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Sustainability Assessment of Municipal Infrastructure Projects Based on Continuous Interval Argumentation Ordered Weighted Average (C-OWA) and Cloud Models

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Abstract: The goals of sustainable development are constantly negatively impacted by infrastructure initiatives. The importance of these projects in advancing the economic, social, and civilizational growth of the country will, however, prevent their construction from being stopped. The overall construction of the project is related to the scientific and unbiased assessment of an infrastructure project's sustainability throughout the decision-making stage. Based on the references documents, this paper establishes an index system for evaluating an infrastructure project's sustainability from three aspects: environment, economy, and society. In the assessment process, the cloud model was used to describe the various attribute values of infrastructure project sustainability, which achieved the uncertainty measures for infrastructure project sustainability, and a cloud model-based assessment method for infrastructure project sustainability was proposed by modifying the attribute value by the penalty factor. Finally, an assessment method for infrastructure project sustainability based on the cloud model was proposed after the attribute values were modified by using a continuous interval argument ordered weighted average (C-OWA) operator. The model carries out an overall sustainability assessment by generating a synthesized cloud with the weight to calculate the similarity of assessment factors, which takes the randomness, fuzziness, and uncertainty of expert qualitative assessment into account, and uses the analytic hierarchy process (AHP) method and the C-OWA operator to determine the weight of the sustainable index and the aggregation of the expert scoring interval. A case study was conducted to clarify how this strategy was applied. The study provides a valuable and useful tool for the operational stage to assess the achievability of municipal infrastructure projects.

Keywords: municipal infrastructure projects; sustainability evaluation; entropy cloud model; continuous interval argument ordered weighted average (C-OWA)

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1. Introduction

It is a well-known truth that municipal infrastructure projects are an essential reflection of the nation's regional modernization since they play a crucial role in generating and sustaining a suitable standard of life [1]. The benefits of these municipal infrastructure projects in terms of flood management, alleviating water shortages, producing renewable energy, ensuring food security, and general economic development have been immense [2–4]. However, the advantages come at a steep price. With large-scale infrastructure construction, many problems have arisen: lack of foresight in infrastructure planning [5], investors' focus on short-term interests and neglect of long-term interests [6], over-emphasis on construction and contempt for maintenance [7], low level of operation [8], degradation of freshwater and soil ecosystems [9,10], soil and river erosion [4,11], and large population resettlements [12]. In addition, infrastructure projects often require significant land use and long-term investment; therefore, it often leads to problems related to noise pollution, ground and water pollution, disturbance to human life and ecosystems, habitat fragmentation, and resources consumption [11].

These problems have not only led to a severe waste of resources but have also impeded the development of municipal infrastructure projects and lost the original intention to improve the living standards of local residents and promote economic development [4,13]. These are concrete manifestations of the sustainability of the project, which are rooted in neglecting to evaluate the sustainability dimension in the feasibility study of a project and the lack of sustainability awareness in these infrastructure-construction and management procedures [14].

The above-mentioned problem is a manifestation of unsustainable municipal infrastructure projects. It can be attributed to the lack of a comprehensive and systematic understanding of the factors involved in the sustainability evaluation of municipal infrastructure projects. In addition, sustainability evaluation of municipal infrastructure projects does not adequately consider the relationship between various factors and lacks a systematic approach to sustainability evaluation [10]. Therefore, it is essential to evaluate the sustainability of infrastructure efforts after they are implemented.

It has also brought the issue of the sustainability of municipal infrastructure projects to the attention of numerous experts and academics. Shen et al. [15] revealed the relative dispersion of project sustainability assessment indicators and helped decision makers to identify the most appropriate solutions based on key assessment indicators (KAIs). This study proposes an alternative method for assessing the sustainability performance of municipal infrastructure projects. Fernandez-Sanchez et al. [16] developed a methodology for identifying, classifying, and defining sustainability indicators and a selected set of indicators based on risk management criteria. In addition, this study highlights the high time and cost problems of the proposed methodology when applied to municipal infrastructure projects in Spain.

Banihashemi et al. [17] identified the critical success factors (CSFs) of the triple bottom line of sustainability (environmental, social, and economic) and proposed project management practices for incorporating sustainability into developing country construction projects after the model had been verified using questionnaire surveys utilizing the analytical technique of partial least squares structural equation modeling (PLS-SEM). According to Aimbavboa et al. [18], the main challenge for sustainable practices in the South African construction industry is the additional cost consumption during construction.

These evaluation methods solve the problem of infrastructure project sustainability evaluation to some extent; however, they mainly focus on one dimension of infrastructure project sustainability or a particular industry, and there is a less systematic evaluation of infrastructure sustainability. At the same time, these evaluation methods are still deficient in measuring and presenting infrastructure project sustainability. Most of them ignore the uncertainty of infrastructure project sustainability, such as fuzziness and randomness. Additionally, most evaluation processes use precise mathematical theory to describe and measure sustainability or classify the evaluation results in a threshold way. The sustainability evaluation often varies from person to person, and the evaluation results have certain randomness and fuzziness.

The cloud model has significant advantages in evaluating things because it handles qualitative concepts and quantitative descriptions in an uncertain way. To reflect the degree of cloud droplet dispersion and the assessment's actual circumstances, the cloud model was used in the evaluation, this paper uses the amount of entropy (En) to reflect the randomness and fuzziness and combines the expectation (Ex) and the excess entropy (He) to avoid the fuzziness and uncertainty in the evaluation. Then, the Analytic Hierarchy Process (AHP) and C-OWA operator are used to calculate the weight of the sustainable index and the aggregation of the expert scoring interval. Finally, the overall sustainability has been evaluated using a synthesized cloud which the weights rebirth into to calculate the similarity of the evaluation factor.

The following is an overview of the paper's main parts: In Section 2, 42 critical factors that affect infrastructure project sustainability are examined through a literature review, and index systems are developed; Section 3 deals with the preliminary questions; Section 4 presents a model for evaluating the sustainability of infrastructure based on cloud model and C-OWA aggregation; Section 5 gives a real-world case study that demonstrates how this approach might be used for municipal infrastructure projects; Section 6 provides discussion and the conclusion.

2. Establishment of Sustainable Indicators

For the duration of an infrastructure project's life cycle, sustainability indicates urban economic, social, and environmental growth. Science and operations should be considered in the design of the positive, sustainable evaluation index system of municipal infrastructure projects, as well as layered and systematic, qualitative and quantitative, and objective and comprehensive. Evaluation index systems are developed based on the nature of a project and are established as a process from individual to general. Examining the literature and specific case studies and inviting educators are all good ways to obtain the sustainability impact of municipal infrastructure projects. After further consultation with experts, the evaluation index system took availability and maneuverability into consideration. This paper summarized 42 factors affecting infrastructure project sustainability by frequency analysis and theoretical analysis after consultation with experts and combing and summarizing the literature of the infrastructure project sustainability study, as shown in Table 1.

Table 1. Analysis of factors influencing sustainability of municipal infrastructure projects.

