-saving transformation by themselves; it can take a value of 100% and achieve the desired effect. By comparing the benefit allocation value of the project before and after the modification of the benefit allocation model, it can be seen

### Table 9: Gray category, gray number, and whitening weight function.

<table>
<thead>
<tr>
<th>Class</th>
<th>Gray category ( e )</th>
<th>Gray number ( \Theta_e )</th>
<th>Whitening weight function</th>
</tr>
</thead>
</table>
| Very large | \( e = 1 \)           | \( \Theta_1 \in [0, 9, \infty) \) | \( f_1[d_{ijk}] = \begin{cases} d_{ijk}/9, d_{ijk} \in [0, 9] \\
1, d_{ijk} \in [9, \infty] \\
0, d_{ijk} \notin [0, \infty] \end{cases} \) |
| Large      | \( e = 2 \)           | \( \Theta_2 \in [0, 7, 14) \) | \( f_2[d_{ijk}] = \begin{cases} d_{ijk}/7, d_{ijk} \in [0, 7] \\
(14 - d_{ijk})/7, d_{ijk} \in [7, 14] \\
0, d_{ijk} \notin [0, 14] \end{cases} \) |
| Average    | \( e = 3 \)           | \( \Theta_3 \in [0, 5, 10) \) | \( f_3[d_{ijk}] = \begin{cases} d_{ijk}/5, d_{ijk} \in [0, 5] \\
(10 - d_{ijk})/5, d_{ijk} \in [5, 10] \\
0, d_{ijk} \notin [0, 10] \end{cases} \) |
| Small      | \( e = 4 \)           | \( \Theta_4 \in [0, 3, 6) \) | \( f_4[d_{ijk}] = \begin{cases} d_{ijk}/3, d_{ijk} \in [0, 3] \\
(6 - d_{ijk})/3, d_{ijk} \in [3, 6] \\
0, d_{ijk} \notin [0, 6] \end{cases} \) |
| Very small | \( e = 5 \)           | \( \Theta_5 \in [0, 1, 2) \) | \( f_5[d_{ijk}] = \begin{cases} 1, d_{ijk} \in [0, 1] \\
2 - d_{ijk}, d_{ijk} \in [1, 2] \\
0, d_{ijk} \notin [0, 2] \end{cases} \) |
that the essence of the change in benefit allocation is to change part of the project benefit from universities and financial institutions to water-saving service enterprises, which is consistent with reality.

5. Concluding Discussion

This research studied the benefit allocation scheme in the CWSM projects in colleges/universities by constructing a game model based on the Shapley value method. The paper regarded the resource investment and contribution of each core stakeholder to the project as the risk source of the project and constructed the benefit allocation model based on risk-sharing and realized the balance between risk and income borne by the core stakeholders of the project, which is fair and reasonable to a certain extent. However, there are some problems that need to be improved: first, when the model is constructed, the corresponding assumptions are put forward, which is an ideal way of benefit allocation. However, in practice, the environment of the project is changeable and there are many unpredictable uncertain factors, which will have an impact on the project benefit allocation scheme. Second, although the paper identifies the risk factors that the core stakeholders of the project should bear, in the actual process of the project, due to the different characteristics of the main participants of the project and the construction environment of the project itself, there are some differences in the project risk factors, but the principle of benefit allocation is the same. Therefore, in practice, as long as the water-saving income of water-saving service enterprises, universities, and financing institutions is close to the actual benefit allocation scheme of all parties, and the error is within an acceptable range, the benefit allocation can be considered reasonable. In addition, the applicability of the model was verified in combination with an actual case.

Table 11: Modification of Shapley value based on risk sharing in CWSM projects (unit: million yuan).

