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Optimization Strategies for Waterfront Plant Landscapes in Traditional Villages: A Scenic Beauty Estimation–Entropy Weighting Method Analysis

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Abstract: This investigation delves into the waterfront plant landscapes of traditional villages in Western Hunan, China, aiming to bolster sustainable ecological resource management, amplify ecological culture, and ameliorate environmental standards. Furthermore, it endeavors to furnish a theoretical scaffold for the meticulous construction and assessment of these landscapes. This study has illustrated the waterfront botanical landscapes of 32 traditional hamlets within the Xiangxi region, integrating prior research on the waterfront botanical regression model based on the Scenic Beauty Estimation (SBE) method. It established and investigated fifteen landscape factors pivotal to the aesthetic valorization of these village waterfronts. The study concocted a beauty quality evaluation model, unearthing a significant correlation ($p < 0.01$) across evaluations by students majoring in landscape architecture, expert landscape architects, and laypersons, thus underscoring a consensus in aesthetic judgments. A noteworthy correlation between the beauty value (Z-value) and the entropy weight value was elucidated through the equation EWM = −0.106 + 0.425ZSBE, showcasing the landscape quality's variance among the studied villages. The formulated evaluation model accentuates the significance of seasonal variation, scale affinity, and a rich hierarchical structure.

Keywords: SBE-EEM method; entropy weight method; traditional village landscape; waterfront ecological design; plant community evaluation

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1. Introduction

Water is essential for sustaining life and shaping environments for humans, animals, and plants. In traditional villages, waterfront landscapes blend natural beauty with cultural heritage, encompassing riverbanks, water bodies, vegetation, wildlife, architecture, pathways, and communal spaces. These landscapes play a crucial role in defining the physical, ecological, cultural, and socioeconomic identity of villages. They foster ecological harmony and cultural identity, offering residents and visitors a sense of peace and belonging.

The study of landscape assessment, originating in the Western academic sphere since the 1960s, has evolved into a multidisciplinary field including landscape ecology, urban planning, aesthetic theory, and tourism studies. This discipline aims to provide a scientific basis for landscape management and decision making [1]. In China, scholarly interest in traditional villages and their landscapes surged in the 1980s amid rapid urbanization. By the late 1990s, these villages were recognized as repositories of ancestral wisdom and folk heritage, drawing public and academic attention.

Landscape assessment is crucial as it provides a structured approach to understanding and evaluating landscapes based on ecological, cultural, and aesthetic criteria [2,3]. It enables informed decision making in landscape management, urban planning, and conservation efforts, ensuring sustainable development while preserving the intrinsic values and functions of landscapes for current and future generations [4]. However, landscape is a multidimensional concept in which biotic and abiotic elements interact at different temporal and spatial scales to produce a wide variety of forms and contents, which makes landscape assessment exceptionally complex [5]. The assessment variables chosen in previous research usually reflect the perceptions and values of the stakeholders involved, and the models chosen are strictly dependent on the system being assessed and the objectives of the model itself [6]. Identifying a methodology that is suitable for all landscape assessment situations is therefore not always possible.

With this background, the assessment of waterfront botanical landscapes in traditional villages necessitates an inimitable approach to evaluating and weighing diverse criteria, a critical aspect of landscape analysis. This field has seen the development of various evaluative methodologies, ranging from the Scenic Beauty Estimation [7], semantic differential [8], and geographic information systems (GIS) [9,10] to more complex analytical frameworks like fuzzy comprehensive evaluation [11], principal component analysis [12], entropy weighting [13], spatial syntactic analysis [14], and the analytic hierarchy process [15]. Introduced by Daniel and Boster [16], the Scenic Beauty Estimation (SBE) method now forms the cornerstone of botanical landscape evaluation, facilitating the aesthetic evaluation of plant arrangements, the assessment of artificial wetland landscapes, and the detailed examination of waterfront scenes across a broad spectrum of environments, including parks, wilderness areas, urban spaces, residential areas, and traditional villages [17].

Illustratively, the study by Materia et al. [18] delves into the visual facets of landscape allure, harnessing the SBE method and colorimetric analyses to forge prognostic models [19]. Their inquiry probes the sway of landscape structural elements and chromatic factors on the visual allure of waterfront landscapes in the Moshan Scenic Area of Donghu Lake, Wuhan, unraveling the symbiotic interplay of these constituents. Analogously, endeavors span the ambit of artificial wetland parks and waterfront precincts. For instance, Stigsdotter et al. [20] leverage the precepts of the SBE method to erect an evaluative framework, qualitatively adjudicating the merits of botanical landscapes predicated on ecological and aesthetic paradigms. Furthermore, Osgood and Luria [21] undertake field surveys of botanical landscapes across 40 plots dispersed within ten waterfront parks in Nanjing. Grounded in images of 20 exemplar plots, their endeavor entails the dissection and quantification of five landscape facets—floral phenology coherence, chromatic congruity, stratum opulence, rhythmic cadences, and commensurate scale—culminating in the formulation of a model for assessing the scenic allure of riverside botanical communities in Nanjing.

Based on the above background, along with the proliferation of research on SBE, the application of the SBE method has been expanded and has been centered on the synergistic amalgamations of the SBE method with other methodologies, such as SBE-AHP [22], SBE-SD [23], SBE-GIS [24], SBE-VRM [25], SBE-PCA [26], SBE-LCJ [27], and SBE-CVM [28]. Entropy weighting emerges as an objective valuation modality for ascertaining the weightage of diverse indicators in holistic evaluations. While its nascent applications germinated in landscape ecology, entropy weighting has proliferated into diverse precincts of landscape assessment research. It finds resonance in urban planning, tourism strategizing, and agricultural landscape evaluations, facilitating multifaceted landscape assessments. As scholarly endeavors burgeon, a surfeit of scholars endeavors to synergize entropy weighting with other evaluation paradigms, augmenting the comprehensiveness and precision of evaluation outcomes. For instance, Batty [29] undertakes a holistic evaluation of urban thoroughfare landscapes through the prism of analytic hierarchy processes and entropy weighting methodologies [27]. Similarly, Brown and Daniel [30] harness entropy weighting in tandem with multi-tiered fuzzy evaluation techniques to undertake a comprehensive assessment of the ecological corridors of Sufeng Mountain on Dongshan Island, Fujian Province [31].

