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Enhanced EDAS Framework for Landscape Planning and Design Quality Evaluation under Single-Valued Neutrosophic Sets

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Abstract: Landscape planning and design quality evaluation is a systematic analysis and assessment of landscape project designs. Its primary goal is to ensure functionality, aesthetics, and sustainability of the design. The evaluation covers aspects such as spatial layout, ecological conservation, plant arrangement, landscape effects, and human-centered considerations. Additionally, the evaluation considers the economic feasibility of the project, the practicality of construction, and the ease of future maintenance, ensuring that the landscape space meets diverse user needs while harmonizing with the natural environment. The landscape planning and design quality evaluation is MAGDM. The single-valued neutrosophic sets (SVNSs) are useful tools to cope with uncertain information during the landscape planning and design quality evaluation. In this paper, the single-valued neutrosophic number EDAS (SVNN-EDAS) model based on single-valued neutrosophic number cosine similarity measure (SVNNCSM) and SVNN cosine function similarity measure (SVNNCFSM) is formed to cope with the MAGDM. The CRITIC model is administrated to obtain the weight numbers in light with the SVNNCSM and SVNNCFSM under SVNSs. Finally, numerical examples and different comparative analysis for landscape planning and design quality evaluation is administrated to validate SVNN-EDAS model.

Keywords: Neutrosophic sets; SVNSs; EDAS model; CSM technique; quality evaluation

1. Introduction

The quality of landscape architecture planning and design is directly related to the sustainability, aesthetics, and functionality of the ecological environment. High-quality planning and design must comprehensively consider natural environments, cultural factors, and economic benefits to ensure harmony between humans and nature. Firstly, the design should follow ecological principles, with rational allocation of vegetation, soil, and water resources to enhance biodiversity and ecological stability. Secondly, it must possess innovation and aesthetic value, integrating local culture and historical context to create unique landscape features. Moreover, the use of scientific and rational design processes and technical tools, such as big data, GIS, and virtual reality, can improve the precision and feasibility of the design, ensuring long-term benefits and social value for landscape projects. The development of landscape architecture planning and design has undergone significant changes over the years, driven by advancements in technology, sustainability, and human-centric approaches. This review summarizes 16 articles chronologically, highlighting the evolution of key concepts in the field.

The remaining sections are formed. The SVNSs is formed in Section 2. The SVNN-EDAS model is formed for MAGDM in Section 3. The landscape planning and design quality evaluation and some comparative analyses is formed to validate the SVNN-EDAS model in Section 4. The conclusion is formed in Section 5.

2. Literature Review

This section reviews the previous papers on the decision-making problem. In 2009, Wang [1] explored the concept of regional characteristics in landscape architecture, emphasizing its critical role in influencing subsequent planning and design work. Around the same time, Hu, Wang and Zhu [2] discussed the challenges faced by the Shanghai World Expo's landscape architecture design and presented innovative solutions to address these challenges. Moving into 2010, Liu [3] focused on the growing importance of the experience economy, where landscape designs needed to cater to the emotional and sensory experiences of individuals. In 2011, Li, Zhu and Wu [4] examined the development trends in landscape architecture, proposing strategies for achieving resource-efficient and sustainable landscapes.

Liu [5] continued this discourse by outlining design principles for residential landscape architecture, stressing locality, historical cultural resources, and sustainable development. In 2013, Cai [6] delved into the challenges of digital landscape design, providing a comprehensive overview of digital methods and the need to promote digitalization in landscape architecture. As the field continued to evolve, Yue, Dai and Jia [7] explored the application of GIS technology in landscape architecture, summarizing its development over 20 years and pointing out future research directions. In 2015, Zhan [8] compared traditional landscape design methods with parametric design approaches, emphasizing the advantages of the latter, while also addressing challenges in its widespread adoption.

In 2016, Wang [9] studied the role of rural landscapes in landscape architecture, noting their potential to provide urban dwellers with relaxation and stress relief. Li [10] then shifted the focus to digital strategies in landscape architecture planning, analyzing their use in a municipal road project in Zhuhai. In 2018, Zhu and Li [11] explored the parametric design of landscape architecture buildings, detailing how digital parameters could dynamically link design and functionality. As technology became more integrated into the field, Han, Wang and Liu [12] examined the value of virtual reality (VR) in landscape architecture, highlighting how VR could improve design visualization and data processing.

Xue [13] further explored the humanization of landscape architecture design, focusing on integrating human needs and preferences into urban landscape planning. In 2022, Li, Wu and Wang [14] addressed the carbon neutrality goal within landscape architecture, proposing strategies for reducing carbon emissions and increasing carbon sequestration through green spaces. The following year, Liu [15] investigated trends in landscape architecture under the guidance of the sponge city concept, emphasizing the importance of integrating water conservation with ecological and aesthetic landscape design. Most recently,

Li and Ding [16] explored the application of big data algorithms in landscape architecture, proposing the use of artificial intelligence and data analytics to address complex design issues related to biodiversity, plant adaptability, and ecological stability. Through these studies, the field of landscape architecture has progressively incorporated sustainability, technology, and human-centered approaches, reflecting a broader trend toward innovative and ecologically responsible design. The integration of digital tools, such as GIS, parametric design, and big data, has further expanded the potential for creating landscapes that are not only functional and aesthetically pleasing but also environmentally sustainable. Figure 1 shows the system of natural areas. Figure 2 shows the relationship between landscape features.

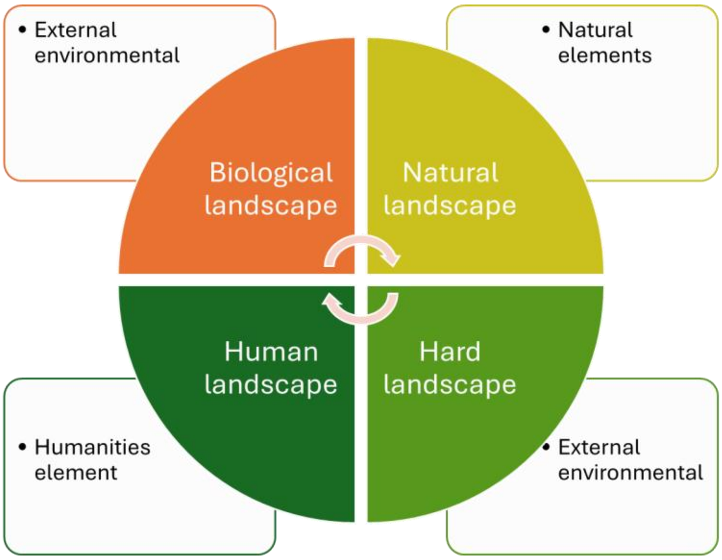

Figure 1. The system of natural areas.

The landscape planning and design quality evaluation is the real-life MAGDM. The SVNSs [17] is useful technique to cope with uncertain information during the landscape planning and design quality evaluation. Furthermore, many techniques administrated the EDAS model [18-21] and CSM model [22] separately to solve the MAGDM. Unfortunately, few valuable existing works were managed the EDAS [18, 19] based on Hamming distance information and CSM model [22] under SVNSs [17].