Index	Influence Factors	Explanation	Reference
Environmental	Flooding risk	Size and risk of potential floodplains area	[19–23]
	Energy consumption	Consumption of energy resources such as electricity, gas, and oil	[15,24–30]
	Raw materials consumption	Consumption of materials used in all project phases, such as cement, wood, steel, bitumen, aggregate, bricks ... etc.	[15,24–26,31]
	Waste recycling and reuse	The utilization and recycling of waste.	[15,24,25,32,33]
	Energy conservation	Energy conservation of construction technology, equipment, material, etc.	[26,34–37]
	Using renewable resources	The utilization of renewable resources, less wastage, and contamination.	[25,28–30,32,38–40]
	Materials with low health risk	Utilization of materials with low health risk.	[25,28]
	Water pollution	Water quality of the entire life cycle of municipal infrastructure projects.	[15,24,25,27,29,32,41–43]
	Air pollution	Air quality of the entire life cycle of municipal infrastructure projects.	[15,24,25,27,29,32,41–43]
	Noise/acoustic pollution	Noise decibels of the entire life cycle of municipal infrastructure projects.	[15,24,25,27,29,32]
	Land use	Protection and rational development and utilization of local cultural relics, natural water systems and underground Spaces, etc.	[34,35,44]
	Greening and environment	Plant diversity and green space ratio., etc.	[6,25,34,35,45]
	Energy performance	Energy performance of the technology in construction and community equipment, use of energy-saving materials, and material selection that takes recycling performance into account, etc.	[34–36,46,47]
	Environmental fusion	The satisfaction of the public sphere and environment.	[15,24,25,29,32,42,48]
	Environmental impact	The impacts of pollutants, emissions, household garbage, etc. on the environment.	[25,32,34]
	Eco-efficiency	Less environmental footprints.	[38,39,49]

Table 1. *Cont.*

Index	Influence Factors	Explanation	Reference
	Biodiversity	The increase in biodiversity and the attraction of other species.	[38,49]
Economy	Life cycle profits	Profits of the entire life cycle of municipal infrastructure projects.	[32,50,51]
	Payback period	The number of years needed to recover the initial cash outlay.	[15]
	Life cycle costs	Costs of the entire life cycle of municipal infrastructure projects.	[37]
	Opportunity costs	Investments in other municipal infrastructure projects will be limited due to the fixed and liquid capital bound to the project.	[25]
	Operation costs	Costs of operation of the infrastructure during the operation period.	[25,26,34,50,52,53]
	Economic fusion	The impacts of pollutants, emissions, household garbage, etc. on the environment.	[25,34]
	Project budget	Total project budget of the infrastructure.	[15,24,25,27,34,54]
	Business activity	Business activities within and around the municipal infrastructure projects.	[34,55]
	Financial returns	Efficiencies in operation management contributed to the increase in profits.	[38,56,57]
	Energy costs	Costs associated with oil, gas, and electricity consumption.	[25]
	Economic performance	The project increases the local economy's productivity and introduces economic benefits to society as a whole.	[25]
	Durability	Service life of municipal infrastructure projects.	[26,37,58]
Social	Government strategy	High-level sustainable policies are being pursued by the government.	[31,35,38,59]
	Cultural continuity	Practices, materials, and styles associated with tradition, such as vernacular architecture.	[24,34,42,45,60–62]
	Stakeholder involvement	Relationship management among stakeholders and participation of stakeholders.	[38,39,63]
	Social adjustment	Settlement intentions, discrimination levels, social references, etc.	[34]
	Public interests	Public consultations, social security, health care, enrollment of children, etc.	[6,34,60,61,64–67]
	Workers' Safety and Health	A safety and health care plan is implemented during the implementation of the project to ensure the safety of the working staff.	[25,37]
	Safety standards	Provision of safety features and amenities for users on built-in infrastructure to lower accident rates	[25,61,68]
	Social satisfaction	Participation in activities and satisfaction with the community among residents	[34,62]
	Productivity improvement of industries and communities	Construction of infrastructure enhances efficiency and productivity in all industries and communities.	[38,69]
	Employment provision	Project implementation adheres to safety and health care principles for protecting the working staff.	[24,25,27,28,32,34,35,43,48,61]
	Adaptability	Capacity of infrastructure to withstand and adapt to external environmental disturbances and changing public requirements.	[70–72]
	Livability of communities	Application of infrastructure for improving the quality of life for people.	[38,39,62]
	Supply capacity of public infrastructure	Improved drainage, parking, service level, capacity, electrical, warning systems, etc.	[24,25,32]

According to Table 1, the classification of indicators can be seen, but the weight of each index in each category and the importance of each index in each specific case is different, so it is necessary to analyze specific issues, use numbers to reflect the importance, and then reflect the sustainability of the project. Entropy is a state parameter that can well reflect the randomness and fuzziness of the concept, so this paper analyzes the parameter values of each index in the specific case by cloud model.

3. Methodology

3.1. Cloud Model

Cloud is the uncertainty transformation model described in language values between a qualitative concept and its numerical representation; or simply, the cloud model is the uncertainty model for qualitative and quantitative interconversion.

Let U be a domain, expressed in exact numbers, and let A be an equivalent qualitative concept in U. For an element X in the domain that is a random instantiation of a concept A, there exists a random number $y \in [0, 1]$ with a stable trend called the degree of determination of X relative to A, i.e., the degree of affiliation. The membership cloud refers to the distribution of membership within the domain, often referred to as the cloud. The cloud is made up of many hazy droplets. As opposed to the cloud droplet, which is a quantitative depiction of the qualitative notion, the cloud's overall form represents critical features of the qualitative concept. In the generation process of cloud droplets, the qualitative concept is mapped onto a quantitative value to demonstrate uncertainty mapping.

The cloud model represents the primitives in natural language–language values. The mathematical properties of the linguistic values are represented by the numerical features of the cloud—expected Ex, entropy En, and excess entropy He.

Expectation Ex: The most representative point of the qualitative concept as well as the most representative sample of the quantitative concept is thought to be an expectation of the spatial distribution of cloud droplets in the domain.

Entropy En: The "entropy" concept was first used in thermodynamics as a state parameter and has since been introduced to measure the degree of uncertainty in statistical physics, information theory, complex systems, etc. The cloud model represents qualitative concepts by entropy, which represents their granularity. As entropy increases, the concept becomes more macroscopic. Furthermore, it serves as a measure of the uncertainty of qualitative conceptions, which is dictated by the concepts' unpredictability and fuzziness. En can be seen as a measure of the qualitative concept's unpredictability. It reflects the dispersion of cloud droplets that can be interpreted as a qualitative concept. On the other hand, a concept inside a domain space can accept a vast number of cloud droplets. As well as qualitative concepts, it measures the range of cloud droplets that can be accepted by a particular concept. The same numeric feature reflecting randomness and fuzziness will inevitably reflect the relevance of both.

Excess entropy He: The unpredictability and fuzziness of entropy, which is the level of cohesiveness between cloud droplets, influence the uncertainty measurement of entropy, known as entropy-of-entropy. Excess entropy indicates greater dispersion, randomness, and thickness of the cloud.

Cloud generator (CG) or cloud production algorithm can be implemented through software with modular components or hardware treated with a cure. This research applied the mathematical software MATLAB to implement the cloud generator. By function, cloud generators can be divided into forward cloud generators and backward cloud generators.

Forward Cloud Generator: Forward cloud generators combine the digital features of 3 clouds (Ex, En, He) in a forward, direct process and the number of cloud drops needed, along with the coordinates of each droplet in the domain and the probability of each cloud drop representing the concept. The principle and occurrence are shown in Figure 1.

Backward Cloud Generator: The backward cloud generator puts a model for changing quantitative quantities into qualitative notions into practice. It may transform a certain volume of precise data into a qualitative concept conveyed in a digital feature (Ex, En, He). The principle and occurrence are shown in Figure 2.

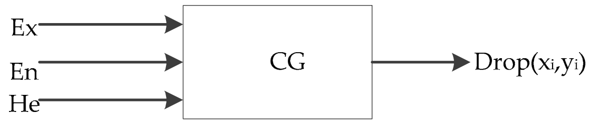

Figure 1. One-dimensional forward cloud generator.