Concurrently, scholars have embarked on myriad inquiries into landscape assessment by marrying the SBE method with the EEM (Entropy Weighting Method). These scholarly inquiries pivot around landscape ecology, land use planning, and ecological environmental impact assessments [32]. Nonetheless, this amalgamated approach confronts a panoply of challenges and constraints in practical application, including the exigencies of data acquisition and processing, and the inherent subjectivity in delineating evaluation criteria and apportioning weights [33].

In contrast to the SBE method, which espouses precision albeit at the expense of adaptability in weight adjustments, the EEM method proffers superior adaptability by affording latitude for weight fine-tuning. Against this backdrop, the present study, centering on the waterfront botanical landscapes of 32 traditional hamlets within the Xiangxi region, interweaves antecedent research on the waterfront botanical regression model predicated on the SBE method. Specifically, the objectives of this study were threefold: first, to generate scenic beauty scores by having 158 evaluators scoring 32 plant communities along the waterfront in the Xiangxi region (a process based on 15 influencing factors); second, to establish a relational model correlating scenic beauty scores with various elemental factors; and third, to unravel the interplay between the waterfront botanical landscapes of traditional hamlets and an eclectic array of constituents based on the relationship model.

2. Materials and Methods

2.1. Study Area

The Xiangxi region, nestled in the northwest of Hunan Province, serves as a nexus point where Hunan, Hubei, Guizhou, and Chongqing converge (Figure 1). Geographically, its coordinates range from approximately 109°10′ to 110°22.5′ east longitude and 27°44.5′ to 29°38′ north latitude. Positioned at the intersection of the northeastern rim of the Yunnan–Guizhou Plateau and the western ridges of Hubei, this locale is typified by a subtropical mountainous monsoon climate. The region benefits from ample precipitation and temperate conditions, boasting average annual temperatures ranging from 15.8 °C to 16.9 °C and an average annual rainfall of 1300–1500 mm. The frost-free period occurs for 250–280 days annually. For our investigation, we selected 32 traditional villages, including Aimencun, Pinglangcun, and Liangdengcun, as focal points. These villages exhibit diverse waterfront landscapes, adorned with a rich array of flora comprising over 60 species, such as *Salix, Melia azedarach*, *Ginkgo biloba* L., *Celtis australis, Pterocarya stenoptera* C. DC, *Cinnamomum camphora* (L.) Presl., and *Sapium sebiferum* (L.) Roxb. The unique botanical profile of these villages epitomizes the waterfront landscape biodiversity prevalent in Hunan Province.

2.2. Scenic Beauty Estimation (SBE) Method

2.2.1. Photography

To capture the breadth of seasonal lake vistas, photography sessions were meticulously planned between April 2022 and April 2023, during optimal daylight hours of 8:30–11:30 AM and 2:30–5:30 PM. Preference was given to periods characterized by clear skies and optimal visibility. Considering the human eye's discernment capacity within a 25-m range, landscape features within this vicinity are particularly striking. Furthermore, the human eye's panoramic field of view, estimated at 220°, guided our sampling grid's dimensions, set at 2 × 25 m to yield plots measuring 50 m by 50 m. A total of 5216 photographs capturing waterfront landscapes were meticulously archived, serving as a foundational dataset. Stringent selection criteria were subsequently applied to ensure the representation of each village's botanical diversity. Thirty-two sets of photographs depicting distinctive plant community patterns were curated, meticulously capturing scenes from all cardinal directions. Digital cameras (Fujifilm Group, Suzhou, China), positioned at a height of 1.6 m, were systematically numbered and subjected to evaluation by diverse evaluators [34].

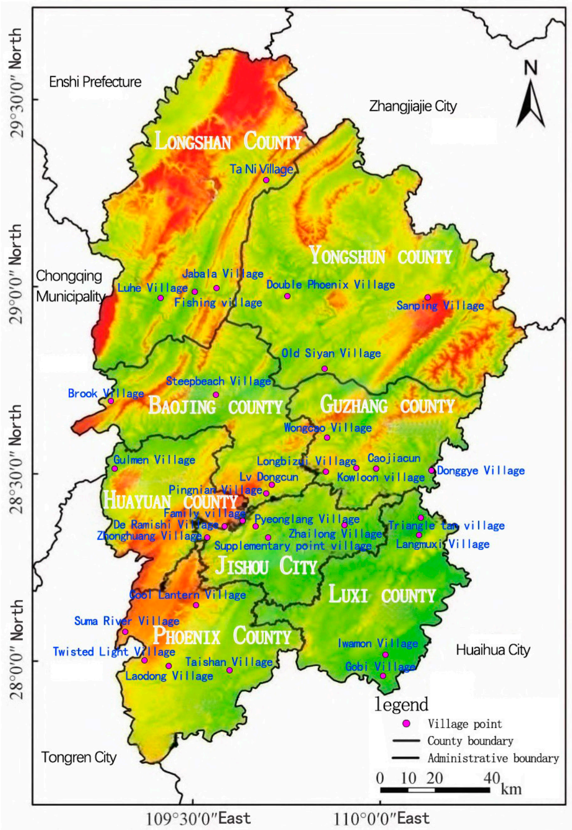

Figure 1. Study sample distribution.

2.2.2. Evaluators

A cohort of 158 evaluators participated in this comprehensive assessment. This cohort comprised 96 landscape architecture students, 12 landscape architecture experts, and 50 individuals from diverse disciplinary backgrounds (encompassing professionals from fields such as urban planning, environmental science, geography, sociology, and others related to the study of landscapes), aged between 18 and 55 years. These evaluators were selected based on their expertise and professional experience relevant to landscape assessment, ensuring a broad spectrum of perspectives. Evaluators were selected based on proficiency in landscape evaluation methodologies, demonstrating expertise through professional experience or academic specialization, and all had normal or corrected-to-normal vision to ensure accurate visual assessment during the evaluation process.