The main contributions of this study are formed:

A. The CRITIC model is formed to obtain weight numbers in light with SVNNCSM and SVNNCFSM.

B. The SVNN-EDAS model is formed in light with SVNNCSM and SVNNCFSM under SVNNs.

C. Finally, numerical examples and comparative analysis for landscape planning

D. Design quality evaluation is administrated to validate the SVNN-EDAS model.

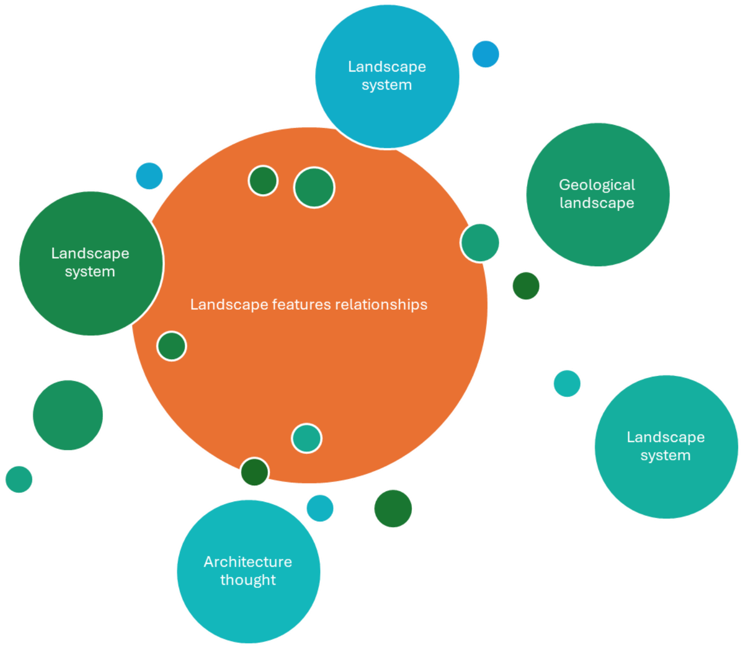

Figure 2. Relationship between landscape features.

2. Preliminaries

Wang et al. [17] formed the SVNSs.

Definition 1 [17]. The SVNSs is formed:

$$QA=\left\{\left(\vartheta,QT_A(\vartheta),QI_A(\vartheta),QF_A(\vartheta)\right)\middle|\vartheta\in\Theta\right\} \quad (1)$$

where $QT_A(\vartheta),QI_A(\vartheta),QF_A(\vartheta)$ depicts truth membership, indeterminacy membership and falsity membership, $QT_A(\vartheta),QI_A(\vartheta),QF_A(\vartheta)\in[0,1]$, $0\le QT_A(\vartheta)+QI_A(\vartheta)+QF_A(\vartheta)\le 3$.

Definition 2 [23]. The score value function (SVF) of $QA=(QT_A,QI_A,QF_A)$ is formed:

$$SVF(QA)=\frac{(2+QT_A-QI_A-QF_A)}{3},SVF(QA)\in[0,1]. \quad (2)$$

Definition 3 [23]. The accuracy value function (AVF) of $QA=(QT_A,QI_A,QF_A)$ is formed:

$$AVF(QA)=QT_A-QF_A,\ AVF(QA)\in[-1,1]\ . \quad (3)$$

Peng et al. [23] formed the order framework between two SVNNs.

Definition 4[23]. Let $QA=(QT_A,QI_A,QF_A)$ and $QB=(QT_B,QI_B,QF_B)$, let $SVF(QA)=\frac{(2+QT_A-QI_A-QF_A)}{3}$ and $SVF(QB)=\frac{(2+QT_B-QI_B-QF_B)}{3}$, and let $AVF(QA)=QT_A-QF_A$ and $AVF(QB)=QT_B-QF_B$, if $SVF(QA)<SVF(QB)$, then:

$QA < QB$; if $SVF(QA) = SVF(QB)$, then: (1)if $AVF(QA) = AVF(QB)$, then $QA = QB$; (2) if $AVF(QA) > AVF(QB)$, then: $QA < QB$.

Definition 6 [24]. Let $QA = (QT_A, QI_A, QF_A)$ and $QB = (QT_B, QI_B, QF_B)$, then SVNN cosine similarity measure (SVNNCSM) based on the $QA = (QT_A, QI_A, QF_A)$ and $QB = (QT_B, QI_B, QF_B)$ is formed:

$$SVNNCSM(QA, QB) = \frac{QT_A \times QT_B + QI_A \times QI_B + QF_A \times QF_B}{\left(\begin{array}{c}\sqrt{(QT_A)^2 + (QI_A)^2 + (QF_A)^2} \\ \cdot\sqrt{(QT_B)^2 + (QI_B)^2 + (QF_B)^2}\end{array}\right)},$$

$$SVNNCSM(QA, QB) \in [0,1], \tag{4}$$

Definition 6 [24]. Let $QA = (QT_A, QI_A, QF_A)$ and $QB = (QT_B, QI_B, QF_B)$, then SVNN cosine function similarity measure (SVNNCFSM) based on the $QA = (QT_A, QI_A, QF_A)$ and $QB = (QT_B, QI_B, QF_B)$ is formed:

$$SVNNCFSM(QA, QB) = \frac{1}{2}\left(\begin{array}{l}\cos\left[\frac{\pi}{6}\left(|QT_A - QT_B| + |QI_A - QI_B| + |QF_A - QF_B|\right)\right] \\ +\cos\left[\frac{\pi}{2}\max\left(\left(|QT_A - QT_B|, |QI_A - QI_B|, |QF_A - QF_B|\right)\right)\right]\end{array}\right)$$

$$SVNNCFSM(QA, QB) \in [0,1], \tag{5}$$

Definition 7 [17]. Let $QA = (QT_A, QI_A, QF_A)$ and $QB = (QT_B, QI_B, QF_B)$, the operations laws are formed:

(1) $QA \oplus QB = (QT_A + QT_B - QT_A \cdot QT_B, QI_A \cdot QI_B, QF_A \cdot QF_B)$;

(2) $QA \otimes QB = (QT_A \cdot QT_B, QI_A + QI_B - QI_A \cdot QI_B, QF_A + QF_B - QF_A \cdot QF_B)$;

(3) $\gamma QA = \left(1 - (1 - QT_A)^\gamma, (QI_A)^\gamma, (QF_A)^\gamma\right), \gamma > 0;$

(4) $(QA)^\gamma = \left((QT_A)^\gamma, (QI_A)^\gamma, 1 - (1 - QF_A)^\gamma\right), \gamma > 0.$

The SVNNWA & SVNNWG model are formed.