<table>
<thead>
<tr>
<th>Core stakeholders</th>
<th>Initial Shapley value</th>
<th>Risk adjustment coefficient</th>
<th>Transfer amount</th>
<th>Modified Shapley value</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water-saving company Y</td>
<td>4.890</td>
<td>0.723 – 1/3 = 0.390</td>
<td>7.628</td>
<td>12.518</td>
<td>↑</td>
</tr>
<tr>
<td>University A</td>
<td>12.714</td>
<td>0.005 – 1/3 = -0.328</td>
<td>-6.415</td>
<td>6.299</td>
<td>↓</td>
</tr>
<tr>
<td>Securities company D</td>
<td>1.956</td>
<td>0.272 – 1/3 = -0.062</td>
<td>-1.213</td>
<td>0.743</td>
<td>↓</td>
</tr>
</tbody>
</table>

(1) This study identified water-saving service enterprises, colleges, and financial institutions as the core stakeholders of CWSM projects in colleges/universities, considering three dimensions of profitability, importance, and risk. The results are consistent with the existing research [17, 23, 42]. Water-saving service enterprises play an important role in the CWSM project. They are participants, executors, and promoters of CWSM project, as well as the most important subjects of project implementation. They play a major role in providing full-service water-saving projects for colleges who have the will to save water but do not have the economic, technical, or management abilities to achieve this goal. Colleges are participants and supervisors of CWSM project, and are indispensable for the smooth implementation of projects. Although colleges do not share the initial investment pressure and directly shared the water-saving income of the project, they provide a vital environment for the implementation of the project. In addition, China’s water-saving enterprises are young with a weak base. It is difficult for them to rely on their own funds to meet all the needs of the project. Evidently, funding issues are a major problem for water-saving service enterprises, so financial institutions are critical to the projects.

(2) Based on game theory, the model constructed by the Shapley value method is relatively reasonable to solve...
the problem of benefit allocation of the core stakeholders of CWSM projects in colleges/universities. However, the results are inconsistent with the actual project situation because the different risks undertaken by the participants are not considered. A reasonable benefit allocation scheme can effectively connect the core stakeholders in the game and simultaneously compensate for the risks of the main participants. Although the Shapley value method can better solve the problem of benefit allocation, it is based on the assumption that cooperative alliance members undertake the same risk and lack a consideration for the impact of risk-taking. Moreover, the Shapley value method is a risk-neutral benefit allocation scheme, which is consistent with the results of Huang et al. [18]. In other words, risk lovers have taken a high risk in the project, but have not received an equivalent benefit. This is unfair and can easily lead to the collapse of the cooperative alliance.

A total of 18 risk factors were identified from the five stages of the process of the CWSM projects in colleges/universities, and the proportion of risks undertaken by each core stakeholder was different. Based on the risk-sharing situation and the COWA-gray fixed weight clustering method, the benefit allocation model established by the Shapley value method was modified. The allocation scheme calculated by the modified model can not only satisfy the relative risk and the core stakeholders’ benefit of the project and basically coincide with the actual situation but also has a certain applicability.

Empirical analysis indicates that water-saving income flows from colleges to WSSEs, and the latter receives more. This is consistent with the research conclusions of Yin et al. [43]. From the perspective of risk-sharing of participants, the allocation scheme is beneficial to resolve conflicts caused by different stakeholders’ requirements, which is in line with the market mechanism of contracted water-saving management. This study used the Delphi method, Shapley value method, and COWA-gray fixed weight clustering method to identify the core stakeholders of the CWSM projects in colleges/universities. Thereafter, this study established a modified model of the benefit allocation of the water-saving benefit sharing CWSM projects in colleges/universities based on the proportion of risk that each core stakeholder bears in the project. Moreover, the issue of benefit allocation among the core stakeholders of CWSM projects in colleges/universities was discussed. The research enriched the benefit allocation theories of CWSM projects, and clarified the risk-sharing situation and proportion of the core stakeholders in the CWSM projects. This study also effectively might help others to better understand the contracted water-saving benefit allocation mechanism.