2.2.3. Evaluation Method

Drawing from prior research by Wen and Burley [35], Jiang and Sun [36], Zhang et al. [37], and others, we formulated a classification system to assess waterfront botanical landscape photographs of traditional villages. This system comprises 15 influencing factors detailed in Table 1, encapsulating diverse aspects such as indigenous tree species, biodiversity, vertical stratification, planting density, shoreland landscapes, symbiosis, and harmony. Evaluators accessed the official website of traditional villages, utilizing the "720 Cloud" panoramic platform to rate waterfront landscape photographs within a 30 s viewing window. Evaluation criteria ranged from −3 (extremely poor) to 3 (excellent), facilitating the assessment of public aesthetic preferences and generating scenic beauty scores (Z-values). Subsequently, the waterfront botanical landscape was deconstructed into elemental components, with quantitative measurements obtained for each factor. Leveraging SPSS 22.0, we established a relational model correlating scenic beauty scores with various elemental factors.

$$Z_{ij} = \left(R_{ij} - \overline{R_j}\right) / S_j \quad (1)$$

$$Z_i = \sum_j Z_{ij} / N_j \quad (2)$$

Z_{ij} represents the standardized value of observer j's evaluation of scene i; R_{ij} represents the evaluation score provided by observer j for scene i; j represents the mean of all evaluation scores provided by observer i; S_j denotes the standard deviation of all evaluation scores provided by observer j; Z_i signifies the standardized score of scenes i; N_j denotes the total number of observers.

Table 1. Decomposition of landscape elements of traditional village waterfront plants.

Classification of Common Factors	Code Name	Elements	Category						
			1	2	3	4	5	6	7
Ecological factors	A1	Native tree species	1 species	2~3 species	4~5 species	6~7 species	8~10 species	11~12 species	More than 13 species
	A2	Species diversity	1 species	2~3 species	4~5 species	6~7 species	8~10 species	11~12 species	More than 13 species
	A3	Rich in layers	1 floor	2 floors	3 floors	Above 3 floors			
	A4	Planting density	<0.1	0.1~0.2	0.2~0.3	0.3~0.4	0.4~0.5	0.5~0.6	>0.6
	A5	Revetment landscape	Extremely stiff	Very stiff	Stiff	General	Natural	Very natural	Extremely natural
Elements of art	B1	Harmonious coexistence	Extremely bad	Very bad	Bad	General	Good	Very good	Excellent
	B2	Artistic composition	Concise	Complete	Equilibrium				
	B3	Both the real and the virtual are born together	Extremely bad	Very bad	Bad	General	Good	Very good	Excellent
	B4	Seasonal phase change	Color number 1	Color number 2	Color number 3	More than 3 kinds of color			
	B5	Green rate	<1/3	1/3~2/3	>2/3				
Functional elements	C1	Anti-jamming capability	Extremely bad	Very bad	Bad	General	Good	Very good	Excellent
	C2	Wide field of vision	Closed	Semi-open	Open				
	C3	Scale affinity	Extremely bad	Very bad	Bad	General	Good	Very good	Excellent
	C4	Accessibility	Extremely bad	Very bad	Bad	General	Good	Very good	Excellent
	C5	Degree of residence	Extremely bad	Very bad	Bad	General	Good	Very good	Excellent

2.3. *Entropy Weighting Method (EEM)*

The entropy weighting method is an objective approach for assigning weights to various indicators in comprehensive evaluations [38]. The following steps outline the process of entropy weighting:

(1) Data Normalization: normalize the data for each indicator to ensure that all indicator values fall within the range of 0 to 1.

(2) Calculate the weight of the *j*th indicator for the *i*th user:

$$y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \quad (3)$$

$$e_j = -K\sum_{i=1}^{m} y_{ij} \ln y_{ij} \quad (4)$$

where m denotes the number of indicators, K represents a constant, and y_{ij} signifies the normalized data for the *i*th indicator.

$$K = \frac{1}{lnm} \quad (5)$$

(3) Compute the information entropy for the jth indicator.
(4) Determine the weight of the *j*th indicator.

$$w_j = \frac{1 - e_j}{\sum_j 1 - e_j} \quad (6)$$

In this process, each indicator's weight is determined based on its contribution to the overall assessment, considering the normalized data and information entropy.

3. Results and Discussion

3.1. Scenic Beauty Estimation (SBE) Method Analysis

3.1.1. Comprehensive Evaluation Analysis

An in-depth examination of the scenic beauty values depicted in Table 2 unveils a prevailing tendency towards the lower end of the spectrum. Notably, 9 groups exhibit negative Z-values, while 23 groups showcase positive Z-values. The mean Z-value for scenic beauty, calculated at 0.048, suggests a moderate quality attributed to the waterfront botanical landscapes spanning the 32 traditional villages within the Xiangxi region. This trend is largely attributed to the prevalence of monoculture among plant species, with indigenous varieties such as *Salix, Pterocarya stenoptera* C. DC, *Cinnamomum camphora* (L.) Presl., and *Sapium sebiferum* (L.) Roxb dominating the landscape, while the incorporation of exotic species remains limited. Furthermore, the juxtaposition lacks emphasis on crucial contrasts such as evergreen versus deciduous foliage, needleleaf versus broadleaf specimens, plant coloration, and planting density.

The analysis of student and expert rating datasets reveals landscape architecture experts and students did not exhibit obvious differences in their evaluation outcomes. Evaluators shared a predilection towards photographs depicting richer plant community compositions, as well as heightened ratings for images featuring flowering species, vibrant foliage, and a harmonious blend of aquatic and terrestrial flora. Conversely, images showcasing solitary or underperforming plants garnered lower ratings. For instance, the penultimate ranked group, D1, registering a Z-value of −0.136, exhibits monotonous plant arrangements, severe pest infestation affecting *Salix* and *Rhododendron pulchrum* Swee, lifeless hardened embankments, and poor waterfront accessibility. Similarly, the third-lowest ranked group, D27, with a Z-value of −0.120, features underperforming *Pterocarya stenoptera* C. DC, a lakeside barrier of green wire mesh fencing, pronounced human disturbances, and severe water pollution. The aquatic plants of *Miscanthus sinensis cv.* withered badly, with bare patches in surrounding plant lawns. Thus, both students and experts favor the amalgamation of diverse woody, shrubby, and herbaceous species in plant communities. This unanimity may be due to the comprehensive training and academic curriculum that both groups undergo, which equips students with knowledge and skills comparable to those of experienced professionals in landscape assessment [39,40].