Definition 8 [23]. If $QA_j = (QT_j, QI_j, QF_j)$, the SVNNWA operator is formed:

$$\begin{aligned}&\text{SVNNWA}_{qw}\left(QA_1, QA_2, \cdots, QA_n\right)=\overset{n}{\underset{j=1}{\oplus}}\left(qw_j QA_j\right)\\&=\left(1-\prod_{j=1}^{n}\left(1-QT_j\right)^{qw_j}, \prod_{j=1}^{n}\left(QI_j\right)^{qw_j}, \prod_{j=1}^{n}\left(QF_j\right)^{qw_j}\right)\end{aligned} \tag{6}$$

with weight $qw=\left(qw_1, qw_2, ..., qw_n\right)^T$, $\sum_{j=1}^{n} qw_j=1.$

Definition 9 [23]. If $QA_j=\left(QT_j, QI_j, QF_j\right)$, the SVNNWG model is formed:

$$\begin{aligned}&\text{SVNNWG}_{qw}\left(QA_1, QA_2, \cdots, QA_n\right)=\overset{n}{\underset{j=1}{\otimes}}\left(QA_j\right)^{qw_j}\\&=\left(\prod_{j=1}^{n}\left(QT_j\right)^{qw_j}, 1-\prod_{j=1}^{n}\left(1-QI_j\right)^{qw_j}, 1-\prod_{j=1}^{n}\left(1-QF_j\right)^{qw_j}\right)\end{aligned} \tag{7}$$

with weight $qw=\left(qw_1, qw_2, ..., qw_n\right)^T$, $\sum_{j=1}^{n} qw_j=1.$

3. Materials and Methods

Then, the SVNN-EDAS model is formed for MAGDM. Let $QY=\left(QY_1, QY_2, \ldots, QY_m\right)$ have alternatives. Let $QZ=\left(QZ_1, QZ_2, \ldots, QZ_n\right)$ be attributes, $qw=\left\{qw_1, qw_2, \ldots, qw_n\right\}$ be weight for QZ_j, where $qw_j \in[0,1], \sum_{j=1}^{n} qw_j=1$. Assume DMs $QD=\left\{QD_1, QD_2, \ldots, QD_l\right\}$ with weight $q\omega=\left\{q\omega_1, q\omega_2, \ldots, q\omega_l\right\}$, $q\omega_k \in[0,1]$, $\sum_{k=1}^{l} q\omega_k=1$. And $QN^{(k)}=\left(QN_{ij}^{(k)}\right)_{m\times n}=\left(QT_{ij}^{(k)}, QI_{ij}^{(k)}, QF_{ij}^{(k)}\right)_{m\times n}$ is called as group SVNN-matrix. The calculating procedures are formed as shown in Figure 3.

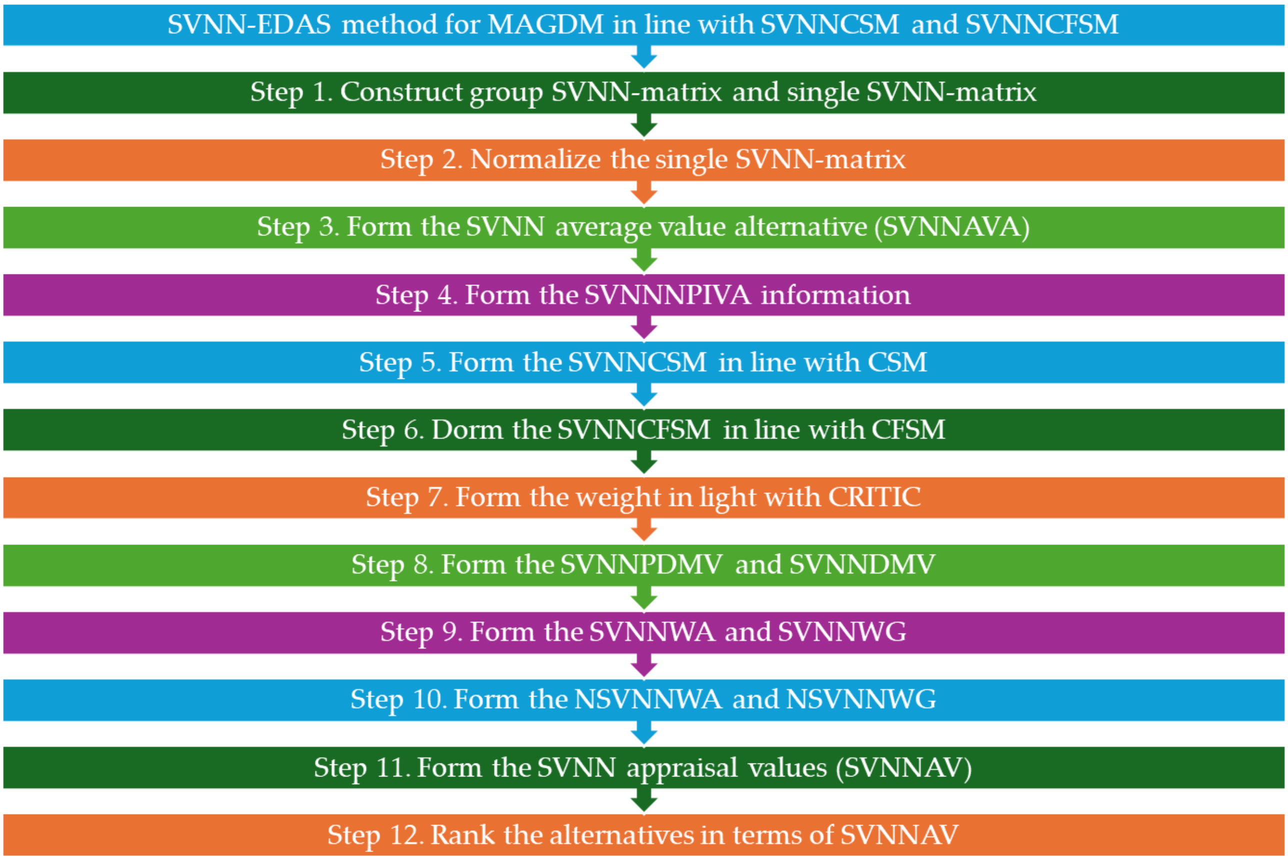

Figure 3. The steps of the proposed model.

Step 1. Form group SVNN-matrix $QN^{(k)}=\left(QN_{ij}^{(k)}\right)_{m\times n}=\left(QT_{ij}^{(k)},QI_{ij}^{(k)},QF_{ij}^{(k)}\right)_{m\times n}$ and single SVNN-matrix $QN=\left(QN_{ij}\right)_{m\times n}$ through SVNNWA technique.

$$QR^{(k)}=\left[QR_{ij}^{(k)}\right]_{m\times n}=\begin{bmatrix} QR_{11}^{(k)} & QR_{12}^{(k)} & \dots & QR_{1n}^{(k)} \\ QR_{21}^{(k)} & QR_{22}^{(k)} & \dots & QR_{2n}^{(k)} \\ \vdots & \vdots & \vdots & \vdots \\ QR_{m1}^{(k)} & QR_{m2}^{(k)} & \dots & QR_{mn}^{(k)} \end{bmatrix} \tag{8}$$

$$QR=\left[QR_{ij}\right]_{m\times n}=\begin{bmatrix} QR_{11} & QR_{12} & \dots & QR_{1n} \\ QR_{21} & QR_{22} & \dots & QR_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ QR_{m1} & QR_{m2} & \dots & QR_{mn} \end{bmatrix} \tag{9}$$

$$QR_{ij}=\left(QT_{ij},QI_{ij},QF_{ij}\right)=\left(1-\prod_{k=1}^{l}\left(1-QT_{ij}^{(k)}\right)^{q\omega_k},\prod_{k=1}^{l}\left(QI_{ij}^{(k)}\right)^{q\omega_k},\prod_{k=1}^{l}\left(QF_{ij}^{(k)}\right)^{q\omega_k}\right) \tag{10}$$

Step 2. Form normalized $QR^N = \left[QR_{ij}^N \right]_{m\times n}$ in line with $QR = \left[QR_{ij} \right]_{m\times n}$

$$QR_{ij}^N = \left(QT_{ij}^N, QI_{ij}^N, QF_{ij}^N \right) = \begin{cases} \left(QT_{ij}, QI_{ij}, QF_{ij} \right), & QZ_j \text{ is a benefit attribute} \\ \left(QF_{ij}, QI_{ij}, QT_{ij} \right), & QZ_j \text{ is a cost attribute} \end{cases} \tag{11}$$