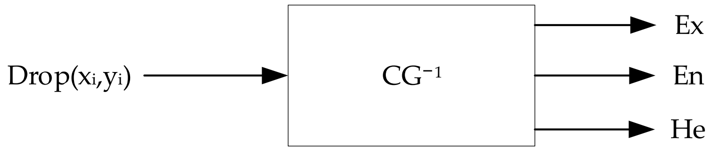

Figure 2. One-dimensional backward cloud generator.

The most prevalent and significant cloud model is the forward cloud. Taking the one-dimensional forward cloud as an example, its algorithm for generating cloud droplets is as follows:

Input: the numerical eigenvalues of the qualitative concept (Ex, En, He) are the digital representation of the cloud model, as well as the number of cloud droplets;

Output: the quantitative value of cloud droplets; that is, the certainty of cloud droplets for qualitative concepts.

Generate the normal random number $En_i = NORM(En, He)$ with En as expectation and He as variance. En_i is the generating function of the normal random number, with En as the expectation and He as the variance;

Generate the normal random number $x_i = NORM(Ex, En_i)$ with En as the expectation and En_i as the standard deviation;

Calculate the certainty of x_i

$$\mu(x_i) = e^{-\frac{(x_i - Ex)^2}{2(En_i)^2}}; \tag{1}$$

Set $\mu(x_i)$ expressed as the conceptual, quantitative certainty of cloud droplets x_i;

Repeat (1)~(4) until a cloud droplet is generated to form a cloud model.

3.2. Continuous Interval Argument Ordered Weighted Average (C-OWA)

Ordered Weighted Average (OWA) operator is mainly used to describe and deal with multi-criteria aggregation problems and form an overall decision function [73]. This conceptualization highlights the importance of OWA weighting vectors for influencing decision-makers' attitudes [74]. Research on operators has gained significant attention in recent years due to its multi-field and multi-angle nature [75]. The OWA operator was employed in this study to resolve the decision scheme's ranking difficulty and to condense the judgment-related data.

An OWA operator of n dimension is a mapping $f : R^n \to R$ with the i^{th} position of a set of order weights $w = w_1, w_2, \cdots, w_n$ such that $w_j \in [0, 1], j = 1, 2, \cdots, n, \sum_{i=0}^{n} w_i = 1$, and the definition of aggregation function is as follows [73,76]:

$$f(a_1, a_2, \cdots, a_n) = \sum_{i=1}^{n} w_i b_i \tag{2}$$

where b_i is the i-th largest element of the collection of aggregated objects $a_1, a_2, \cdots, a_n$. OWA is a unified framework for decision-making under uncertainty. The following qualities are required for it to be chosen w [77]: (1) there is an order to the weights; that means $w_n \leq \cdots \leq w_2 \leq w_1$ or $0 \leq w_1 \leq w_2 \leq \cdots \leq w_n$; (2) in summary data, the weights do not depend on the size of the sets but on the order in which they are sorted $b_1, b_2, \cdots, b_n$ and the degree of optimism of the decision maker.

On the basis of this definition, process weight assembling and rank data a_i $(i = 1, 2, \cdots, n)$ down sequencing, since a_i and w_i are non-correlated, w_i can be defined in advance as it only relates to the i^{th} position. Different OWA operators correspond to various weight vectors as a result.

Due to OWA operators only being suitable for the aggregation of discrete data, a new continuous interval data information aggregation operator was proposed [78]:

Let $[a, b]$ be the interval number, and $f_\rho([a, b]) = \int_0^1 \frac{d\rho(y)}{dy}(b - y(b - a))dy$, which $\rho : [0, 1] \to [0, 1]$ is a function with the following properties: (1) $\rho(0) = 0$; (2) $\rho(1) = 1$; (3) if $x > y$, then $\rho(x) \geq \rho(y)$. Then f is called Continuous Interval Argument Ordered Weighted Average (C-OWA) and ρ is called Basic Unit-interval Monotonic (BUM) function.

This definition defines the interval $[a, b]$ of definite uncertainty after the function of the C-OWA operator f; it is transformed into a deterministic value, which integrates each interval data.

Set the level of optimism among policymakers to $\lambda = \int_0^1 \rho(y)dy(0 \leq \lambda \leq 1)$, then it can be obtained: $f_\rho([a, b]) = \lambda b + (1 - \lambda)a$. For any BUM function ρ, there is $a \leq f_\rho([a, b]) \leq b$. In the special case, if $\rho(y) = y^r (r \geq 0)$, then $f_\rho([a, b]) = \frac{b+ra}{r+1}$. Among them, the value of parameter r can express the risk attitude of decision makers. When $r = 1$, the decision maker is risk neutral. When $r \in [0, 1)$, the decision maker is risk preference (optimistic). In addition, when $r \in (1, +\infty)$, the decision maker is risk aversion (pessimism). When different values of r are taken, then (1) $r \to 0$, $f_\rho([a, b]) = b$; (2) $r = 1$, $f_\rho([a, b]) = (a + b)/2$; (3) $r \to +\infty$, $f_\rho([a, b]) = a$. The computational flow of the C-OWA operator is shown in Figure 3.

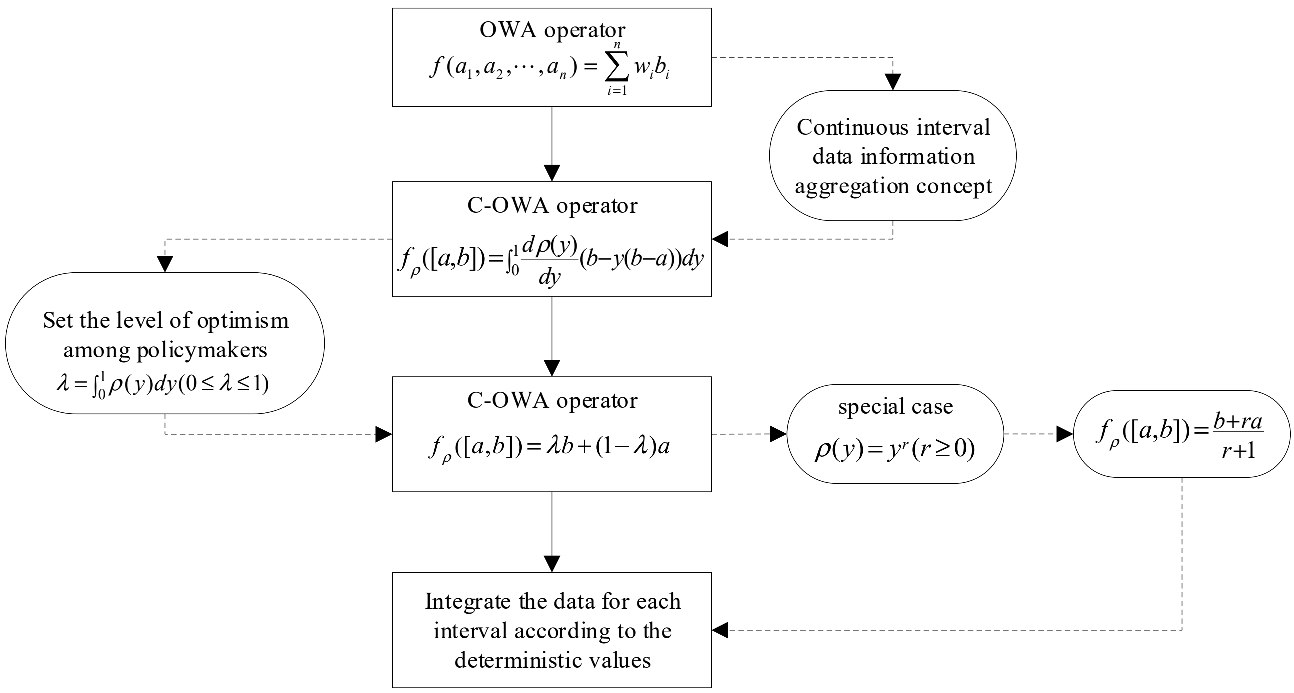

Figure 3. C-OWA operator flow chart.