Regarding group D2, comprising photographs showcasing a composition of *Metasequoia glyptostroboides* Hu & W. C. Cheng, *Cinnamomum camphora* (L.) Presl., *Paulownia, Pinus massoniana* Lamb, *Phoebe zhennan* S. Lee, *Indocalamus tessellatus* (Munro) Keng f., *Cortaderia selloana,* and *Jasminum mesnyi* Hance, experts generally appreciate the presence of evergreen *Cinnamomum camphora* (L.) XWPresl. and *Phoebe zhennan* S. Lee, evergreen *Pinus massoniana* Lamb., deciduous flowering *Paulownia*, year-round green *Indocalamus tessellatus* (Munro) Keng f., and the yellow-flowered *Jasminum mesnyi* Hance along with shallow-water or wetland *Cortaderia selloana*. However, other landscape architecture students also rated these images relatively low. This underscores the existence of certain subjectivity and bias within the SBE method. It is plausible that the winter season during photography resulted in plant desiccation, thereby affecting the visual appeal and subsequently influencing the score assessments.

Table 2. Analysis of the composition of the tested plant community and the value of landscape beauty and entropy weight.

Community Vertical Structure Type	NO.	Plant Configuration Structure Composition Name	Growth	Scenic Value	Entropy Weight	Results	Ranking
Tree brush grass	D8	*Pterocarya stenoptera* C. DC + *Melia azedarach* + *Osmanthus fragrans var. semperflorens* + *Sapium sebiferum* (L.) Roxb + *Podocarpus macrophyllus* (Thunb.) D. Don + *Musa basjoo* Siebold + *Yulania liliiflora* Desr. + *Cerasus* sp. + *Cercis chinensis* Bunge + *Chaenomeles speciosa* (Sweet) Nakai + *Rhododendron pulchrum* Sweet + *Pittosporum tobira* (Thunb.) W. T. Aiton + *Camellia japonica* L. + *Salvia leucantha* + *Nandina domestica* Thunb. + *Cyperus involucratus* Rottb. + *Festuca elata* Keng ex E. B. Alexeev.	Exuberant	0.265	0.732	Excellent	1
	D4	*Sapium sebiferum* (L.) Roxb + *Acer palmatum* Thunb. in Murray + *Cyperus involucratus* Rottbo + *Ruellia simplex* + *Thalia dealbata* Fraser + *Oenanthe javanica* (Blume) DC. + *Petunia hybrida* (Hook.) E. Vilm. + *Vinca major* Linn. + *Variegata Loud* + *Lonicera japonica* Thunb. + *Arundo donax var. Versiocolor Stokes* + *Phalaris arundinacea* Linn. + *Iris tectorum* Maxim. + *Euphorbia humifusa* Willd. ex Schlecht.	Good	0.131	0.564	Very good	6
	D16	*Koelreuteria elegans* + *Sapium sebiferum* (L.) Roxb + *Sapindus mukorossi* Gaertn. + *Magnolia Grandiflora* Linn. + *Cinnamomum camphora* (L.) Presl. + *Hibiscus mutabilis* Linn. + *Nerium indicum* Mill + *Rosa chinensis* Jacq. + *Gardenia jasminoides* J. Ellis + *Camellia japonica* L. + *Liriope platyphylla* Wang et Tang + *Festuca elata* Keng ex E. B. Alexeev	Exuberant	0.189	0.583	Very good	4
	D18	*Pterocarya stenoptera* C. DC + *Muehlenbeckia complexa* Meisn. + *Ligustrum lucidum* + *Ginkgo biloba* L. + *Rhododendronsimsii&R* + *Osmanthus* sp. + *Hedera nepalensis var. sinensis* (Tobl.) Rehd + *Dianthus chinensis* L. + *Populus nigra* L. + *Citrus maxima* (Burm.) Merr. cv. Jiangyong Yu + *Punica granatum* L. + *Populus davidiana* Dode + *Pelargonium hortorum* L. H. Bailey + *Ceratostigma plumbaginoides* + *Ophiopogon bodinieri* Levl. + *Liriope platyphylla* (Decne.) L. H. Bailey	Good	0.125	0.506	Very good	8
	D6	*Catalpa speciosa* (Barney) Engelm + *Eucalyptus robusta* Smith + *Cinnamomum zeylanicum* + *Phyllostachys nigra* (Lodd. ex Lindl.) Munro + *Livistona chinensis* (Jacq.) R. Br. + *Pterocarya stenoptera* C. DC + *Distylium racemosum* Sieb. et Zucc. + *ephyranthescandida*	Good	0.043	0.422	Good	17
	D5	*Pterocarya stenoptera* C. DC + *Broussonetia papyrifera* + *Melia azedarach* L. + *Pteroceltis tatarinowii* Maxim. + *Nandina domestica* Thunb. + *Morus nigra* L. + *Osmanthus* sp. + *Mucunapruriens* (L.) DC. + *Sabina chinensis* (L.) Ant. + *Clematis acerifolia* + *Celtis australis* + *Mallotus repandus* + *Paulownia tomentosa* + *Senna bicapsularis* + *Bambusa vulgaris* + *Nephrolepis cordifolia*	Good	0.059	0.448	Good	14

