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Multi-Valued Neutrosophic Set for Quality Evaluation of Public Landscape Space Design Surrounding Historic and Cultural Districts Based on Computer-Aided Design

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Abstract: The integration of Computer-Aided Design (CAD) into the evaluation of public landscape spaces surrounding historic and cultural districts presents a transformative approach to urban heritage planning. This study explores an uncertainty framework for assessing the quality of landscape designs through digital simulation, focusing on historical compatibility, aesthetic coherence, sustainability, accessibility, and community engagement. By leveraging CAD tools, planners and designers can visualize proposed interventions with high precision, enabling the assessment of both tangible and intangible heritage values. The methodology ensures that public spaces not only preserve the cultural identity of their surroundings but also enhance their usability and environmental performance. The proposed evaluation model contributes to evidence-based planning by bridging traditional conservation principles with contemporary digital technologies. This study uses Multi-Valued Neutrosophic Set (MVNS) to overcome uncertainty and vague information. This study uses eight criteria and seven alternatives to be evaluated.

Keywords: Multi-Valued Neutrosophic Set (MVNS); Public Landscape; Historic and Cultural Districts; Computer-Aided Design.

1. Introduction

The NS is a set where each member of the world has a degree of truth, indeterminacy, and falsehood, respectively, the nonstandard unit interval. Smarandache first postulated neutrosophic logic and neutrosophic sets (NSs). This is obviously an expansion of the regular interval [0,1][1], [2].

Additionally, whereas the included uncertainty depends on the degrees of belongingness and non-belongingness, the uncertainty stated here, or the indeterminacy factor, is reliant on truth and falsity values. Furthermore, the NSs example stated above may be written as x(0.5, 0.2, 0.6). NSs are challenging to apply to actual circumstances, nevertheless, in the absence of a detailed explanation. As a result, single-valued neutrosophic sets (SVNSs), an extension of NSs, were proposed[3], [4].

However, while expressing their assessment values for each parameter in SNSs, decision-makers may also be cautious. SNSs will not be able to handle situations where, for instance, a statement has a 0.6 or 0.7 chance of being true, a 0.2 or 0.3 chance of being false, and a 0.1 or 0.2 degree of uncertainty. The above-mentioned drawbacks would persist if SNSs' operations and comparison methodology were expanded to multiple values[5], [6]. As a result, multi-valued neutrosophic sets (MVNSs) were described by Wang and Li [7] and this study defines multi-valued neutrosophic numbers (MVNNs).

2. Literature Review

Cooperation Due to the rapid rate of urbanization, there is a great need for landscape planning that properly optimizes public spaces. Urbanization has targeted China, a nation that has seen significant economic and demographic expansion. The Grand Cultural Canal Park, which has played a major role in the nation's development since ancient times, is renowned for its visual attractiveness. However, it is urgently necessary to use modern computer technology for landscape design that effectively utilizes the region's accessible public space. Sun et al. [8] focused on leveraging the Artis plugin, which is especially designed for environment planning, to use computer-aided design in landscape planning. The unique tools in this plugin assist landscape planners in precisely examining the area's features, such as water bodies, planar sections, and topography. Additionally, by incorporating micro-level elements that have a direct impact on the environment, they suggested a four-phased model that facilitates the creation of landscape planning activities.

The Support Vector Machine (SVM) technique is used Xing et al. [9] to optimize landscape art design in CAD. The SVM model is used to direct the CAD modeling process once it has been trained to understand the characteristics and rules of landscape art design. This approach has demonstrated notable processing time benefits and a maximum improvement in modeling accuracy of 26.55% when compared to the comparison algorithm.

Urban cultural legacy is a significant conduit of human history and culture, according to Song Wang's [10] computer learning algorithm idea and naïve Bayesian algorithm model. The current shape and spiritual meaning are the result of long-term accumulation and evolution. China has developed a three-tiered protection system of renowned cities, famous streets, and cultural protection structures because of its successful urban heritage conservation efforts since the reform and opening. The practice of heritage protection has gradually moved from traditional urban architecture protection to anthropology, cultural geography, and other humanities and social sciences as computer-aided CAD system theory in the field of urban heritage continues to mature. CAD systems have also deepened the understanding of "culture" in heritage.