Step 3. Form the SVNNAVA (SVNN average value alternative).

$$SVNNAVA = \left[SVNNAVA_j \right]_{1\times n} = \left[\frac{\overset{m}{\underset{i=1}{\oplus}} QR_{ij}^N}{m} \right]_{1\times n} \tag{12}$$

$$\left[SVNNAVA_j \right]_{1\times n} = \left(1 - \prod_{i=1}^{m} \left(1 - QR_{ij}^N \right)^{\frac{1}{m}}, \prod_{i=1}^{m} \left(QI_{ij}^N \right)^{\frac{1}{m}}, \prod_{i=1}^{m} \left(QF_{ij}^N \right)^{\frac{1}{m}} \right)_{1\times n} \tag{13}$$

Step 4. Form the SVNNNPIVA (SVNN positive ideal value alternative):

$$SVNNPIVA_j = \left(QT_j^{N+}, QI_j^{N+}, QF_j^{N+} \right) \tag{14}$$

$$SVF\left(SVNNPIVA_j \right) = \max_i SVF\left(QR_{ij}^N \right) \tag{15}$$

Step 5. Form the SVNNCSM information between $QR_{ij}^N = \left(QT_{ij}^N, QI_{ij}^N, QF_{ij}^N \right)$ and $SVNNPIVA_j = \left(QT_j^{N+}, QI_j^{N+}, QF_j^{N+} \right)$.

$$SVNNCSM\left(QR_{ij}^N, SVNNPIVA_j \right) = \frac{QT_{ij}^N \times QT_j^{N+} + QI_{ij}^N \times QI_j^{N+} + QF_{ij}^N \times QF_j^{N+}}{\sqrt{\left(QT_{ij}^N \right)^2 + \left(QI_{ij}^N \right)^2 + \left(QF_{ij}^N \right)^2} \cdot \sqrt{\left(QT_j^{N+} \right)^2 + \left(QI_j^{N+} \right)^2 + \left(QF_j^{N+} \right)^2}} \tag{16}$$

Step 6. Form the SVNNCFSM information between $QR_{ij}^N = \left(QT_{ij}^N, QI_{ij}^N, QF_{ij}^N \right)$ and $SVNNPIVA_j = \left(QT_j^{N+}, QI_j^{N+}, QF_j^{N+} \right)$.

$$SVNNCFSM\left(QR_{ij}^N, SVNNPIVA_j \right) = \frac{1}{2} \left(\begin{array}{l} \cos\left[\frac{\pi}{6} \left(\left| QT_{ij}^N - QT_j^{N+} \right| + \left| QI_{ij}^N - QI_j^{N+} \right| + \left| QF_{ij}^N - QF_j^{N+} \right| \right) \right] \\ + \cos\left[\frac{\pi}{2} \max\left(\left(\left| QT_{ij}^N - QT_j^{N+} \right|, \left| QI_{ij}^N - QI_j^{N+} \right|, \left| QF_{ij}^N - QF_j^{N+} \right| \right) \right) \right] \end{array} \right) \tag{17}$$

Step 7. Form the weight numbers in line with CRITIC.

The CRITIC model [25] is formed for weights values.

(1) The SVNNCCV (SVNN correlation coefficient values) are formed.

$$SVNNCCV_{jt}=\frac{\sum_{i=1}^{m}\left(\varphi\left(CSM_{ij}\right)-\varphi\left(CSM_{j}\right)\right)\times\left(\varphi\left(CSM_{it}\right)-\varphi\left(CSM_{t}\right)\right)}{\sqrt{\sum_{i=1}^{m}\left(\varphi\left(CSM_{ij}\right)-\varphi\left(CSM_{j}\right)\right)^{2}}\times\sqrt{\sum_{i=1}^{m}\left(\varphi\left(CSM_{it}\right)-\varphi\left(CSM_{t}\right)\right)^{2}}}, \quad (18)$$

where

$$\varphi\left(CSM_{j}\right)=\frac{1}{2m}\sum_{i=1}^{m}\begin{pmatrix}SVNNCSM\left(QR_{ij}^{N},SVNNPIVA_{j}\right)\\+SVNNCFSM\left(QR_{ij}^{N},SVNNPIVA_{j}\right)\end{pmatrix},$$

$$\varphi\left(CSM_{t}\right)=\frac{1}{2m}\sum_{i=1}^{m}\begin{pmatrix}SVNNCSM\left(QR_{it}^{N},SVNNPIVA_{t}\right)\\+SVNNCFSM\left(QR_{it}^{N},SVNNPIVA_{t}\right)\end{pmatrix},$$

$$\varphi\left(CSM_{ij}\right)=\frac{1}{2}\begin{pmatrix}SVNNCSM\left(QR_{ij}^{N},SVNNPIVA_{j}\right)\\+SVNNCFSM\left(QR_{ij}^{N},SVNNPIVA_{j}\right)\end{pmatrix},$$

$$\varphi\left(CSM_{it}\right)=\frac{1}{2}\begin{pmatrix}SVNNCSM\left(QR_{it}^{N},SVNNPIVA_{t}\right)\\+SVNNCFSM\left(QR_{it}^{N},SVNNPIVA_{t}\right)\end{pmatrix}$$

(2) Form the SVNNSDV (SVNN standard deviation values).

$$SVNNSDV_{j}=\sqrt{\frac{1}{m-1}\sum_{i=1}^{m}\left(\varphi\left(CSM_{ij}\right)-\varphi\left(CSM_{j}\right)\right)^{2}} \quad (19)$$

(3) Form attribute weight numbers.

$$qw_{j}=\frac{SVNNSDV_{j}\sum_{t=1}^{n}\left(1-SVNNCCV_{jt}\right)}{\sum_{j=1}^{n}\left(SVNNSDV_{j}\sum_{t=1}^{n}\left(1-SVNNCCV_{jt}\right)\right)} \quad (20)$$

Step 8. Form the SVNN positive distance measure values from SVNNAVA (SVNNPDMV) and SVNN negative distance measures values from SVNNAVA (SVNNNDMV):

For the positive attributes:

$$SVNNPDMV_{ij} = \frac{1}{2}\left(\begin{array}{c}\frac{\max\left(0, SVNNCSM\left(QR_{ij}^{N}, SVNNPIVA_j\right) - SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right)\right)}{SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right)} \\ + \frac{\max\left(0, SVNNCFSM\left(QR_{ij}^{N}, SVNNPIVA_j\right) - SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right)\right)}{SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right)}\end{array}\right) \tag{21}$$

$$SVNNNDMV_{ij} = \frac{1}{2}\left(\begin{array}{c}\frac{\max\left(0, SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right) - SVNNCSM\left(QR_{ij}^{N}, SVNNPIVA_j\right)\right)}{SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right)} \\ + \frac{\max\left(0, SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right) - SVNNCFSM\left(QR_{ij}^{N}, SVNNPIVA_j\right)\right)}{SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right)}\end{array}\right) \tag{22}$$