4. Establishment of a Sustainability Evaluation Model of Infrastructure Based on the Cloud Model

4.1. Sustainable Evaluation of Municipal Infrastructure Projects Based on the Cloud Model

The digital attributes of the cloud model are introduced in accordance with the characteristics of randomness, fuzziness, and other uncertainties of infrastructure project sustainability, as well as the attribute state preferences of decision-makers in the evaluation process, using the expectation, entropy, and excess entropy to describe the attribute values of infrastructure project sustainability, reflecting the uncertainty measure of infrastructure project sustainability. Combining fuzziness, randomness, and discreteness organically enables the transformation between uncertainty language and quantitative value. The evaluation process is as follows:

(1) Based on the sustainable development level of each indicator, the importance of each indicator is judged on the basis of dividing the sustainable development level, and the weight of each indicator is determined by applying AHP for a two-by-two comparison;
(2) The evaluation interval of each secondary evaluation factor is determined by combining expert judgment and expert inquiry, and the C-OWA operator is applied to obtain each index cloud's digital eigenvalues;
(3) The cloud model for each primary evaluation factor is generated from the cloud digital features of the secondary evaluation factors;
(4) In similarity calculation, the digital eigenvalues of the first-order evaluation factor are compared, with each standard sustainability sub-cloud corresponding to the evaluation factor to calculate the similarity;
(5) We use the similarity of the obtained first-order evaluation factor for overall sustainability assessment.

Figure 4 illustrates the sustainability assessment process in this study.

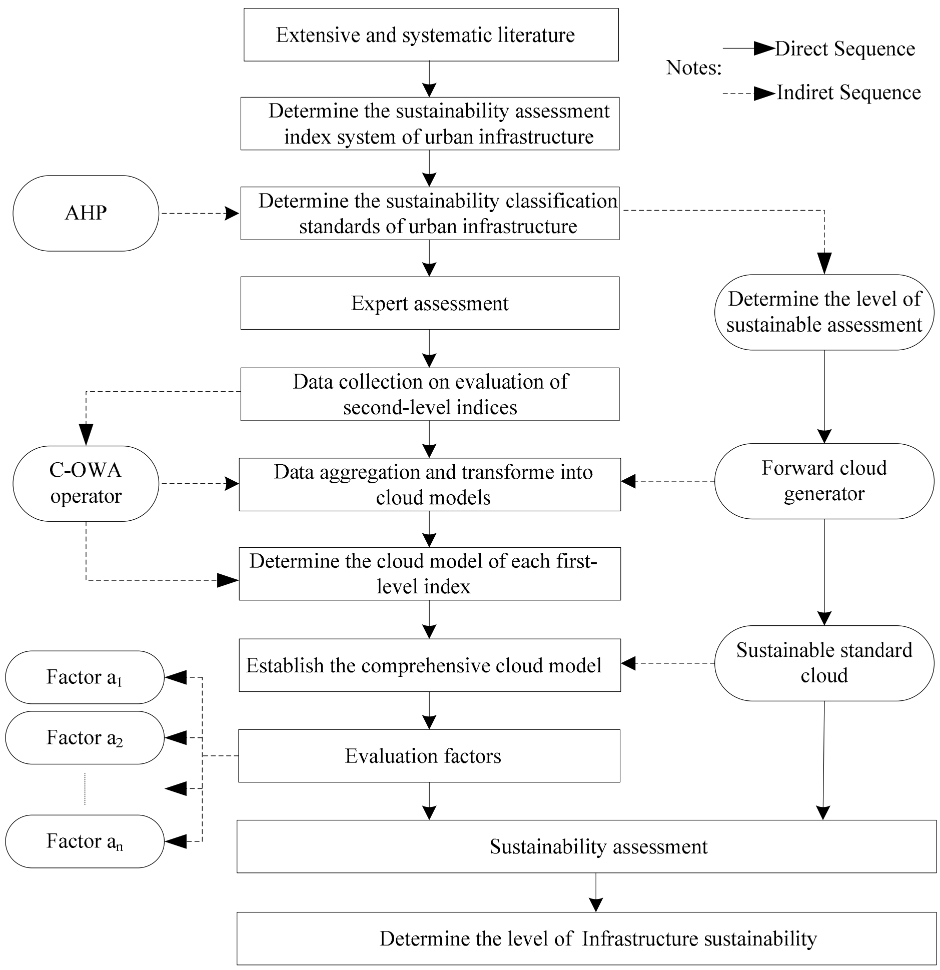

Figure 4. Sustainability evaluation process based on cloud model and C-OWA aggregation method.

4.2. Generation of Sustainability Standard Cloud

In order to evaluate, a series of standard clouds need to be pre-set in the system. As a reference for entity evaluation, each standard cloud corresponds to an evaluation factor indicating the corresponding sustainable level. Assuming that the range of sustainable evaluation scores for municipal infrastructure projects is [0, 10], the interval is divided into n sub-intervals $[R_{\min}, R_{\max}]$, corresponding to their respective levels of sustainability. The calculation of the standard cloud is as follows [79]:

(1) Calculate the expectation according to the upper ${R_{\max}}^i$ and lower ${R_{\min}}^i$ of the i interval:

$$Ex_i = \begin{cases} {R_{\min}}^{(i)}, & i = 1 \\ \frac{{R_{\min}}^{(i)} + {R_{\max}}^{(i)}}{2}, & 1 < i < n; \\ {R_{\max}}^{(i)}, & i = n \end{cases} \quad (3)$$

(2) Calculate entropy based on the results in (1):

$$En_i = \frac{Ex_{i+1} - Ex_i}{3}; \quad (4)$$

(3) Computational excess entropy $He_i = k_i$.

$He = k$ reflects the randomness of sustainability, the value should not be too large because the larger the He, the greater error of Ex, the greater the randomness of sustainability, and the more difficult to determine the results. There is currently no extremely developed approach for figuring out the value of He that can be chosen based on the real circumstance and practical experience.

The forward cloud generator and the semi-cloud generator produce the standard clouds of each evaluation factor in accordance with the cloud model's identified digital eigenvalues (Ex, En, He) (rising and falling clouds).

4.3. Cloud Processing of Attribute Values

In evaluating the sustainability of municipal infrastructure projects, experts can often only give qualitative knowledge of each attribute because it is difficult to provide the digital eigenvalues of the cloud directly. Therefore, this paper adopts the group decision-making method. The expert individual gives the score interval number of the attribute value and then transforms the clustered interval number into the cloud model. The specific steps of the algorithm are as follows:

Step 1: According to the actual situation of the project, the experts give the evaluation interval of the attribute on the domain [0, 10] in the light of a certain scale;

Step 2: The C-OWA operator is used to assemble the evaluation interval number of each expert;

Step 3: Using the OWA operator for integration based on Step 2, the assembly interval number is obtained;

Step 4: The resulting assembly interval number is transformed into the cloud model.

In Step 3, the OWA operator is slightly modified as follows: sort according to the numerical size obtained in Step 2, but when the OWA operator is integrated, the interval number is used as the basic data of operation. The addition and multiplication operations involved are defined as follows:

If the interval number is $[a, b]$ and $[n, m]$, $\tau \in R^+$, the addition and multiplication of the interval number are determined as follows:

$$[a, b] \oplus [n, m] = [a + n, b + m]; \quad (5)$$

$$\tau[a, b] = [\tau a, \tau b]. \quad (6)$$

The calculation method of transforming the interval number into the cloud model in step (4) are as follows: Use the Formula (1) to calculate the expectation Ex_i; calculate the entropy and the excess entropy according to the formulas $En = \frac{R_{\max} - R_{\min}}{6}$ and $He_i = k$.