3. Definitions of Multi-Valued Neutrosophic Set (MVNS)

This section shows the definitions and operations of MVNS. The MVNS can be defined as[11], [12]:

$$A = \{(y, T_A(y), I_A(y), F_A(y)) | y \in Y\}$$

Where $T_A(y), I_A(y), F_A(y)$ refers to truth, indeterminacy, and falsity functions which values between [0,1] and satisfy the following condition.

$$0 \leq c, d, e, \leq 1$$

$$0 \leq c^+ + d^+ + e^+ \leq 3$$

$$c \in T_A(y), d \in I_A(y), e \in F_A(y)$$

$$c^+ = \sup T_A(y)\,, d^+ = \sup I_A(y)\,, e^+ = \sup F_A(y)$$

The complement of MVNS is obtained by:

$$A^c = \left(\bigcup\nolimits_{e \in F_A} \{e\}, \bigcup\nolimits_{d \in I_A} \{1-d\}, \bigcup\nolimits_{c \in T_A} \{c\}\right)$$

Let two multi-valued neutrosophic numbers (MVNNs) such as: $A = (T_A, I_A, F_A)$ *and* $B = (T_B, I_B, F_B)$ and their operations are defined by:

$$\omega A = \begin{pmatrix} \bigcup\nolimits_{c_A \in T_A} \left\{\frac{(1+c_A)^\omega - (1-c_A)^\omega}{(1+c_A)^\omega + (1-c_A)^\omega}\right\}, \\ \bigcup\nolimits_{d_A \in I_A} \left\{\frac{2(d_A)^\omega}{(2-d_A)^\omega + (d_A)^\omega}\right\}, \\ \bigcup\nolimits_{e_A \in F_A} \left\{\frac{2(e_A)^\omega}{(2-e_A)^\omega + (e_A)^\omega}\right\} \end{pmatrix}$$

$$A^\omega = \begin{pmatrix} \bigcup\nolimits_{c_A \in T_A} \left\{\frac{2(c_A)^\omega}{(2-c_A)^\omega + (c_A)^\omega}\right\}, \\ \bigcup\nolimits_{d_A \in I_A} \left\{\frac{(1+d_A)^\omega - (1-d_A)^\omega}{(1+d_A)^\omega + (1-d_A)^\omega}\right\}, \\ \bigcup\nolimits_{e_A \in F_A} \left\{\frac{(1+e_A)^\omega - (1-e_A)^\omega}{(1+e_A)^\omega + (1-e_A)^\omega}\right\} \end{pmatrix}$$

$$A \oplus B = \begin{pmatrix} \bigcup\nolimits_{c_A \in T_A, c_B \in T_B} \left\{\frac{c_A + c_B}{1 + c_A c_B}\right\}, \\ \bigcup\nolimits_{d_A \in I_A, d_B \in I_B} \left\{\frac{d_A d_B}{1 + (1-d_A)(1-d_B)}\right\}, \\ \bigcup\nolimits_{e_A \in F_A, e_B \in F_B} \left\{\frac{e_A e_B}{1 + (1-e_A)(1-d_B)}\right\} \end{pmatrix}$$

$$A\otimes B=\begin{pmatrix}\bigcup_{c_A\in T_A,c_B\in T_B}\left\{\frac{c_Ac_B}{1+(1-c_A)(1-c_B)}\right\},\\ \bigcup_{d_A\in I_A,d_B\in I_B}\left\{\frac{d_A+d_B}{1+d_Ad_B}\right\},\\ \bigcup_{e_A\in F_A,e_B\in F_B}\left\{\frac{e_A+e_B}{1+e_Ae_B}\right\}\end{pmatrix}$$

$$\omega A=\begin{pmatrix}\frac{(1+c_A)^\omega-(1+c_A)^\omega}{(1+c_A)^\omega+(1+c_A)^\omega},\\ \frac{2(d_A)^\omega}{(2-d_A)^\omega+(d_A)^\omega},\\ \frac{2(e_A)^\omega}{(2-e_A)^\omega+(e_A)^\omega}\end{pmatrix}$$

Example 1

Let $A=(\{0.6\},\{0.1,0.2\},\{0.2\})$

$\omega=2$

$2\ A\ =$

$$2\otimes A=(\frac{2\times 0.6}{2\times 0.6\ \ +0.1+0.2},\frac{0.1}{2\times 0.6+0.1+0.2},\frac{0.2}{2\times 0.6+0.1+0.2},\frac{0.2}{0.6+0.1+0.2}$$