5.1. Limitations and Future Research. This study points to a solution for the benefit allocation of CWSM projects in colleges/universities, but there are still some limitations. First, the premise of applying the Shapley value method for the benefit allocation of water-saving is that the characteristic function values of different alliance combinations are known (that is, the specific income generated by different combinations of cooperative alliances). Because of the characteristics and complexity of the project itself, the process of estimating the characteristic value of the alliance is complex and difficult to determine. Second, when we modified the model of benefit allocation based on risk sharing, COWA-gray weight clustering method was used to evaluate the risk, and the expert scoring method to quantify the risk. These subjective methods have a certain impact on the accuracy of the benefit allocation. In addition, CWSM projects in colleges/universities have three operation modes: water-saving benefit sharing, water-saving effect guarantee, and water cost trusteeship. Accordingly, the benefit allocation schemes of the other two modes should be further explored. Lastly, the results of this study are only based on colleges in China. Whether they can be extended to international universities still needs further discussion.

5.2. Policy Implications. The shortage of water resources is the main environmental problem and water saving is the most direct and effective way to solve this problem. The government vigorously promotes the contract water-saving mode in colleges/universities due to its huge water-saving potential. This mode provides financial and technical support for the CWSM project of colleges/universities, reduces the financial pressure of colleges/universities, and also provides ideas for the project management. Benefit allocation is the key for the CWSM project. If the parties to the contract fail to reach a consensus or even disagree on the benefit allocation of the project that will indirectly increase the process of repeated negotiation, which may also lead to the termination of the project. This study introduces the game theory to study the benefit allocation of CWSM projects in colleges/universities, and verifies the rationality of benefit allocation of core stakeholders of projects from a scientific point of view. To a certain extent, it will resolve the conflicts caused by different interest requirements of different stakeholders and mobilize the initiative and enthusiasm of all parties to the project, which is of great significance for promoting the application of contract water-saving management mode in CWSM project of colleges/universities, realizing the breakthrough of water-saving management technology, and scientifically allocating water-saving benefits. The following suggestions are presented for the implementation of the CWSM projects in colleges/universities:

5.2.1. In Benefit Allocation

(i) The government should improve the water-saving policies and regulations, protect the rights and interests of water-saving service enterprises, and regulate the operation and management of the enterprises. Moreover, the authorities should focus on cost compensation for water-saving service enterprises, strengthen their ability to respond to risks,
and completely mobilize the enthusiasm of water-saving service enterprises to participate in projects.

(ii) Colleges should strengthen the publicity and popularization of contracted water-saving management, and improve the water-saving awareness of managers and issue financial incentive policies, so as to provide an impetus for the implementation of CWSM project. The government should establish an “Investment Guarantee Fund” and provide commercial loan guarantee services for CWSM projects in colleges/universities, as well as implement interest-free or discount policies to ensure smooth financing.

(iii) When signing a contract, universities and water-saving service enterprises should entrust a third-party assessment agency with industry authority to make a written agreement on such matters as water-saving measures, the amount of income, and supervision. After the implementation of the project, all project stakeholders will work according to the agreed process, which can effectively resolve the conflicts caused by improper benefit allocation.

5.2.2. In Risk Management

(i) Water-saving service enterprises should conduct investigations and surveys on nationwide CWSM projects in colleges/universities, collect all risk sources, and establish a risk source identification database. When implementing a new project, the database would help identify and monitor the risk factors.

(ii) The contract should specify the terms and conditions and refine the rights and responsibilities of the risk-sharing between the core stakeholders in the CWSM projects. Moreover, full consideration should be given to whether the risks taken by the project participants are equal to the benefits and whether the distribution scheme satisfies the participants’ ability to control risks and bear losses. Furthermore, participants need to incorporate the relevant punitive measures into the contract to restrict behavior throughout the project.

(iii) The project’s core stakeholders should construct an effective risk assessment and analysis method based on their own risks, improve the early warning mechanisms, and propose risk response strategies, i.e., risk avoidance, transfer, resolution, and mitigation. Relevant departments should formulate a project risk response plan to avoid or reduce the project risks to ensure the achievement of water-saving goals.

Data Availability

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

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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