For the negative attributes:

$$SVNNPDMV_{ij} = \frac{1}{2}\left(\begin{array}{c}\frac{\max\left(0, SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right) - SVNNCSM\left(QR_{ij}^{N}, SVNNPIVA_j\right)\right)}{SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right)} \\ + \frac{\max\left(0, SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right) - SVNNCFSM\left(QR_{ij}^{N}, SVNNPIVA_j\right)\right)}{SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right)}\end{array}\right) \tag{23}$$

$$SVNNNDMV_{ij} = \frac{1}{2}\left(\begin{array}{c}\frac{\max\left(0, SVNNCSM\left(QR_{ij}^{N}, SVNNPIVA_j\right) - SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right)\right)}{SVNNCSM\left(SVNNAVA_j, SVNNPIVA_j\right)} \\ + \frac{\max\left(0, SVNNCFSM\left(QR_{ij}^{N}, SVNNPIVA_j\right) - SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right)\right)}{SVNNCFSM\left(SVNNAVA_j, SVNNPIVA_j\right)}\end{array}\right) \tag{24}$$

Step 9. Form the SVNN weighted averaging values (SVNNWAV) and SVNN weighted geometric values (SVNNWGV).

$$SVNNWAV_i = \sum_{j=1}^{n} qw_j \cdot SVNNPDMV_{ij}, \tag{25}$$

$$SVNNWGV_i = \sum_{j=1}^{n} qw_j \cdot SVNNNDMV_{ij} \, , \tag{26}$$

Step 10. Form the $NSVNNWAV_i$ and $NSVNNWGV_i$ in line with normalized $SVNNWAV_i$ and $SVNNWGV_i$:

$$NSVNNWAV_i = \frac{SVNNWAV_i}{\max_i \left(SVNNWAV_i \right)}, \tag{27}$$

$$NSVNNWGV_i = 1 - \frac{SVNNWGV_i}{\max_i \left(SVNNWGV_i \right)}, \tag{28}$$

Step 11. Form the SVNNAV (SVNN appraisal values).

$$SVNNAV_i = \frac{1}{2} \left(NSVNNWAV_i + NSVNNWGV_i \right) \tag{29}$$

Step 12. In light with the information of SVNNAV, the larger SVNNAV information, the better one is.

4. Results and Discussions

In this section, we will share the results we've gathered and provide a detailed discussion of their meaning. Our goal is to emphasize the importance of these findings and explore their implications in relation to the broader objectives of our study.

4.1 Problem Definitions

This part defines the criteria and alternatives used in this study. Figure 4 shows the criteria and alternatives.

In this work, the landscape planning and design quality evaluation is formed through SVNN-EDAS technique. Five landscape planning and design schemes $A = A_1, A_2, \ldots, A_m$ which are evaluated through five experts with equal weight values in light with four attributes:

Functionality (C_1): The design should meet the needs of users by providing a well-organized functional layout and smooth circulation. Different areas, such as relaxation zones, activity areas, and viewing spaces, should be clearly distinguished, while ensuring easy connectivity between these zones for user convenience. Additionally, considerations like accessibility and site safety are essential.

Aesthetic Appeal (C_2): The landscape design needs to be visually attractive, with a harmonious overall layout, rich spatial layering, and well-coordinated landscape elements. The integration of hardscape and softscape should be unified and orderly, creating an artistic visual experience. Factors such as color, texture, plant morphology, and seasonal changes should also be considered to ensure that the landscape remains appealing throughout the year.

Ecology and Sustainability (C_3): The design should prioritize ecological protection and restoration, making efficient use of natural resources to minimize environmental impacts.

Plant selection should be suited to the local climate and soil conditions, enhancing biodiversity. Additionally, effective water management and energy conservation should be incorporated to achieve sustainable development goals.

Feasibility of Construction and Maintenance (C_4): The design should be practical and achievable during construction, avoiding overly complex or difficult-to-execute concepts. The convenience of future maintenance should also be fully considered, ensuring that the landscape can maintain its visual appeal and functionality over time while minimizing maintenance costs and effort. Then, the SVNN-EDAS model is formed to achieve the optimal landscape planning and design scheme.

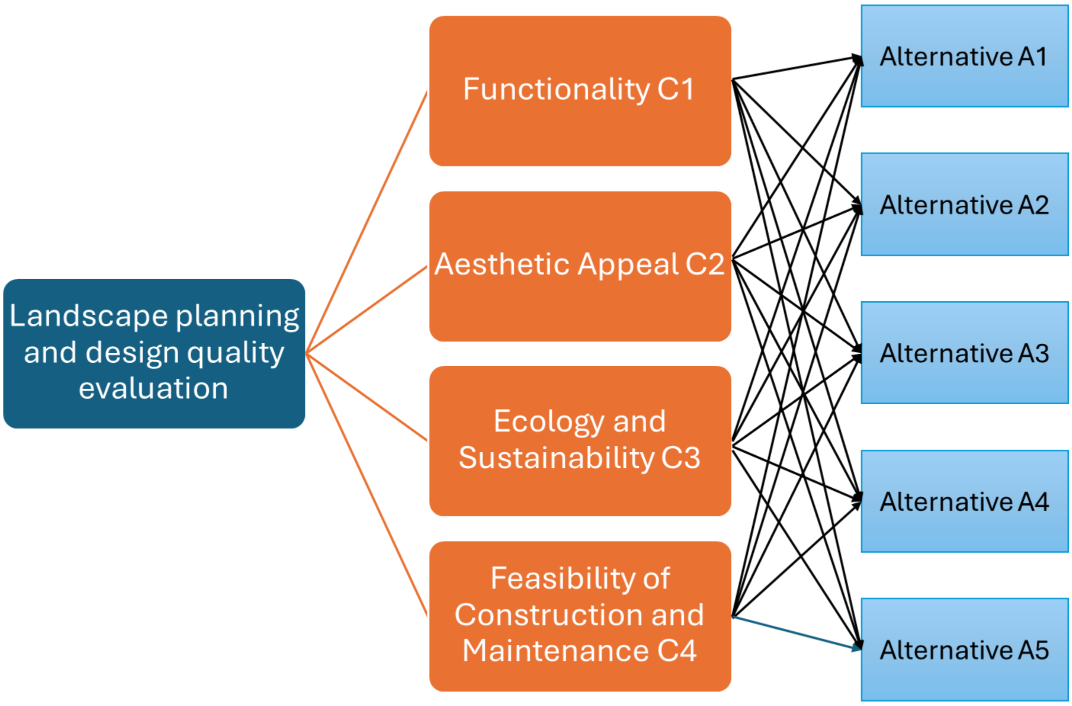

Figure 4. The criteria and alternatives.

The quality evaluation of landscape planning and design is a systematic and comprehensive analysis and assessment of the design scheme of a landscape project. Its aim is to ensure that the project meets expectations in terms of aesthetics, functionality, ecology, and sustainability. First and foremost, the core of the evaluation lies in the rationality of spatial layout, assessing whether the design effectively utilizes land resources to create a clearly defined functional zoning, fluid circulation, and appropriately scaled spatial structure.

In addition, the landscape design should harmonize with the surrounding natural environment, ensuring a balanced overall visual effect and ecological system. This includes careful consideration of factors such as topography, climate, and vegetation. Plant arrangement is another key aspect of the evaluation. The selection, combination, and layout of plant species should follow ecological principles, not only providing a pleasing landscape effect but also enhancing the ecological functions of the site, such as improving air quality and regulating the microclimate. Meanwhile, the integration of hardscape (such as paving and architectural elements) with softscape (such as vegetation and water features) should be harmonious and unified, reflecting both aesthetic appeal and practicality. Beyond visual and ecological considerations, landscape design must also pay attention to human-centered concerns.