4.4. Formation of First-Order Assessment Factor Cloud

After the cluster interval number obtained from the C-OWA operator is transformed into a cloud model, the digital eigenvalue of the secondary evaluation factor can be calculated first with the help of the synthesized cloud theory in the virtual cloud, and then the calculated digital eigenvalue can be used to generate the Cloud Model of each primary evaluation factor. The formula is as follows:

$$\begin{cases} Ex = \frac{Ex_1 \times En_1 \times \omega_1 + Ex_2 \times En_2 \times \omega_2 + \cdots + Ex_n \times En_n \times \omega_n}{En_1 \times \omega_1 + En_2 \times \omega_2 + \cdots + En_n \times \omega_n} \\ En = En_1 \times \omega_1 + En_2 \times \omega_2 + \cdots + En_n \times \omega_n \\ He = \frac{He_1 \times En_1 \times \omega_1 + He_2 \times En_2 \times \omega_2 + \cdots + He_n \times En_n \times \omega_n}{En_1 \times \omega_1 + En_2 \times \omega_2 + \cdots + En_n \times \omega_n} \end{cases}. \quad (7)$$

Among them, the expectation of each secondary evaluation factor is Ex_1, Ex_2, … … , Ex_n, the entropy of each secondary evaluation factor is En_1, En_2, … … , En_n, the super entropy of each secondary evaluation factor is He_1, He_2, … … , He_n, and n is the number of secondary factors under this primary evaluation factor.

4.5. Comprehensive Evaluation of the Sustainability of Municipal Infrastructure Projects

In order to better evaluate the sustainability of municipal infrastructure projects, economic, social, and environmental aspects of municipal infrastructure projects can be evaluated separately by the following process.

Using the Formula (7), the numerical eigenvalues of the first-order evaluation factor (Ex, En, He) are obtained, compared with the standard sustainability sub-cloud of the evaluation factors, and the similarity is calculated to find the standard sub-cloud that is closest to it. The sustainability level corresponding to the standard sub-cloud is the entity's sustainability level.

Respectively, set the synthesized cloud and standard cloud as $MYC_1(Ex_1, En_1, He_1)$ and $MYC_2(Ex_2, En_2, He_2)$. The satisfaction cloud MYC_1 was passed through the forward cloud generator of the Cloud Model to generate a cloud droplet x_i. If the determination of x in the satisfaction cloud MYC_2 is μ, the mean is the similarity of the satisfaction cloud MYC_1 and the satisfaction cloud MYC_2, recorded as δ.

Input: $MYC_1(Ex_1, En_1, He_1)$, $MYC_2(Ex_2, En_2, He_2)$;

Output: output δ (the resemblance between the synthesized cloud and the standard cloud).

The specific steps of the algorithm are as follows:

(1) A random normal number with En_1 as expectation and He_1 as standard deviation is generated in the synthesized cloud MYC_1;

$$En_1{}' = normrnd(En_1{}' He_1{}^2) \quad (8)$$

(2) A random normal number with Ex_1 as expectation and $En_1{}'$ as standard deviation is generated in the synthesized cloud MYC_1;

$$X_1 = normrnd(Ex_1, En_1{}'^2) \quad (9)$$

(3) The determination degree is calculated by substituting X_1 into the standard cloud MYC_2;

$$\mu_i{}' = e^{-\frac{(x_i - Ex)^2}{2(En_i)^2}} \quad (10)$$

(4) Repeat steps 2 and 3 until n determinations ($\mu_i{}'$) are generated;

(5) Calculation of similarity:

$$\delta = \frac{1}{n}\sum \mu_i{}'. \quad (11)$$

The calculated synthesized cloud and standard cloud are calculated for cloud model similarity to find the highest grade of similarity. The overall sustainability is then evaluated using the similarity of the obtained first-level evaluation factor, and the certainty (π_j) of the jth evaluation grade for infrastructure project sustainability is calculated, with the largest evaluation grade being the final overall sustainability evaluation grade for the infrastructure project.

$$\pi_j = \sum \delta_{ij} \times \omega_i \tag{12}$$

5. Case Analysis

Take the Second Ring Road Expressway renovation project in City A as an example. The total length of the Second Ring Road Expressway project is 65.31 km, with a total investment of approximately RMB 22.39 billion, of which the construction cost is approximately RMB 17.89 billion (approximately RMB 15.83 billion for main works and RMB 2.06 billion for ancillary works). The project is divided into 14 tender sections. The main works include 13 interchanges, 6 river bridges, 12 cross-line bridges, 45 flyovers, and 2 graben passages. According to the actual situation of the project, the relevant government departments used the AHP method to determine the weight of each sustainable index of the project according to the real situation of the project and then evaluated each index based on the C-OWA operator. Five decision-making experts were first engaged in rating the sustainability indicators of the project based on actual project information, as shown in Table 2.

Table 2. Sustainability evaluation of a highway project in a city.

First Evaluation Factor	Weight	Second Evaluation Factor	Weight	Five Expert Scores
Environment	0.49	Flooding risk	0.11	[7, 8] [8, 9] [7, 8] [8, 8.5] [7, 8]
		Energy consumption	0.05	[5, 5.5] [8, 9] [8, 9] [8.5, 9] [7, 8]
		Raw materials consumption	0.09	[6, 7] [7.5, 8.5] [7, 8.5] [8.5, 9.5] [7, 8]
		Waste recycling and reuse	0.03	[5, 5.5] [6, 8] [8, 8.5] [8, 8.5] [6, 7]
		Energy conservation	0.07	[6, 7] [8, 9] [8, 9] [7, 8.5] [8, 9]
		Using renewable resources	0.12	[7, 8] [7, 9] [7, 8] [8, 9] [8, 9]
		Materials with low health risk	0.06	[6, 7] [6, 8] [7, 8] [7, 8.5] [8, 9]
		Water pollution	0.08	[7, 7.5] [7, 8] [7, 8] [6.5, 8.5] [6, 7]
		Air pollution	0.03	[5, 5.5] [6, 8] [7, 8.5] [8, 8.5] [5, 6]
		Noise/acoustic pollution	0.03	[5, 5.5] [7, 8] [8, 8.5] [8, 9] [6, 7]
		Land use	0.12	[8, 9] [8, 8.5] [8, 9.5] [8, 9] [5.5, 6.5]
		Greening and environment	0.10	[7, 8] [7, 8] [8, 9.5] [7, 8.5] [8, 9]
		Energy performance	0.01	[5, 6] [7, 9] [9, 9.5] [7, 8] [8, 9]
		Environmental fusion	0.03	[6, 6.5] [7, 8.5] [7, 8] [6.5.7.5] [5, 6]
		Environmental impact	0.03	[6, 8] [6, 8] [8, 8.5] [8, 8.5] [4, 5]
		Eco-efficiency	0.03	[6, 6.5] [7, 9] [7, 8] [7.5, 8.5] [6, 7]
		Biodiversity	0.05	[7, 8] [8, 9] [8, 8.5] [6, 5, 7.5] [4, 5]
Economy	0.29	Life cycle profits	0.08	[7, 7.5] [7, 8] [9, 9.5] [8, 8.5] [7, 8]
		Payback period	0.13	[7, 9] [7, 8.5] [8, 9.5] [7, 8] [6, 7]
		Life cycle cost	0.03	[5, 6] [6, 8] [8, 9.5] [7.5, 8.5] [8, 9]
		Opportunity costs	0.07	[6, 7] [7, 9] [8, 9] [6.5, 8.5] [7, 8]
		Operation costs	0.13	[8, 9] [7, 8.5] [8, 8.5] [7, 9] [6, 7]
		Economic fusion	0.07	[6, 7] [7, 8] [8, 9] [8, 8.5] [5, 6]
		Program budget	0.13	[8, 8.5] [6, 8] [8, 8.5] [8, 8.5] [6, 7]
		Business activity	0.04	[6, 7] [7, 8.5] [7, 8.5] [7.5, 8.5] [5.5, 6.5]
		Financial returns	0.07	[7, 8] [7, 8] [6, 7] [8, 9] [4, 5]
		Energy costs	0.07	[7, 8] [6, 8] [7, 8.5] [7.5, 9] [4, 5]
		Economic performance	0.04	[5, 6] [8, 9] [8, 9] [8, 9] [5, 6]
		Durability	0.13	[8, 9] [8, 8.5] [8, 9] [7, 8] [6, 7]
Social	0.22	Government strategy	0.04	[5, 5.5] [8, 9] [7, 7.5] [8.5, 9] [5, 6]
		Cultural continuity	0.18	[9, 9.5] [7, 8] [9, 9.5] [8, 8.5] [7, 8]
		Stakeholder involvement	0.05	[5, 6] [7, 8.5] [7, 7.5] [6.5, 8.5] [6, 7]
		Social adjustment	0.13	[7, 8] [7.5, 8.5] [7, 8] [7.5, 9] [7, 8]