Table 2. *Cont.*

Community Vertical Structure Type	NO.	Plant Configuration Structure Composition Name	Growth	Scenic Value	Entropy Weight	Results	Ranking
Tree brush grass	D3	*Elaeocarpus sylvestris* + *Celtis sinensis* + *Magnolia liliiflora* Desr. + *Cinnamomum camphora* (L.) Presl. + *Ginkgo biloba* L. + *Ligustrum×vicaryi* Rehder + *Isodon rubescens*	General	−0.048	0.097	Very bad	27
	D29	*Populus tomentosa* Carr + *Pterocarya stenoptera* C. DC + *Ligustrum lucidum* + *Platanus acerifolia* + *Ginkgo biloba* L. + *Dendrocalamus latiflorus* Munro + *Lycium chinense* Miller + *Photinia serrulata* Lindl. + *Loropetalum chinense* (R. Br.) Oliv.	Exuberant	0.199	0.685	Very good	3
	D10	*Salix* + *Loropetalum chinense* (R. Br.) Oliv. + *Ligustrumquihoui* Carr + *Festuca elata* Keng ex E. B. Alexeev	General	−0.054	0.012	Bad	28
	D9	*Pterocarya stenoptera* C. DC + *Davidia involucrata* Baill. + *Acer negundo* L. + *Acacia dealbata* Link + *Aruncus sylvester* Kostel. + *Cyperus involucratus* Rottboll	General	−0.046	0.081	Bad	25
	D1	*Salix babylonica* + *Sapium sebiferum* (L.) Roxb + *Rhododendron pulchrum* Sweet + *Iris tectorum* Maxim.	General	−0.136	0.032	Very bad	31
	D25	*Yulania×soulangeana* (Soul.-Bod.) D. L. Fu + *Prunus cerasifera* Ehrhar f. + *Amygdalus persica* L. + *Gardenia jasminoides* Ellis + *Ligustrum×vicaryi* Rehder + *Festuca elata* Keng ex E. B. Alexeev	Good	0.079	0.463	Very good	12
	D24	*Cryptomeria fortunei* Hooibrenk + *Michelia figo* (Lour.) Spreng + *Canna indica* + *Ilex crenata cv. Convexa* Makino	Good	0.026	0.325	General	20
	D30	*Sapium sebiferum* (L.) Roxb + *Urtica fissa* E.Pritz. + *Cinnamomum camphora* (L.) Presl. + *Oreocnide frutescens* (Thunb.) Miq. + *Streblus asper* Lour. + *Debregeasia orientalis* C.J.Chen + *Cinnamomum zeylanicum*	Good	0.039	0.457	General	19
Joe Grass	D17	*Magnolia Grandiflora* Linn. + *Salix* + *Magnolia liliflora* Desr + *Cerasus* sp. + *Lagerstroemia indica* L. + *Osmanthus* sp. + *Prunuspseudocerasus* + *Rhododendron pulchrum* + *Ligustrum lucidum* + *Loropetalum chinense var. rubrum* + *Buxus sinica*	Exuberant	0.254	0.680	Very good	2
	D26	*Cinnamomum camphora* (L.) Presl. + *Photinia serrulata Lindl.* + *Catalpa ovata* G.Don + *Melia azedarach* + *Pterocarya stenoptera* C. DC + *Metasequoia glyptostroboides* Hu & W. C. Cheng + *Catalpa speciosa* (Barney) Engelm + *Dendrocalamus latiflorus* Munro + *Sambucus chinensis* Lindl.	Good	0.024	0.389	Good	21
	D11	*Dendrocalamus latiflorus* Munro + *Pterocarya stenoptera* C. DC + *Broussonetia papyrifera* + *Cercis chinensis* Bunge + *Hymenocallis littoralis* (Jacq.) Scalisb. + *Spiraea thunbergii* Bl. + *Mikania micrantha* Kunth + *Polypogon fugax* Nees ex Steud. + *Ophiopogon bodinieri* Levl. + *Scilla scilloides* (Lindl.) Druce + *Reineckia carnea* (Andr.) Kunth + *Fatsia japonica* (Thunb.) Decne. et Planch + *Jasminum mesnyi* Hance + *Liriope platyphylla* Wang et Tang + *Nandina domestica* Thunb.	Good	0.018	0.409	Good	22

Table 2. *Cont.*

Community Vertical Structure Type	NO.	Plant Configuration Structure Composition Name	Growth	Scenic Value	Entropy Weight	Results	Ranking
Joe Grass	D20	*Pterocarya stenoptera* C. DC + *Celtis australis* + *Jasminum mesnyi* Hance + *Euryops pectinatus* + *Spiraea japonica* L. f. + *Nephrolepis exaltata var.* Bostoniens (L.) Darenport + *Salvia leucantha*	Good	0.089	0.435	Good	11
	D28	*Ginkgo biloba* L. + *Liquidambar formosana* + *Taxodium distichum* (L.) Rich. + *Rhododendronsimsii&R* + *Iris tectorum* Maxim. + *Puerariae Lobatae Radix*	General	0.101	0.264	General	10
	D2	*Metasequoia glyptostroboides* Hu & W. C. Cheng + *Cinnamomum camphora* (L.) Presl. + *Paulownia* + *Pinus massoniana* Lamb. + *Phoebe zhennan* S. Lee + *Indocalamus tessellatus* (Munro) Keng f. + *Cortaderia selloana* + *Jasminum mesnyi* Hance	General	−0.047	0.051	Bad	26
	D13	*Cinnamomum camphora* (L.) Presl. + *Pistacia chinensis* Bunge + *Pteris semipinnata* L. Sp.	Good	0.073	0.423	Very good	13
	D22	*Pterocarya stenoptera* C. DC + *Elaeocarpus sylvestris* + *Salix* + *Melia azedarach* + *Zoysia tenuifolia* Willd. ex Trin.	Bad	−0.032	0.016	Bad	24
	D19	*Celtis australis* + *Artemisia sylvatica* + *Pinellia ternata* (Thunb.) Breit. + *Pteris multifida* Poir.	Bad	−0.141	0.074	Bad	32
	D27	*Pterocarya stenoptera* C. DC + *Miscanthus sinensis cv.* + *Oxalis corymbosa* DC.	Bad	−0.120	0.062	Bad	30
	D12	*Pterocarya stenoptera* C. DC + *Picea asperata mast* + *Platanus wrightii* + *Dendrocalamus latiflorus* Munro + *Broussonetia papyrifera* + *Setaria viridis* (L.) Beauv.	Good	0.040	0.451	Good	18
	D31	*Fraxinus excelsior* + *Amygdalus persica* (L.) Batsch + *Iris japonica* Thunb.	General	0.010	0.298	General	23
	D7	*Quercus palustris* Muench. + *Pterocarya stenoptera* C. DC + *Robinia pseudoacacia* L. + *C. florida*	Good	0.114	0.478	Good	9
Shrub and grass	D21	*Acer palmatum* Thunb. + *Hosta plantaginea* (Lam.) Aschers. + *Hydrangea macrophylla* + *Ligustrumquihoui* Carr + *Chlorophytum comosum* (Thunb.) Jacques + *Camellia oleifera* Abel. + *Nandina domestica* Thunb. + *O. gratissimum var. gratissimum* + *Tagetes erecta* L. + *Mentha spicata*	Good	0.149	0.604	Very good	5
	D15	*Campsis radicans* (L.) Seem + *Euphorbia humifusa* Willd. ex Schlecht. + *Jasminum mesnyi* Hance + *Dianthusbarbatus* + *Mentha spicata* + *Catharanthus roseus* (L.) G. Don + *Acorus tatarinowii* + *Glandularia tenera* (Spreng.) Cabrera + *Ceratostigma plumbaginoides* + *Salvia leucantha* + *Rosa multiflora* Thunb.	Good	0.058	0.501	Good	15
	D14	*Ailanthus altissima* (Mill.) Swingle + *Melia azedarach* + *Salix alba* L. + *Euphorbia humifusa* Willd. ex Schlecht. + *Fallopia multiflora* (Thunb.) Harald	Good	0.045	0.489	Good	16
	D23	*Taxodium ascendens* Brongn. + *Salix* + *Cinnamomum camphora* (L.) Presl. + *Eichhorniacrassipes*	General	−0.089	0.022	Very bad	29
The grass	D32	*Ruellia simplex* + *Canna glauca* L. + *Cyperus involucratus* Rottboll + *Hedera nepalensis var. sinensis* (Tobl.) Rehd + *Jasminum nudiflorum* + *Pontederia cordata* L. + *Rosa chinensis* Jacq. + *Epipremnum aureum* + *Iris pseudacorus* L.	Exuberant	0.127	0.596	Very good	7