$=(0.8824,0.1105,0.2439,0.2439)$

$Let\ B\ =(\{0.5\},\{0.3,0.2\},\{0.3\})$

$A\oplus B=$

$T=0.6+0.5-(0.6\times 0.5)=0.8$

$I=0.1+0.3-(0.1\times 0.3)=0.37$

$F=0.2+0.2-(0.2\times 0.2)=0.36$

$A\oplus B=(0.8,0.37,0.36,0.25)$

$A\otimes B=$

$T=0.6\times 0.5=0.3, I=0.1\times 0.3=0.03, F=0.2\times 0.2=0.04$

$A\otimes B=(0.3,0.03,0.04,0.25)$

Example 2

Let $C=(\{0.7\},\{0.2,0.3\},\{0.3\})$

$\omega=1.5$

$1.5\otimes C=$

$T = \frac{1.5\times0.7}{1.5\times0.7+0.2+0.3} = 0.7778, I = 0.1111, F = 0.1667,$

$\Rightarrow 1.5 \otimes C = (0.7778, 0.1111, 0.1667, 0.3)$

$Let\ D = (\{0.4\}, \{0.5, 0.1\}, \{0.4\})$

$C \oplus D =$

$T = 0.7 + 0.4 - (0.7 \times 0.4) = 0.82, I = 0.2 + 0.5 - (0.2 \times 0.5) = 0.6, F = 0.3 + 0.1 - (0.3 \times 0.1)$

$= 0.37 \Rightarrow C \oplus D = (0.82, 0.6, 0.37, 0.35$

Example 3

$Let\ E = (0.5, 0.3, 0.4, 0.2)$

$\omega = 3$

$3 \otimes E =$

$T = \frac{3\times0.5}{3\times0.5+0.3+0.4} = 0.7895, I = 0.1579, F = 0.2105$

$Let\ F = (\{0.6\}, \{0.1, 0.2\}, \{0.3\})$

$E \otimes F = (0.3, 0.03, 0.08, 0.25)$

$E \oplus F = (0.8, 0.37, 0.52, 0.25)$

4. Results

This section shows the criteria weights and ranking the alternatives of Quality Evaluation of Public Landscape Space Design Surrounding Historic and Cultural Districts Based on Computer-Aided Design. This study uses eight criteria and seven alternatives such as:

- Historical Context Integration
- Spatial Functionality
- Aesthetic Harmony
- Environmental Sustainability
- User Accessibility and Inclusion
- Digital Simulation Accuracy
- Maintenance Feasibility
- Community Participation in Design

The alternatives are:

- Heritage Core Garden
- Interactive Cultural Plaza
- Green Corridor with Smart Lighting
- Eco-Recreational Park
- Historical Timeline Walkway

- Urban Oasis with Digital Wayfinding
- Cultural Amphitheater Garden

Steps of the implementation of the methodology are introduced such as:

- Evaluate the criteria and alternatives using the opinions of experts and decision makers.

- Combine the opinions of experts and decision makers.

- Weights of criteria are computed using the average method.

- Rank the alternatives based on the highest value in the weighted matrix.

Four experts use MVNNs to evaluate the criteria and alternatives as shown in Table 1. These numbers are converted to crisp values as shown in Figures 1-4. The criteria weights are computed using the average method such as 0.190556491, 0.165261382, 0.052276561, 0.150084316, 0.10286678, 0.097807757, 0.21753794, 0.023608772.

Table 1. Opinions of experts.