Table 2. *Cont.*

First Evaluation Factor	Weight	Second Evaluation Factor	Weight	Five Expert Scores
		Public interests	0.03	[5, 6] [8, 8.5] [8, 9] [8, 8.5] [6, 7]
		Workers' Safety and Health	0.08	[6, 7] [8, 9] [8, 9] [8, 9] [6, 7]
		Safety standards	0.13	[7, 8] [7.5, 8.5] [9, 9.5] [8.5, 9] [6, 7]
		Social satisfaction	0.02	[5, 6] [7, 8] [9, 9.5] [8.5, 9] [8, 9]
		Productivity improvement of industries and communities	0.04	[6, 7] [8, 9] [8, 9] [7.5, 8] [6, 7]
		Employment provision	0.09	[7, 7.5] [7, 8.5] [7, 8.5] [8, 9] [6, 7]
		Adaptability	0.08	[5, 7] [7, 8.5] [7, 8] [8, 8.5] [6, 7]
		Livability of communities	0.08	[5, 6.5] [7.5, 8.5] [7, 8] [8.5, 9] [7, 8]
		Supply capacity of public infrastructure	0.04	[6, 8] [8, 9] [8, 9] [8.5, 9] [7, 8]

The decision-making steps are as follows:

Step 1: Evaluation factor standard cloud generation

This stage categorizes infrastructure sustainability into four categories: excellent, good, medium, and bad. The corresponding scoring interval and cloud model digital eigenvalues are shown in the table. Let the rating interval with the optimal sustainability grade be [9, 10], the desired value ex is 10 according to Formula (3), the entropy is 0.5 according to Formula (4), and the excess entropy value is 0.05. In the same way, the numerical eigenvalues of the sustainable evaluation grade are good, medium, and poor. As shown in Table 3.

Table 3. Digital eigenvalues of the standard cloud.

Sustainability Levels	Score Interval	Digital Eigenvalues of Cloud Models (*Ex*, *En*, *He*)		
		Economy	Social	Environment
Excellent	[9, 10]	(10.0, 0.5, 0.05)	(10.0, 0.5, 0.05)	(10.0, 0.5, 0.05)
Good	[8, 9]	(8.5, 0.5, 0.05)	(8.5, 0.5, 0.05)	(8.5, 0.5, 0.05)
Medium	[6, 8]	(7.0, 0.5, 0.05)	(7.0, 0.5, 0.05)	(7.0, 0.5, 0.05)
Bad	[0, 6]	(0, 2.33, 0.23)	(0, 2.33, 0.23)	(0, 2.33, 0.23)

Step 2: Use the C-OWA operator to find the aggregation interval

This step combines the indicators of the five invited experts rated based on years of engineering experience. The experts are conservative in the sustainable assessment of the project, so the BUM function is taken as $\rho(y) = y^2$. The interval after aggregation is indicated by [A, B], as shown in Table 4.

Table 4. Integration intervals by using C-OWA operators.

Indicator	a	b	f	A	B
Flooding risk	8	9	8.33	7.3	8.2
	8	8.5	8.17		
	7	8	7.33		
	7	8	7.33		
	7	8	7.33		
Energy consumption	8.5	9	8.67	7.6	8.5
	8	9	8.33		
	8	9	8.33		
	7	8	7.33		
	5	5.5	5.17		

Table 4. *Cont.*

Indicator	a	b	f	A	B
Raw materials consumption	8.5 7.5 7 7 6	9.5 8.5 8.5 8 7	8.83 7.83 7.50 7.33 6.33	7.2	8.3
Waste recycling and reuse	8 8 6 6 5	8.5 8.5 8 7 5.5	8.17 8.17 6.67 6.33 5.17	6.6	7.8
Energy conservation	8 8 8 7 6	9 9 9 8.5 7	8.33 8.33 8.33 7.50 6.33	7.6	8.8
Using renewable resources	8 8 7 7 7	9 9 9 8 8	8.33 8.33 7.67 7.33 7.33	7.3	8.7
Materials with low health risk	8 7 7 6 6	9 8.5 8 8 7	8.33 7.50 7.33 6.67 6.33	6.8	8.1
Water pollution	7 7 7 6.5 6	8 8 7.5 8.5 7	7.33 7.33 7.17 7.17 6.33	6.8	7.9
Air pollution	8 7 6 5 5	8.5 8.5 8 6 5.5	8.17 7.50 6.67 5.33 5.17	6.1	7.5
Noise/acoustic pollution	8 8 7 6 5	9 8.5 8 7 5.5	8.33 8.17 7.33 6.33 5.17	6.9	7.8
Land use	8 8 8 8 5.5	9.5 9 9 8.5 6.5	8.50 8.33 8.33 8.17 5.83	7.8	8.8
Greening and environment	8 8 7 7 7	9.5 9 8.5 8 8	8.50 8.33 7.50 7.33 7.33	7.3	8.5
Energy performance	9 8 7 7 5	9.5 9 9 8 6	9.17 8.33 7.67 7.33 5.33	7.3	8.6

Table 4. *Cont.*

Indicator	a	b	f	A	B
Environmental fusion	7	8.5	7.50	6.4	7.3
	7	8	7.33		
	6.5	7.5	6.83		
	6	6.5	6.17		
	5	6	5.33		
Environmental impact	8	8.5	8.17	6.5	8.0
	8	8.5	8.17		
	6	8	6.67		
	6	8	6.67		
	4	5	4.33		
Eco-efficiency	7.5	8.5	7.83	6.7	7.9
	7	9	7.67		
	7	8	7.33		
	6	7	6.33		
	6	6.5	6.17		
Biodiversity	8	9	8.33	7.0	7.9
	8	8.5	8.17		
	7	8	7.33		
	6.5	7.5	6.83		
	4	5	4.33		
Life cycle profits	9	9.5	9.17	7.4	8.2
	8	8.5	8.17		
	7	8	7.33		
	7	8	7.33		
	7	7.5	7.17		
Payback period	8	9.5	8.50	7.0	8.5
	7	9	7.67		
	7	8.5	7.50		
	7	8	7.33		
	6	7	6.33		
Life cycle cost	8	9.5	8.50	7.1	8.4
	8	9	8.33		
	7.5	8.5	7.83		
	6	8	6.67		
	5	6	5.33		
Opportunity costs	8	9	8.33	6.9	8.4
	7	9	7.67		
	7	8	7.33		
	6.5	8.5	7.17		
	6	7	6.33		
Operation costs	8	9	8.33	7.3	8.6
	8	8.5	8.17		
	7	9	7.67		
	7	8.5	7.50		
	6	7	6.33		
Economic fusion	8	9	8.33	6.9	7.8
	8	8.5	8.17		
	7	8	7.33		
	6	7	6.33		
	5	6	5.33		
Program budget	8	8.5	8.17	7.4	8.3
	8	8.5	8.17		
	8	8.5	8.17		
	6	8	6.67		
	6	7	6.33		