3.1.2. Threshold (Critical Value) Analysis

Minimum Value: The scenic beauty value ranking last is D19, with a scenic beauty Z-value of −0.141. The water surface is covered with green *Hydrilla verticillata* (L. f.) Royle, *Spirulina,* and *Chlorella* species, emitting a foul odor, indicative of severe eutrophication. Additionally, there are electric poles nearby, and the area is overrun with weeds.

Maximum Value: The scenic beauty value ranking first is D8, with a scenic beauty Z-value of 0.265. This site boasts a diverse array of natural woody, shrubby, climbing, and herbaceous plant communities, focusing on their variety, structure, hierarchy, and appearance. Emphasis is placed on seasonal changes, with flowering plants such as *Magnolia liliiflora* Desr., *Cerasus* sp., *Cercis chinensis* Bunge, *Chaenomeles speciosa* (Sweet) Nakai, and *Rhododendron pulchrum* Sweet blooming in spring, while plants for autumn viewing include *Osmanthus fragrans var. Semperflorens*, *Sapium sebiferum* (L.) Roxb, *Nandina domestica* Thunb., and *Salvia leucantha*. Attention is paid to the morphology, color, charm, and fragrance of each plant material.

3.1.3. Inter-Judge Correlation Analysis in Scoring

Utilizing one-way analysis of variance, it becomes evident that, within the landscape architecture expert group, landscape architecture major student group, and non-landscape architecture major student group, when $p < 0.01$, the correlation among these three groups of judges is exceptionally significant. Hence, it is discernible that the scoring results among the judges are effective, indicating a commendable consistency in the evaluation of waterfront botanical landscapes in traditional villages across different demographics. This coherence aptly reflects the scenic beauty characteristics of the study area. Comparatively, when juxtaposed with the landscape architecture expert group as the benchmark, the landscape architecture major student group exhibits the highest scores, indicating a stronger correlation.

3.2. Analysis of Evaluation Results Using the EMM and Correlative Examination of SBE and EEM Evaluation Outcomes

Upon meticulous examination of the tabulated data in Table 2, it becomes apparent that the pinnacle of entropy weight is epitomized by D8, boasting a formidable 0.732, while the nadir is represented by D10, meagerly registering at 0.012. This hierarchical ranking of waterfront botanical landscape excellence across the traditional villages of the Xiangxi region unfolds as follows, cascading from the zenith to the nadir: D8 > D29 > D17 > D21 > D32 > D16 > D4 > D18 > D15 > D14 > D7 > D25 > D30 > D12 > D5 > D20 > D13 > D6 > D11 > D26 > D24 > D31 > D28 > D3 > D9 > D19 > D27 > D15 > D1 > D23 > D22 > D10. The congruence of these findings with those derived from the SBE methodology accentuates the practical viability and methodological coherence of employing the entropy weight approach in landscape assessment endeavors. Furthermore, it elucidates the intrinsic subjectivity entrenched within the SBE paradigm.

A meticulous amalgamation of the 32 distinct photographic sets unfurls discernible botanical motifs adorning the waterfront vistas of traditional villages. These encompass a myriad of arrangements including arboreal-shrub-herb, arboreal-herb, and shrub-herb compositions, interwoven with corresponding scenic beauty values (Z) and botanical community designations, meticulously detailed in Table 2. Remarkably, the scenic beauty values (Z) span the spectrum from −0.141 to 0.265, while the entropy weights traverse the range from 0.012 to 0.732, as artistically depicted in Figure 2. Evidently, a cogent correlation emerges between diminished scenic beauty values (Z) and proportionately reduced entropy weights. Regression analysis divulges an R^2 value of 0.035, surpassing the critical threshold of 0.3, thereby validating the explanatory prowess of the independent variables, elucidating 35% of the variance in the dependent variable. The Durbin–Watson statistic, perched at 1.906, nestles within the coveted confines of 1.5 to 2.5, approximating the ideal at 2, emblematic of optimal statistical conditions. Moreover, the regression standardized residuals flaunt a Gaussian distribution, emblematic of the normalized comportment of the sample data.

Subsequently, the rigorous scrutiny of questionnaire data ensued, meticulously scrutinizing the instrument's efficacy. The Kaiser–Meyer–Olkin (KMO) coefficient of 0.805 transcends the requisite threshold of 0.7, bolstered by a statistically significant value of 0.000, unequivocally affirming the instrument's robust reliability in assessing the quality of waterfront botanical landscapes in traditional village settings [41,42]. This robust validation underpins the aptitude of the dataset for incisive factor analysis. Linear regression analysis unveils the compelling equation of EWM = −0.106 + 0.425ZSBE, emblematic of a resolute nexus between the two methodological paradigms.

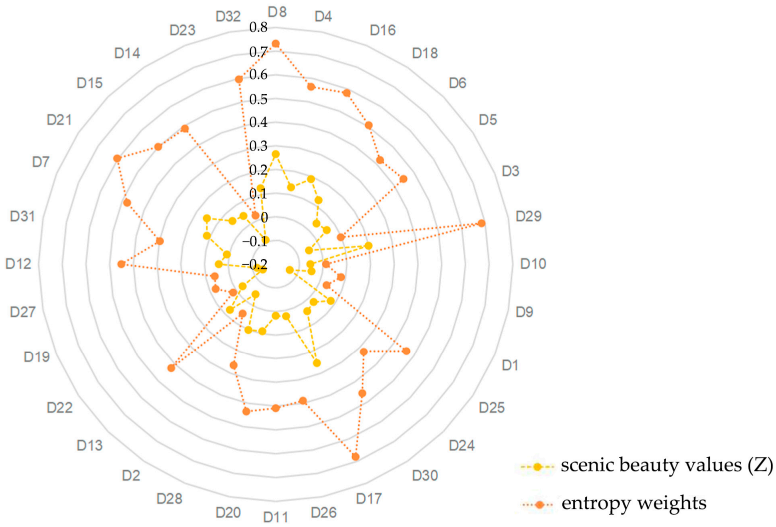

Figure 2. Comparison of degree distribution value and entropy weight value of scenic beauty in plant communities.