This means evaluating whether the design sufficiently meets the needs of users by providing a comfortable, safe, and convenient experience. Considerations include aspects such as barrier-free design, site safety, and the accessibility of facilities. Economic efficiency and construction feasibility are also critical factors in the evaluation. The design scheme should not only adhere to the budget and ensure the rational use of resources, but also account for the technical challenges and cost control during the construction process. Furthermore, the ease of future maintenance and management must be included in the assessment.

The design should feature sustainability and ease of maintenance, ensuring that the project can maintain its landscape effects and functional performance over its lifecycle. Through this multidimensional evaluation, landscape planning and design can achieve a comprehensive balance and optimization in terms of aesthetics, functionality, ecology, and economics, ultimately creating high-quality landscape spaces that promote harmonious coexistence between humans and nature.

Table 1. Linguistic scale and SVNNs

Linguistic terms	**SVNNs**
Very High	(0.0,1.0,1.0)
High	(0.10,0.90,0.90)
Medium High	(0.30,0.70,0.70)
Medium	(0.50,0.50,0.50)
Medium Low	(0.70,0.30,0.30)
Low	(0.90,0.10,0.10)
Very Low	(1.00,0.00,0.00)

Table 2. The combined decision matrix

	C_1	C_2	C_3	C_4
A_1	(0.67, 0.31, 0.35)	(0.27, 0.46, 0.62)	(0.56, 0.38, 0.49)	(0.28, 0.24, 0.32)
A_2	(0.54, 0.39, 0.46)	(0.43, 0.36, 0.34)	(0.26, 0.37, 0.26)	(0.54, 0.43, 0.38)
A_3	(0.48, 0.37, 0.51)	(0.54, 0.49, 0.48)	(0.52, 0.33, 0.49)	(0.45, 0.18, 0.29)
A_4	(0.54, 0.29, 0.38)	(0.62, 0.25, 0.36)	(0.64, 0.45, 0.32)	(0.53, 0.29, 0.18)
A_5	(0.46, 0.32, 0.43)	(0.41, 0.28, 0.32)	(0.48, 0.46, 0.33)	(0.45, 0.49, 0.36)

Results

Step 1. Create the decision matrix with opinions of three experts and decision makers. These experts use the linguistic terms as shown in Table 1 to evaluate the criteria and alternatives. Then we combined it as shown in Table 2.

Step 2. Normalize the decision matrix as shown in Table 3.

Table 3. The standardized SVNN-matrix

	C_1	C_2	C_3	C_4
A_1	(0.67, 0.31, 0.35)	(0.27, 0.46, 0.62)	(0.56, 0.38, 0.49)	(0.28, 0.24, 0.32)
A_2	(0.54, 0.39, 0.46)	(0.43, 0.36, 0.34)	(0.26, 0.37, 0.26)	(0.54, 0.43, 0.38)
A_3	(0.48, 0.37, 0.51)	(0.54, 0.49, 0.48)	(0.52, 0.33, 0.49)	(0.45, 0.18, 0.29)
A_4	(0.54, 0.29, 0.38)	(0.62, 0.25, 0.36)	(0.64, 0.45, 0.32)	(0.53, 0.29, 0.18)
A_5	(0.46, 0.32, 0.43)	(0.41, 0.28, 0.32)	(0.48, 0.46, 0.33)	(0.45, 0.49, 0.36)

Step 3. Calculate the SVNNAVA as shown in Table 4.

Table 4. The SVNNAVA

	SVNNAVA	SVNNNPIVA
C_1	(0.28, 0.19, 0.24)	(0.67, 0.31, 0.35)
C_2	(0.31, 0.15, 0.26)	(0.62, 0.25, 0.36)
C_3	(0.23, 0.12, 0.31)	(0.64, 0.45, 0.32)
C_4	(0.27, 0.24, 0.16)	(0.38, 0.43, 0.54)

Step 4. Define the SVNNNPIVA

Step 5. Obtain the values of single-valued neutrosophic number cosine similarity measure as shown in Table 5.

Table 5. The single-valued neutrosophic number cosine similarity measure.

Alternatives	C_1	C_2	C_3	C_4	Alternatives	C_1	C_2	C_3	C_4
A_1	1.0000	0.5827	0.6008	0.6698	A_1	1.0000	0.6388	0.6586	0.7344
A_2	0.8326	0.8063	0.8020	1.0000	A_2	0.9128	0.8840	0.8792	1.0000
A_3	0.7043	0.7286	0.5789	0.4344	A_3	0.7722	0.7988	0.6347	0.4762
A_4	0.8721	1.0000	1.0000	0.7840	A_4	0.9561	1.0000	1.0000	0.8596
A_5	0.5926	0.5501	0.8240	0.7634	A_5	0.6497	0.6030	0.9034	0.8369

Step 6. Compute the SVNN cosine function similarity measure.

Step 7. Form the weights numbers in light with CRITIC as shown in Figure 5.

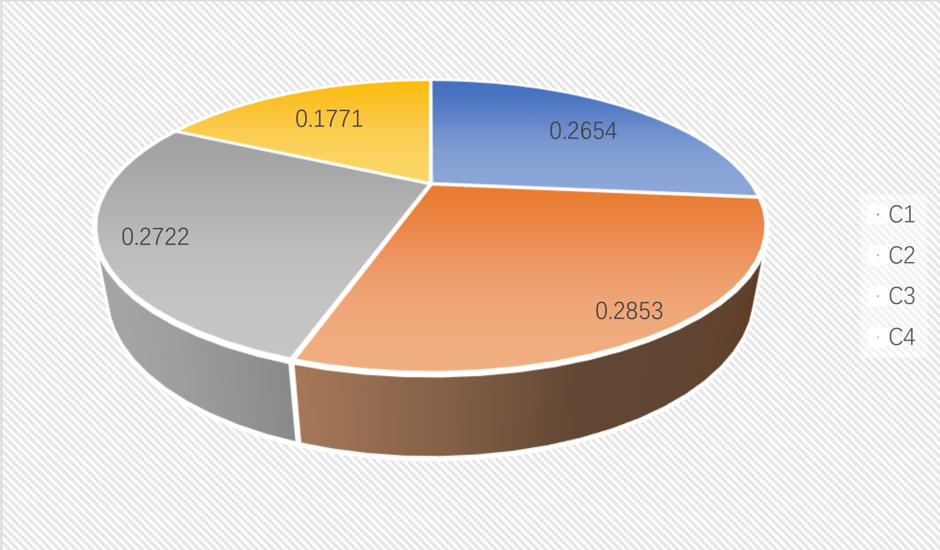

Figure 5. The criteria weight numbers.

Step 8. Form the SVNNPDMV and SVNNNDMV as shown in Table 6.

Table 6. The SVNNPDMV and SVNNNDMV.

	C_1	C_2	C_3	C_4		C_1	C_2	C_3	C_4
A_1	0.1708	0.0000	0.0000	0.0000	A_1	0.0000	0.1485	0.1585	0.0538
A_2	0.0434	0.0859	0.0524	0.2441	A_2	0.0000	0.0000	0.0000	0.0000
A_3	0.0000	0.0045	0.0000	0.0000	A_3	0.0910	0.0000	0.1813	0.3006
A_4	0.0848	0.2408	0.2118	0.0659	A_4	0.0000	0.0000	0.0000	0.0000
A_5	0.0000	0.0000	0.0755	0.0443	A_5	0.2080	0.1827	0.0000	0.0000

Step 9-11. Form the SVNNWAV information, SVNNWGV information and Form the SVNNA as shown in Figure 6

Step 12. Rank the alternatives as shown in Figure 7.