Table 4. *Cont.*

Indicator	a	b	f	A	B
Business activity	7.5	8.5	7.83	6.7	8.0
	7	8.5	7.50		
	7	8.5	7.50		
	6	7	6.33		
	5.5	6.5	5.83		
Financial returns	8	9	8.33	6.6	7.6
	7	8	7.33		
	7	8	7.33		
	6	7	6.33		
	4	5	4.33		
Energy costs	7.5	9	8.00	6.6	8.0
	7	8.5	7.50		
	7	8	7.33		
	6	8	6.67		
	4	5	4.33		
Economic performance	8	9	8.33	7.1	8.1
	8	9	8.33		
	8	9	8.33		
	5	6	5.33		
	5	6	5.33		
Durability	8	9	8.33	7.6	8.4
	8	9	8.33		
	8	8.5	8.17		
	7	8	7.33		
	6	7	6.33		
Government strategy	8.5	9	8.67	6.7	7.5
	8	9	8.33		
	7	7.5	7.17		
	5	6	5.33		
	5	5.5	5.17		
Cultural continuity	9	9.5	9.17	8.0	8.7
	9	9.5	9.17		
	8	8.5	8.17		
	7	8	7.33		
	7	8	7.33		
Stakeholder involvement	7	8.5	7.50	6.4	7.7
	7	7.5	7.17		
	6.5	8.5	7.17		
	6	7	6.33		
	5	6	5.33		
Social adjustment	7.5	9	8.00	7.2	8.2
	7.5	8.5	7.83		
	7	8	7.33		
	7	8	7.33		
	7	8	7.33		
Public interests	8	9	8.33	7.3	8.0
	8	8.5	8.17		
	8	8.5	8.17		
	6	7	6.33		
	5	6	5.33		
Workers' Safety and Health	8	9	8.33	7.4	8.4
	8	9	8.33		
	8	9	8.33		
	6	7	6.33		
	6	7	6.33		

Table 4. *Cont.*

Indicator	a	b	f	A	B
Safety standards	9 8.5 7.5 7 6	9.5 9 8.5 8 7	9.17 8.67 7.83 7.33 6.33	7.6	8.5
Social satisfaction	9 8.5 8 7 5	9.5 9 9 8 6	9.17 8.67 8.33 7.33 5.33	7.8	8.6
Productivity improvement of industries and communities	8 8 7.5 6 6	9 9 8 7 7	8.33 8.33 7.67 6.33 6.33	7.2	8.0
Employment provision	8 7 7 7 6	9 8.5 8.5 7.5 7	8.33 7.50 7.50 7.17 6.33	7.0	8.2
Adaptability	8 7 7 6 5	8.5 8.5 8 7 7	8.17 7.50 7.33 6.33 5.67	6.7	7.8
Livability of communities	8.5 7.5 7 7 5	9 8.5 8 8 6.5	8.67 7.83 7.33 7.33 5.50	7.1	8.1
Supply capacity of public infrastructure	8.5 8 8 7 6	9 9 9 8 8	8.67 8.33 8.33 7.33 6.67	7.7	8.7

Step 3: Cloud processing of attribute value

Cloud processing is carried out for the evaluation interval after aggregation; that is, the eigenvalue of the cloud model (Ex, En, He) is obtained according to the above formula, as shown in Table 5.

Step 4: Use the weight in Table 2 to generate a synthesized cloud of first-level evaluation factors, as shown in Table 6. The MATLAB 2016a software processing is undertaken according to the data in Table 6, and the specific code is shown in Table 7. The sustainability synthesized cloud is shown in Figure 5.

Step 5: Calculation of evaluation factor similarity

The similarities with the respective standard cloud are calculated based on the economic, social, and environmental sustainability cloud models in Table 6, and the results are shown in Table 8.

Table 5. Cloudification results of sustainability indicators.

Indicator	Integration Interval [A, B]	Attribute Value (*Ex*, *En*, *He*)
Flooding risk	[7.3, 8.2]	(7.75, 0.15, 0.02)
Energy consumption	[7.6, 8.5]	(8.06, 0.16, 0.02)
Raw materials consumption	[7.2, 8.3]	(7.75, 0.20, 0.02)
Waste recycling and reuse	[6.6, 7.8]	(7.16, 0.20, 0.02)
Energy conservation	[7.6, 8.8]	(8.19, 0.19, 0.02)
Using renewable resources	[7.3, 8.7]	(8.00, 0.23, 0.02)
Materials with low health risk	[6.8, 8.1]	(7.44, 0.23, 0.02)
Water pollution	[6.8, 7.9]	(7.34, 0.28, 0.03)
Air pollution	[6.1, 7.5]	(6.78, 0.24, 0.02)
Noise/acoustic pollution	[6.9, 7.8]	(7.36, 0.14, 0.01)
Land use	[7.8, 8.8]	(8.30, 0.15, 0.02)
Greening and environment	[7.3, 8.5]	(7.92, 0.20, 0.02)
Energy performance	[7.3, 8.6]	(7.92, 0.22, 0.02)
Environmental fusion	[6.4, 7.3]	(6.89, 0.15, 0.02)
Environmental impact	[6.5, 8.0]	(7.23, 0.24, 0.02)
Eco-efficiency	[6.7, 7.9]	(7.33, 0.20, 0.02)
Biodiversity	[7.0, 7.9]	(7.44, 0.15, 0.02)
Life cycle profits	[7.4, 8.2]	(7.78, 0.14, 0.01)
Payback period	[7.0, 8.5]	(7.73, 0.24, 0.02)
Life cycle cost	[7.1, 8.4]	(7.77, 0.21, 0.02)
Opportunity costs	[6.9, 8.4]	(7.63, 0.25, 0.03)
Operation costs	[7.3, 8.6]	(7.94, 0.23, 0.02)
Economic fusion	[6.9, 7.8]	(7.38, 0.15, 0.02)
Program budget	[7.4, 8.3]	(7.83, 0.15, 0.02)
Business activity	[6.7, 8.0]	(7.34, 0.22, 0.02)
Financial returns	[6.6, 7.6]	(7.13, 0.17, 0.02)
Energy costs	[6.6, 8.0]	(7.30, 0.23, 0.02)
Economic performance	[7.1, 8.0]	(7.56, 0.17, 0.02)
Durability	[7.6, 8.4]	(8.03, 0.14, 0.01)
Government strategy	[6.7, 7.5]	(7.09, 0.13, 0.01)
Cultural continuity	[8.0, 8.7]	(8.33, 0.11, 0.01)
Stakeholder involvement	[6.4, 7.7]	(7.08, 0.21, 0.02)
Social adjustment	[7.2, 8.2]	(7.67, 0.17, 0.02)
Public interests	[7.3, 8.0]	(7.66, 0.11, 0.01)
Workers' Safety and Health	[7.4, 8.4]	(7.88, 0.17, 0.02)
Safety standards	[7.6, 8.5]	(8.05, 0.14, 0.01)
Social satisfaction	[7.8, 8.6]	(8.17, 0.14, 0.01)
Productivity improvement of industries and communities	[7.2, 8.0]	(7.59, 0.14, 0.01)
Employment provision	[7.0, 8.2]	(7.59, 0.20, 0.02)
Adaptability	[6.7, 7.8]	(7.27, 0.19, 0.02)
Livability of communities	[7.1, 8.1]	(7.59, 0.17, 0.02)
Supply capacity of public infrastructure	[7.7, 8.7]	(8.17, 0.17, 0.02)

Table 6. Synthesized cloud for economic, social, and environmental sustainability.