3.3. Factor Analysis of Common Factors

Regression analysis in Table 3 reveals that multicollinearity statistics exhibit VIF < 5, indicating the absence of multicollinearity among the independent variables. Simultaneously, factors such as species diversity, hierarchical richness, planting density, embankment landscapes, symbiotic harmony, artistic composition, interplay of reality and illusion, seasonal variations, green view ratio, disturbance resilience, expansive views, scale affinity, and stayability demonstrate significant prominence (Sig.F < 0.05), implying notable differences and the genuine efficacy of the regression equation.

Within the non-standardized coefficient B values, seasonal variations (0.045) surpass scale affinity (0.044), hierarchical richness (0.036), disturbance resilience (0.030), embankment landscapes (0.025), expansive views (0.023), green view ratio (0.013), species diversity (0.012), symbiotic harmony (−0.028), and stayability (−0.032), with artistic composition (−0.037) and interplay of reality and illusion (−0.042) exhibiting the lowest values (Table 3). This elucidates that seasonal variations, scale affinity, hierarchical richness, disturbance resilience, embankment landscapes, and expansive views receive higher ratings from both students and experts, subtly reflecting their profound emphasis on botanical color, seasonal changes, plant diversity, hierarchical structure, and spatial coherence in waterfront spaces.

For the non-standardized coefficient B values of indigenous tree species (Sig.F = 0.208) and accessibility (Sig.F = 0.462) exceeding 0.05, the differences are insignificant, indicating that students and experts do not exhibit a bias towards engaging within the interior of waterfront botanical landscapes. However, for indigenous tree species, while other major students tend to assign lower scores, experts demonstrate consistency, which is reasonable and justified. Nevertheless, experts universally acknowledge the pivotal role of indigenous tree species in waterfront botanical landscapes, emphasizing their significance [43]. Therefore, in accordance with the data presented in Table 3, a regression model was developed to assess the scenic beauty of waterfront botanical landscapes in traditional villages within the Xiangxi region. Employing SPSS 22.0, the raw data pertaining to 15 influential factors were subjected to analysis. Factors exhibiting a significance level (Sig.F) greater than 0.05 were excluded from the model, while those with a Sig.F less than 0.05 were retained. Thus, the constructed model, denoted as ZSBE, is expressed as follows: ZSBE = 0.072 + 0.012A1 + 0.036A2 − 0.053A3 + 0.025A4 − 0.028A5 − 0.037B1 − 0.042B2 + 0.045B3 + 0.013B4 + 0.030C1 + 0.023C2 + 0.044C3 − 0.032C4.

Table 3. Coefficients.

Models		Non-Standardized Coefficients		Significance	Entropy Weight
		B	Standard Error		
1	(constant)	0.072	0.346	0.834	
Ecological elements	Species diversity	0.012	0.008	0.018	0.274
	Rich in layers	0.036	0.009	0.000	0.301
	Planting density	−0.053	0.010	0.000	0.014
	Revetment landscape	0.025	0.009	0.005	0.216
	Harmonious coexistence	−0.028	0.009	0.001	0.066
Artistic elements	Artistic composition	−0.037	0.009	0.000	0.010
	Both the real and the virtual are born together	−0.042	0.010	0.000	0.039
	Seasonal phase change	0.045	0.010	0.000	0.352
	Green rate	0.013	0.011	0.028	0.104
Functional elements	Anti-jamming capability	0.030	0.013	0.037	0.222
	Wide field of vision	0.023	0.009	0.006	0.287
	Scale affinity	0.044	0.010	0.000	0.343
	Degree of residence	−0.032	0.009	0.000	0.021

Notably, the model demonstrates significant consistency in scale affinity with the findings of John et al. [14] regarding scale appropriateness. Similarly, the model's demonstration of species diversity aligns with Sun et al.'s [24] study on plant diversity. Additionally, the model's findings on embankment landscapes and symbiotic harmony correspond to Calvin et al.'s [22] research on waterfront landscapes and the overall environmental harmony. Furthermore, the model's findings on seasonal variations resonate with Ohta [44] exploration of the quantity of ornamental colors.

Moreover, as per Table 3, symbiotic harmony, stayability, artistic composition, and interplay of reality and illusion exhibit negative values, indicating their significant adverse impact on scenic beauty.

The coefficient value of symbiotic harmony is −0.028, with $p = 0.001$, signifying negative significance. This is attributed to the lack of emphasis on water landscape management and plant maintenance in traditional villages, coupled with limited investment, resulting in scarce lakeside vegetation, malodorous water bodies, exposed plants, and even local soil erosion [45]. In some areas, due to anthropogenic intervention or natural succession, waterfront plant communities may trend towards singularity.

The coefficient value of stayability is −0.032, with $p = 0.000$, demonstrating negative significance. Certain waterfront botanical landscapes in traditional villages may be situated in remote areas with poor road conditions or a lack of clear traffic indicators, making it challenging for tourists to reach these sites. Additionally, certain waterfront areas may pose safety hazards, such as slippery surfaces or unstable riverbanks, affecting tourists' sense of safety and willingness to stay.

The coefficient value of artistic composition is −0.037, with $p = 0.000$, indicating negative significance. The artistic composition of some waterfront botanical landscapes in traditional villages lacks a sense of overall design. Plant selection and arrangement may not be systematically planned, resulting in a disorderly and unstructured landscape lacking hierarchy and aesthetic appeal [46]. Additionally, the disregard for the relationship between plants and elements such as water bodies, skies, and surrounding architecture leads to a flat and lackluster composition, devoid of depth and dimension. Furthermore, the presence of nearby modern buildings and objects such as high-voltage lines affect the overall visual impression. Therefore, if the landscape quality of traditional villages needs to be improved, the stewardship of waterfront water bodies needs to be elevated, and this entails meticulous tasks such as the eradication of overgrown vegetation, dead trees, and invasive weeds, alongside strategic replanting or reconfiguration of flora across diverse functional zones. This endeavor seeks to restore community cohesion while augmenting botanical diversity [47,48]. Varied planting schemes, encompassing combinations like camphor trees paired with *Scirpust-abernaemontani*, *Cerasus* sp., and *Phyllostachys heteroclada* Oliv. alongside *Pontederia cordata* L., *Phyllostachys heteroclada* Oliver, and *Mangrove*, orchestrate a harmonious symphony of biodiversity. Concomitantly, initiatives aimed at abating pollution and ameliorating water quality are paramount. Efforts must be directed towards harmonizing arboreal, shrub, and herbaceous elements, with due consideration to the integration of indigenous tree species and the optimization of the green view ratio to seamlessly blend verdant landscapes with village environs.