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	({0.4} ,{ 0.1} , {0.2})	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})
A_2	({0.4} ,{ 0.1} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} , {0.2} ,{ 0.3})	({0.6} , {0.2} , {0.2,0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} ,{ 0.1} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})
A_3	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.5} , {0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.6} , {0.2} , {0.2,0.3})
A_4	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.5} , {0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} , {0.2} ,{ 0.3})
A_5	({0.6} , {0.2} , {0.2,0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.5} , {0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})
A_6	({0.6} , {0.2} , {0.2,0.3})	({0.6} , {0.2} , {0.2,0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} , {0.2} ,{ 0.3})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})
A_7	({0.4} , {0.2} ,{ 0.3})	({0.4} , {0.2} ,{ 0.3})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} , {0.2} ,{ 0.3})	({0.4} , {0.2} ,{ 0.3})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.6} , {0.2} , {0.2,0.3})
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	({0.7} ,{ 0.1,0.2} , {0.2})	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})
A_2	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} , {0.2} ,{ 0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})
A_3	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.6} , {0.2} , {0.2,0.3})
A_4	({0.4} ,{ 0.1} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.5} , {0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} ,{ 0.1} , {0.2})	({0.5} , {0.2} , {0.1})	({0.4} , {0.2} ,{ 0.3})
A_5	({0.4,0.5} ,{ 0.2} , {0.1})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} ,{ 0.1} , {0.2})	({0.5} , {0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.6} , {0.2} , {0.2,0.3})
A_6	({0.7} ,{ 0.1,0.2} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} , {0.2} ,{ 0.3})
A_7	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} , {0.2} ,{ 0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} , {0.2} ,{ 0.3})	({0.6} , {0.2} , {0.2,0.3})
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	({0.4} ,{ 0.1} , {0.2})	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})
A_2	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} , {0.2} ,{ 0.3})	({0.6} , {0.2} , {0.2,0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} ,{ 0.1} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})
A_3	({0.4} , {0.2} ,{ 0.3})	({0.4} ,{ 0.1} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.5} , {0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.6} , {0.2} , {0.2,0.3})
A_4	({0.6} , {0.2} , {0.2,0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.4} , {0.2} ,{ 0.3})	({0.4} , {0.2} ,{ 0.3})
A_5	({0.7} ,{ 0.1,0.2} , {0.2})	({0.4} , {0.2} ,{ 0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4,0.5} ,{ 0.2} , {0.1})
A_6	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} , {0.2} ,{ 0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.4} , {0.2} ,{ 0.3})
A_7	({0.5} , {0.2} , {0.1})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.6} , {0.2} , {0.2,0.3})	({0.4} , {0.2} ,{ 0.3})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.6} , {0.2} , {0.2,0.3})
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	({0.4} , {0.2} ,{ 0.3})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.6} , {0.2} , {0.2,0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.5} , {0.2} , {0.1})
A_2	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.4} ,{ 0.1} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})
A_3	({0.4,0.5} ,{ 0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.5} , {0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.3} ,{ 0.1,0.2} ,{ 0.4})
A_4	({0.5} , {0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.6} , {0.2} , {0.2,0.3})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.5} , {0.2} , {0.1})	({0.6} , {0.2} , {0.2,0.3})	({0.6} , {0.2} , {0.2,0.3})
A_5	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.4} ,{ 0.1} , {0.2})	({0.5} , {0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.5} , {0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})
A_6	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.5} , {0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.4,0.5} ,{ 0.2} , {0.1})	({0.4} ,{ 0.1} , {0.2})	({0.5} , {0.2} , {0.1})
A_7	({0.4} ,{ 0.1} , {0.2})	({0.3} ,{ 0.1,0.2} ,{ 0.4})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.7} ,{ 0.1,0.2} , {0.2})	({0.6} , {0.2} , {0.2,0.3})	({0.5} , {0.2} , {0.1})	({0.4,0.5} ,{ 0.2} , {0.1})

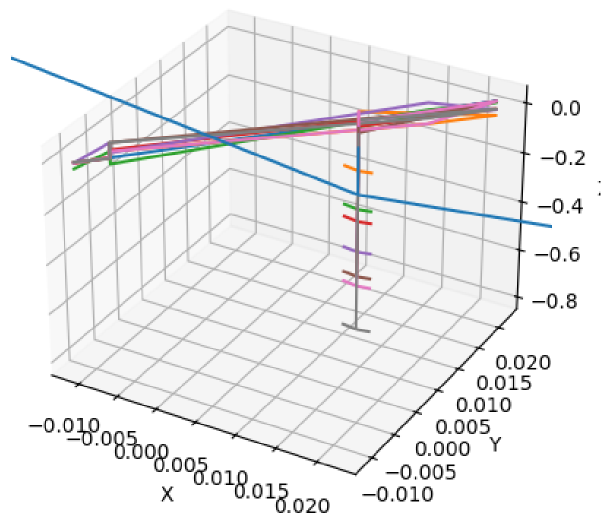

Figure 1. First crisp values.