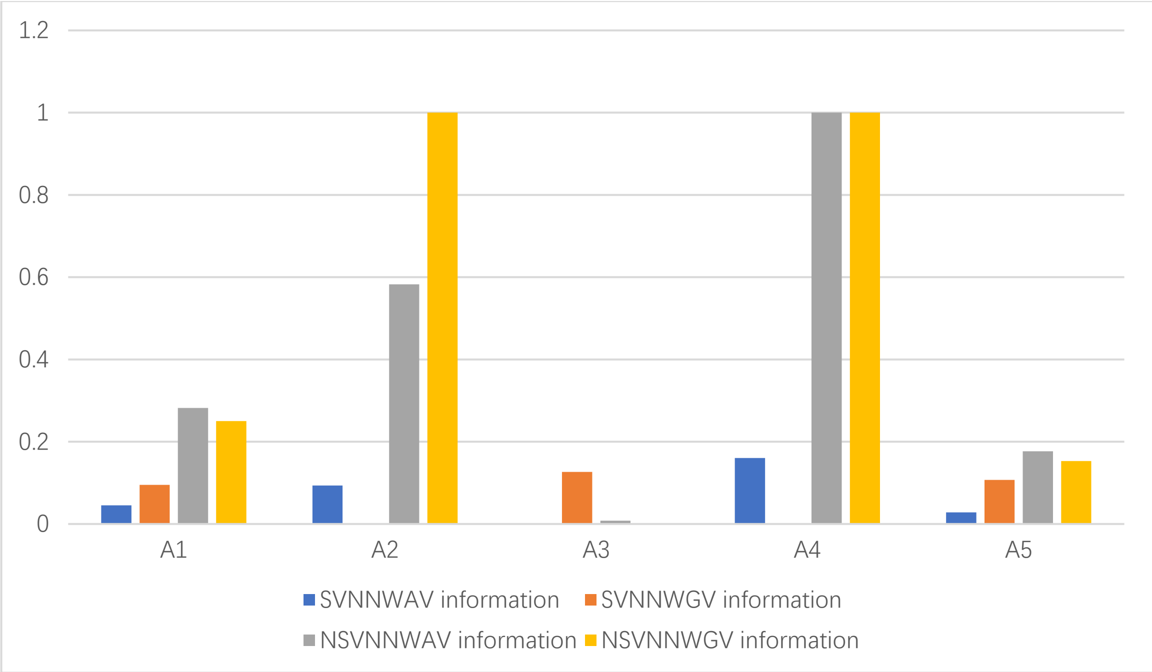

Figure 6. The values of NSVNNWAV information & NSVNNWGV information.

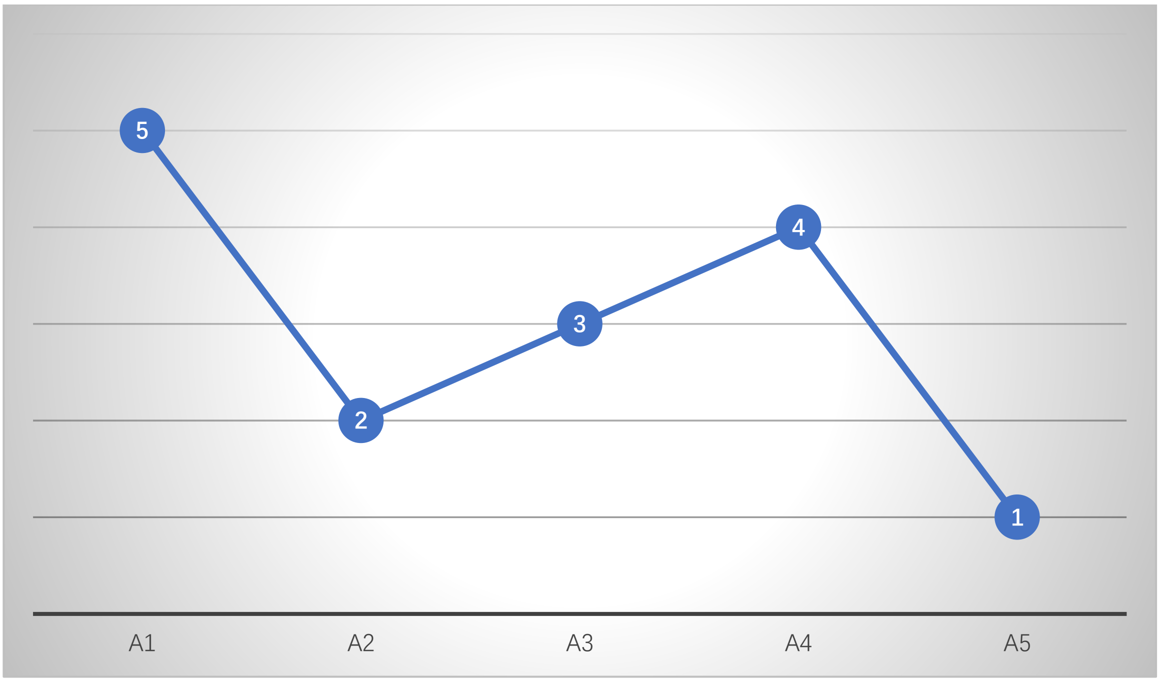

Figure 7. The rank of alternatives.

4.2. Comparative analysis

The formed SVNN-EDAS model is always compared with SVNNWA model [23], SVNNWG model [23], SVNN-WASPAS model [26], SVNN-TODIM technique [27], SVNN-TOPSIS technique [28] and SVNN-CODAS technique [29]. The sufficient comparative results are shown in Figure 8.