The coefficient value of interplay of reality and illusion is −0.042, with $p = 0.000$, demonstrating negative significance. Some waterfront botanical landscapes in traditional villages exhibit a lack of harmony with surrounding architectural and environmental elements, disrupting overall harmony. Moreover, inappropriate plants in terms of form, color, and texture may lead to overly dense or sparse plant arrangements, making it challenging to create an ideal interplay of reality and illusion.

According to Zube and Sell [49] and Choumert and Cormier [50], it is suggested that the extracted principal components should cumulatively explain 60% to 70% of the data variance. Therefore, by rotating the principal component factor loading matrix, three principal components were extracted (Table 4), with a cumulative variance contribution rate based on eigenvalues exceeding 1 reaching 83.065% > 60%, and three principal components were named accordingly. Factor 1, representing ecological elements, embodies the ecological benefits, stability, resilience, and landscape effects of the waterfront landscapes in traditional villages, thus named ecological elements. Factor 2, reflecting artistic elements, encapsulates the form and distribution of plants, spatial depth, dynamic aesthetics, varied emotions, and thoughts, hence named artistic elements. Factor 3, primarily mirroring functional elements, portrays the complexity, uncertainty, openness, permeability, coordination, and comfort of waterfront environments, thus named functional elements. Within ecological elements, hierarchical richness, embankment landscapes, and species diversity exert a higher influence on the quality of waterfront botanical landscapes in traditional villages. This underscores people's emphasis on the diversity and richness of plant species, as well as the ecological stability and aesthetics of plant landscapes. Within artistic elements, seasonal variations and green view ratio exert a greater influence on the quality of waterfront botanical landscapes in traditional villages, reflecting people's focus on the comfort and impact brought by flowering in spring, lushness in summer, color change in autumn, and leaf fall in winter. Within functional elements, scale affinity, expansive views, disturbance resilience, and stayability exert a greater influence on the quality of waterfront botanical landscapes in traditional villages, highlighting people's emphasis on the visual effects and comfort of waterfront plant landscapes and the scenic beauty of landscapes. Additionally, as per Table 3, in the evaluation system of waterfront botanical landscapes in traditional villages in Xiangxi region, the entropy weight is largest for ecological elements (0.873) > functional elements (0.871) > artistic elements (0.505).

Table 4. Component matrix after rotation.

Serial Number	Classification of Common Factors	Project (Variable Layer)	Component				
			1	2	3	4	5
1	Ecological elements	Species diversity	0.787	0.618	−0.446	0.588	0.596
2		Rich in layers	−0.010	−0.598	0.044	0.768	0.225
3		Planting density	0.415	−0.593	0.431	0.501	0.361
4		Revetment landscape	−0.278	−0.155	0.541	−0.358	0.692
5	Artistic elements	Harmonious coexistence	0.707	0.419	0.169	−0.576	0.402
6		Artistic composition	0.535	0.347	0.769	0.537	0.051
7		Both the real and the virtual are born together	0.478	0.688	0.625	−0.307	0.402
8		Seasonal phase change	0.674	0.496	0.391	0.304	0.233
9		Green rate	0.868	−0.422	0.347	0.513	0.201
10	Functional elements	Anti-jamming capability	−0.579	0.344	0.526	0.345	−0.389
11		Wide field of vision	0.947	0.618	0.391	0.620	0.555
12		Scale affinity	−0.365	0.504	−0.525	0.267	0.515
13		Degree of residence	0.594	−0.610	0.127	0.471	−0.361

Note: extraction method is principal component analysis; rotation method is maximum variance method and Kaiser normalization; rotation convergence of 6 iterations.

4. Conclusions

This study used SBE-EEM analysis to evaluate the quality of beauty value of 32 waterfront plant communities in western Hunan, and employing the entropy weight method to scrutinize the determinants influencing the quality of traditional village waterfront botanical landscapes revealed pivotal landscape elements. The statistics show that the evaluation of the quality of waterfront botanical landscapes across 32 traditional villages in the Xiangxi region yielded Z-values ranging from −0.141 to 0.265. Overall, the scoring outcome was deemed “fair,” indicating the necessity for further enhancements to achieve desired landscape development outcomes. Notably, the Z-value of scenic beauty demonstrated a robust correlation with the entropy weight value. Moreover, the statistical analysis revealed a significant correlation ($p < 0.01$) among the three examined groups: landscape architecture major students, professional experts, and non-landscape architecture professionals. This underscores the consistent evaluation of waterfront botanical landscapes in traditional villages, reflecting the inherent scenic beauty characteristics of the study area. Analysis of the regression equation highlighted the influential landscape elements affecting waterfront botanical landscapes in traditional villages, including seasonal variations, scale affinity, hierarchical richness, disturbance resilience, embankment landscapes, expansive views, green view ratio, species diversity, symbiotic harmony, stayability, artistic composition, interplay of reality and illusion, and planting density. Identifying the most exemplary site in plant community landscape quality appraisal offers a blueprint for fortifying traditional village waterfront botanical landscapes and rural greening endeavors in the foreseeable future.

The amalgamation of the SBE and entropy weight methodologies yields nuanced and objective evaluation outcomes. However, lingering lacunae persist such as inadequacies in comprehensively encapsulating plant landscape elements, oversight of interconnectivity between landscape facets, neglect of temporal and spatial dynamics, and the inherent subjectivity–objectivity conundrum. While the SBE method leans on expert judgment, imbued with inherent subjectivity, the entropy weight method pivots on empirical data, accentuating objectivity. Yet, achieving equipoise between subjectivity and objectivity remains elusive, thereby impeding the attainment of veracious evaluation outcomes.

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