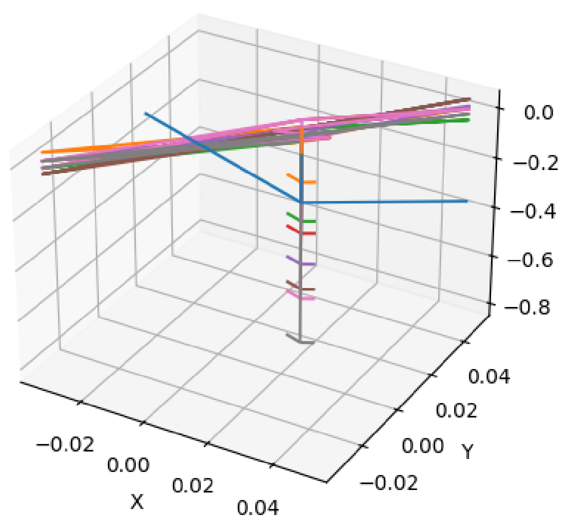

Figure 2. Second crisp values.

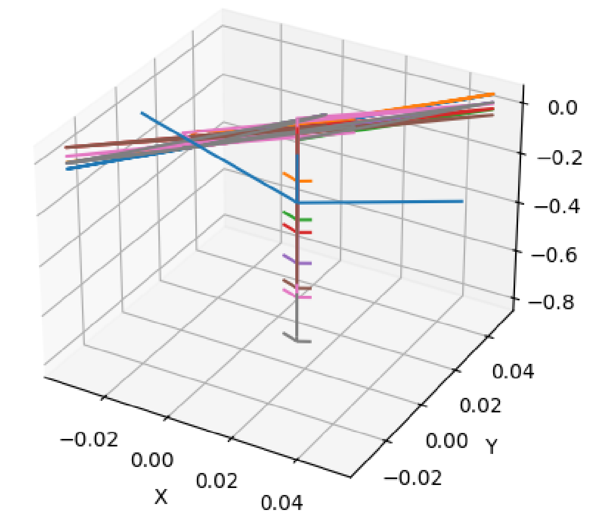

Figure 3. Third crisp values.

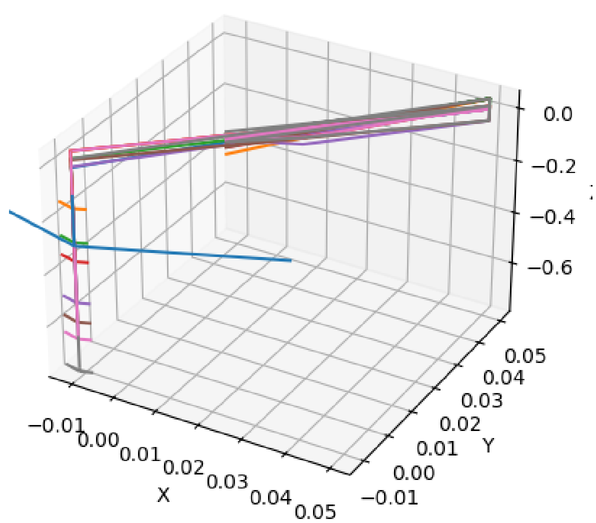

Figure 4. Fourth crisp values.

Weighted matrix are computed as shown in Figure 5. The alternatives are ranked as shown in Figure 6. The results show alternative 1 is the best and alternative 7 is the worst.

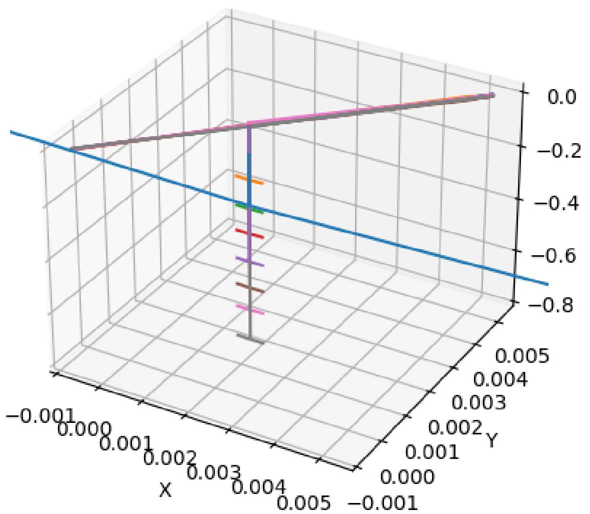

Figure 5. Weighted matrix.