First Evaluation Factor	Economic Sustainability	Social Sustainability	Environmental Sustainability
(Ex, En, He)	(7.679, 0.188, 0.019)	(7.328, 0.163, 0.016)	(7.705, 0.202, 0.021)

As can be seen from Table 8, the economic sustainability of the project is medium, the social sustainability is medium, and the environmental sustainability is medium, but the degree of its affiliation to the good is also high, which can be regarded as the upper middle.

Step 6: Overall sustainability assessment of the project

Table 7. Synthesized cloud MATLAB code.

Economic Sustainability

```
Ex = 7.679; Ex, En, He
En = 0.188;
He = 0.019;
n = 3000;
X = zeros (1, n);
Y = zeros (1, n);
X (1: n)= normrnd (Ex, He, 1, n);
for i = 1: n
 En_1 = normrnd (En, He, 1, 1);
X (1, i) = normrnd (Ex, En_1, 1);
Y (1, i) = exp (−(X (1, i) − Ex)ˆ2/(2*En_1ˆ2));
plot (X, Y, '>', 'MarkerEdgeColor', 'b', 'markersize', 4);
grid on;
end
hold on;
Social sustainability:
Ex = 7.328;
En = 0.163;
He = 0.016;
n = 3000;
X = zeros (1, n);
Y = zeros (1, n);
X (1: n) = normrnd (Ex, He, 1, n);
for i = 1: n
En_1 = normrnd (En, He, 1, 1);
X (1, i) = normrnd (Ex, En_1, 1);
Y (1, i) = exp(−(X (1, i) − Ex)ˆ2/(2*En_1ˆ2));
plot (X, Y, '.', 'MarkerEdgeColor', 'k', 'markersize', 4);
grid on;
end
hold on;
Environmental sustainability:
Ex = 7.705;
En = 0.202;
He = 0.021;
n = 3000;
X = zeros (1, n);
Y = zeros (1, n);
X (1: n) = normrnd (Ex, He, 1, n);
for i = 1: n
En_1 = normrnd (En, He, 1, 1);
X (1, i) = normrnd (Ex, En_1, 1);
Y (1, i) = exp (−(X (1, i) − Ex)ˆ2/(2*En_1ˆ2));
plot (X, Y, '*', 'MarkerEdgeColor', 'r', 'markersize', 4);
grid on;
end
```

Table 8. Subordinate status of sustainability level of evaluation factors at each level.

	Economic Sustainability	**Social Sustainability**	**Environmental Sustainability**
Excellent	0.00004	0	0.00003
Good	0.2782	0.0922	0.3376
Medium	0.4593	0.8082	0.4233
Bad	0.0044	0.0072	0.0038

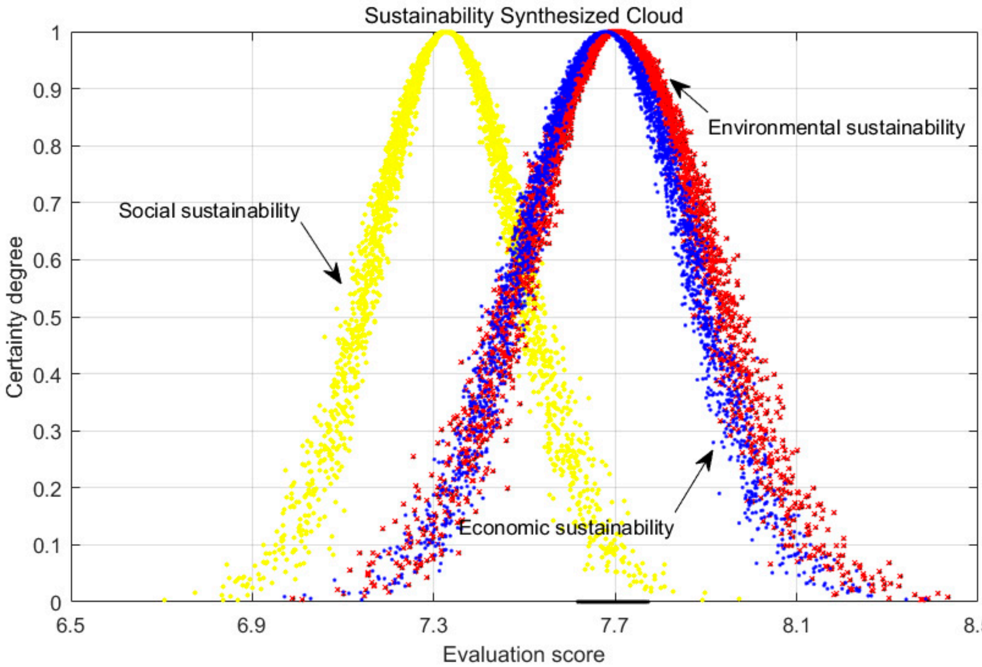

Figure 5. Sustainability synthesized cloud.

Using the Formula (12), the overall sustainability assessment of the project is as follows, as shown in Table 9:

Table 9. Overall project sustainability assessment results.

Sustainability Level	Excellent	Good	Medium	Bad
Degree of membership	0.00003	0.2756	0.59923	0.00544

The infrastructure project has the highest overall sustainability level of medium membership. However, the degree of its subordinate to good is also high, so its sustainability grade should be upper middle.

6. Discussion and Conclusions

Various initiatives in municipal infrastructure projects are having a negative impact on the goal of sustainable development. Nevertheless, these projects will continue to grow because they are essential for the economic, social, and environmental development of the country. Therefore, this study develops a comprehensive sustainability evaluation indicator system for the operational phase of municipal infrastructure projects that considers three aspects: environmental, economic, and social. This research proposes a novel hybrid evaluation method that combines cloud modeling theory with AHP and C-OWA operators to analyze and evaluate the sustainability of municipal infrastructure projects. As a result of this approach, the AHP method and the C-OWA operator are used to determine the weights of sustainability indicators and the aggregation of expert scoring intervals to eliminate the problems associated with randomness, ambiguity, and uncertainty in expert qualitative evaluations. The cloud model theory describes various attributes related to the sustainability of municipal infrastructure projects to measure the degree of uncertainty associated with such projects. By modifying the attribute values with penalty factors, this study proposes a cloud model-based evaluation method for the sustainability of municipal infrastructure projects, and then evaluates the overall sustainability of such projects. To demonstrate its feasibility, this paper illustrates the application of this evaluation system and strategy using the Second Ring Expressway Improvement Project in City A as an example. The indicator system proposed in this paper can facilitate a comprehensive analysis of the sustainability of municipal infrastructure in facility projects. In addition, it can help solve the problem of ambiguous expert scores due to different levels of knowledge and working experience, and effectively balance the different needs of quantitative and qualitative indicators. The final evaluation of the improved municipal infrastructure projects can also visualize environmental, economic, and social sustainability levels.

This research can be used as a reference for future municipal infrastructure projects in establishing sustainability evaluation and indicator systems. However, there are still some limitations. First, this paper attempts to assess the sustainability of municipal infrastructure projects from a macro perspective, so there is still room for further improvement in terms of specific indicators. In addition, the specific focus of sustainability assessment varies from country to country and region to region. Since this paper is conducted in the context of China, it is difficult to verify the extent of its evaluation methodology. Therefore, it is recommended that in future research, more attention should be paid to refining sustainability indicators for municipal infrastructure projects so that they can be more widely applied.

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