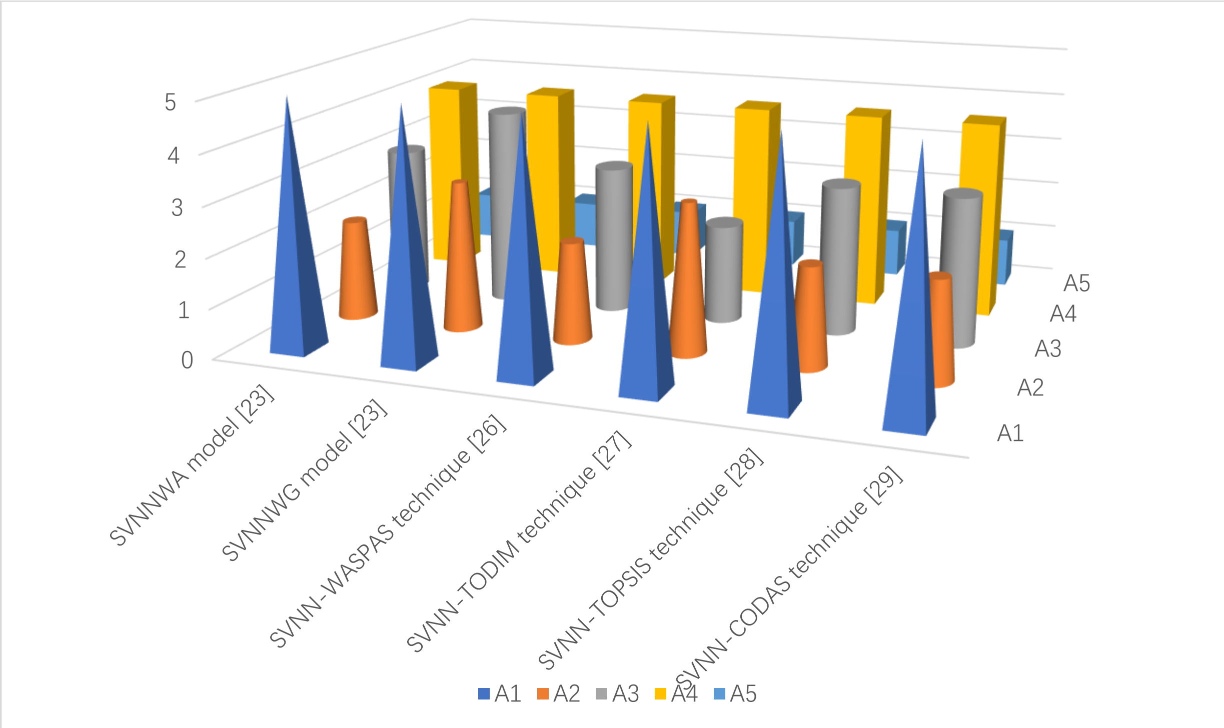

Figure 8. Comparative analysis results.

The similarity coefficients between SVNNWA model [23], SVNNWG model [23], SVNNIGWHM operator [30], SVNNIGWGHM operator [30], SVNN-WASPAS model [26], SVNN-TODIM model [27], SVNN-TOPSIS model [28], SVNN-VIKOR model [31], SVNN-CODAS model [29] and SVNN-EDAS model was obtained in light with WS coefficients [32, 33], the derived results are formed in Figure 9.

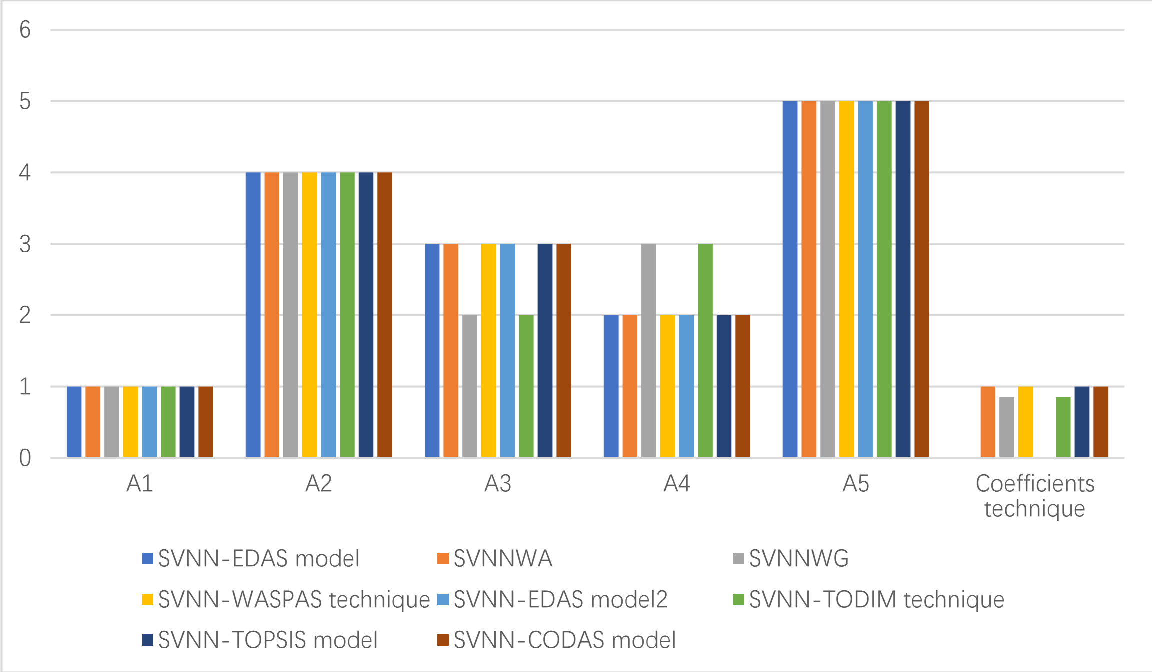

Figure 9. The WS coefficient.

The WS coefficient information corroborates the order of SVNN-EDAS model is same to the order of SVNNWA operator [23], SVNN-WASPAS model [26], SVNN-TOPSIS model [28] and SVNN-CODAS model [29]; the WS coefficient information corroborates the order of SVNN-EDAS model is slightly different from the order of SVNNWG model [23] and SVNN-TODIM model [27]. This verifies the SVNN-EDAS model is effective. Thus, the main advantages of SVNN-EDAS model are formed: (1) the formed SVNN-EDAS not only corroborated the uncertainty for MAGDM, but also portrays the average distance from the SVNNAVA during the landscape planning and design quality evaluation. (2) the formed SVNN-EDAS conducted different behavior of SVNNCSM and SVNNCFSM model as MAGDM when these models are combined. At the same time, the main difference between existing SVNN-EDAS model[34] and the formed SVNN-EDAS model are constructed: (1) The CRITIC model of existing SVNN-EDAS model[34] is constructed based on Euclid distance and CSM, while the CRITIC model of formed SVNN-EDAS model is constructed in light with SVNNCSM and SVNNCFSM; (2) the existing SVNN-EDAS model[34] is constructed based on Euclid distance and CSM, while the formed SVNN-EDAS model is constructed in light with SVNNCSM and SVNNCFSM.

4.3 Managerial Implications

There are various managerial implantations on landscape planning and design evaluation to change the design goals into actionable outcomes to obtain the economic and ecological outcomes.

I. Managers need to ensure the landscape design projects align with the strategic aims of sustainability and ecological results.

II. Managers can easily make many decisions to gather various data from different stakeholders like governments, organizations and environmental firms.

III. Managers must keep the efficient use of resources to reduce the landscape negative impacts.

IV. Managers can evaluate landscape design compared with other quality standards to keep their design competitive in markets.

5. Conclusion

The quality evaluation of landscape planning and design is a comprehensive analysis and assessment of landscape project designs to ensure functionality, aesthetics, ecology, and sustainability. The evaluation includes the rationality of spatial layout, the harmony between landscape design and the natural environment, the scientific arrangement of plants, and the organic integration of hard and soft landscapes. It also considers whether the design provides a comfortable experience and meets diverse user needs. In addition to visual effects, the effectiveness of ecological protection and resource utilization are important evaluation criteria. Furthermore, the project's cost-efficiency, construction feasibility, and ease of future maintenance are key factors. Through this evaluation, the design ensures that the project meets its objectives while maintaining good long-term landscape effects and functionality, promoting harmonious coexistence between humans and nature. The landscape planning and design quality evaluation is MAGDM. In this paper, the SVNN-EDAS model based on SVNNCSM and SVNNCFSM is formed to cope with the MAGDM. The CRITIC is administrated to obtain the weight numbers in light with the SVNNHD and SVNNCSM under SVNSs. Finally, numerical examples for landscape planning and design quality evaluation and comparative analysis are administrated to validate SVNN-EDAS model.

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