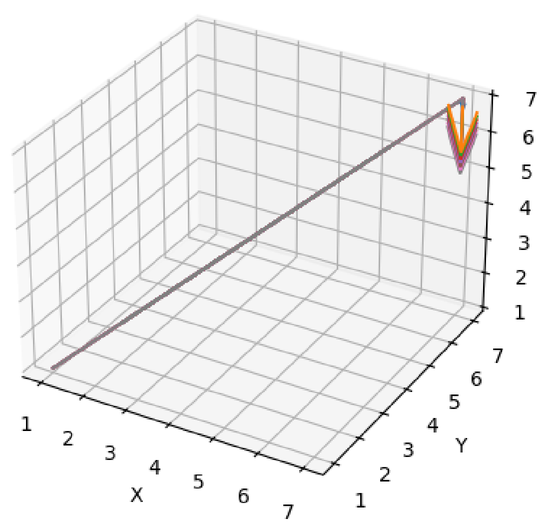

Figure 6. Rank of alternatives.

5. Implications

I. Enhanced Decision-Making for Urban Planners: The use of CAD in evaluating design quality enables planners to visualize, simulate, and refine landscape concepts with precision, leading to more informed and culturally sensitive development strategies.

II. Preservation of Cultural Identity: CAD-based evaluations allow for a careful balance between modern functionality and historical preservation, ensuring that development does not compromise the unique identity of cultural districts.

III. Objective and Repeatable Assessment: A structured evaluation model using CAD metrics (e.g., spatial accuracy, environmental simulations) promotes consistency in design quality assessments, making the process more transparent and reproducible.

IV. Community-Centered Design Innovation: Quality evaluation frameworks highlight the importance of inclusive and participatory design. By assessing how well public input is integrated, CAD tools can support more democratic and responsive landscape planning.

V. Integration of Technology in Heritage Conservation: This evaluation approach illustrates how modern technologies like BIM (Building Information Modeling) and AR (Augmented Reality) can be used to respect, visualize, and maintain heritage sites.

VI. Support for Interdisciplinary Collaboration: Combining historical expertise, architecture, environmental science, and computer modeling fosters multidisciplinary innovation in public space design and evaluation.

6. Conclusions

The quality evaluation of public landscape space design surrounding historic and cultural districts using Computer-Aided Design (CAD) tools marks a critical step toward harmonizing heritage conservation with modern urban development. This approach enables a comprehensive and data-supported analysis of design alternatives, ensuring alignment with cultural values, environmental standards, and user needs. The study demonstrates that CAD-based evaluation frameworks can enhance transparency, repeatability, and stakeholder collaboration in design processes. Importantly, such systems empower planners to anticipate the visual, functional, and environmental implications of proposed landscape interventions before physical implementation. This study used the multi-valued neutrosophic sets to overcome uncertainty and vague information. We showed the definitions of multi-valued neutrosophic numbers and their operations. We computed the criteria weights and ranking the alternatives. Moving forward, the integration of advanced technologies—such as artificial intelligence, augmented reality, and real-time participatory platforms—will further refine these evaluations. Ultimately, CAD-based landscape quality assessments offer a forward-looking solution for preserving the integrity of cultural districts while meeting contemporary public space demands.

7. Future Directions

I. Development of AI-Integrated Evaluation Systems: Future evaluation frameworks may incorporate artificial intelligence and machine learning to automate the analysis of design elements and predict public engagement levels based on previous projects.

II. Real-Time Public Feedback Mechanisms: Incorporating real-time digital platforms that allow citizens to interact with CAD designs and offer input can enhance participatory planning and refine evaluation criteria.

III. Creation of Standardized CAD Evaluation Protocols: Establishing universal guidelines for assessing CAD-based public landscape designs will improve quality control and promote international best practices in heritage-sensitive environments.

IV. Augmented and Virtual Reality Enhancements: Using AR/VR in CAD environments can help simulate pedestrian experiences, seasonal changes, or historical overlays, enabling more immersive quality evaluations before implementation.

V. Environmental Simulation Integration: Future CAD evaluation systems should integrate climate modeling and environmental impact predictions (e.g., carbon footprint, thermal comfort) to enhance sustainability.

VI. Mobile and Cloud-Based Evaluation Platforms: Enabling cloud-based access to CAD evaluation models can facilitate stakeholder collaboration and allow decentralized contributions from various disciplines and geographic locations.

VII. Dynamic Updating of Evaluation Criteria As societal values shift, evaluation models must adapt. Future frameworks should incorporate adaptive criteria responsive to evolving cultural, environmental, and accessibility needs.

VIII. Expanded Use in Other Contexts This approach could be extended to evaluate other culturally sensitive landscapes, such as indigenous lands, sacred sites, or post-industrial heritage areas.

Acknowledgements

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