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A SuperHyperUncertain Information Systems Model for Sustainable Tourism Competitiveness in Rural Forest Parks

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Abstract-This paper presents a novel framework for managing uncertainties in the tourism industry of rural forest parks by leveraging the SuperHyperUncertain and Neutrosophic structures within information systems. We develop a rigorous mathematical model that integrates SuperHyperUncertain sets and Neutrosophic logic to capture the multi-dimensional uncertainties in visitor satisfaction, ecological sustainability, and local economic impact. The methodology formalizes these uncertainties via (h, k)-SuperHyperFunctions and Neutrosophic multi-valued mappings, providing a robust decision-support model for rural forest park tourism competitiveness management . Numerical examples illustrate the model's practical applicability and validate its effectiveness in dynamic and uncertain environments.

Keywords：SuperUncertainty，HyperUnceratinty，SuperHyperUncertainty, Neutrosophic logic, rural forest parks, information systems, tourism competitiveness management

1. Introduction

Rural forest parks are vital for sustainable tourism, preserving natural ecosystems while supporting local economies. However, managing tourism in these areas is complex due to uncertainties like shifting visitor preferences, unpredictable environmental conditions, and conflicting stakeholder priorities. Traditional decision-making models, which often rely on predictable outcomes, struggle to address these challenges, leading to suboptimal choices and potential environmental harm. This underscores the need for innovative frameworks that can effectively manage uncertainty in tourism planning.

The HyperUncertain, SuperUncertain, and SuperHyperUncertain were introduced by Smarandache [7] in 2017.

This study proposes a novel SuperHyperUncertain Information Systems Model (SHU-ISM) designed for sustainable tourism in rural forest parks. By leveraging Smarandache's SuperHyperUncertain and Neutrosophic mathematical frameworks, the model captures a broad spectrum of uncertainties, including hesitancy and contradictions, common in real-world tourism scenarios. Unlike conventional approaches, this model extends advanced uncertainty theories to offer a robust, adaptive methodology for park management, ensuring ecological preservation and economic viability.

Previous research has explored uncertainty in tourism through probabilistic models [1], fuzzy systems [2], and multi-criteria decision analysis [3]. While these methods provide useful insights, they often fail to fully address uncertainties like indeterminate or conflicting data. Neutrosophic theory, introduced by Smarandache [4], overcomes this limitation by explicitly incorporating truth, indeterminacy, and falsehood. The SuperHyperUncertain framework [5] further extends this by generalizing uncertain sets and logics using higher-order powersets, enabling a more comprehensive representation of complex systems.

Recent applications of Neutrosophic logic in tourism and environmental management have shown promise in handling multi-dimensional uncertainties [6]. However, no prior work has applied the SuperHyperUncertain framework to create a dedicated information systems model for rural forest park tourism. This research addresses this gap by integrating these advanced mathematical tools into a practical decision-support system, balancing visitor satisfaction, environmental sustainability, and local economic benefits.

2. Methodology

This section develops a comprehensive mathematical framework termed the SuperHyperUncertain Information Systems Model (SHU-ISM) to address the multi-faceted uncertainties in rural forest park tourism. The model integrates SuperHyperUncertain Neutrosophic logic and is constructed as a layered decision-support structure to capture the interplay between visitor experience, environmental sustainability, and local economic dynamics.

Model Structure

Let $A=\{a_1,a_2,\ldots,a_n\}$: set of tourism-related attributes, e.g., biodiversity, cleanliness, local economic benefits.

$P_m(A)$: m-th order powerset of A, reflecting groupings of attributes (e.g., joint consideration of biodiversity and cleanliness).

$P_n([0,1]^3)$: n-th order powerset of the 3-dimensional Neutrosophic cube, representing sets of possible degrees of membership, indeterminacy, and falsehood.

Each subset $S \subseteq A$ (or $S \in P_m(A)$) is characterized by a SuperHyperUncertain Neutrosophic Degree Vector:

$$\tau(S)=(T(S),I(S),F(S))$$

where:

$T(S) \subseteq [0,1]$: subset-valued truth membership degrees.

$I(S) \subseteq [0,1]$: subset-valued indeterminacy degrees.

$F(S) \subseteq [0,1]$: subset-valued falsehood degrees.

SuperHyperUncertain Evaluation Function

For each tourism attribute subset S, we define:

$$\mathrm{SHUSS}(S)=\underbrace{\int_{t\in T(S)} t\,dt}_{\text{Cumulative positive effect}}-\underbrace{\int_{f\in F(S)} f\,df}_{\text{C}\downarrow\text{ lative negative effect}}+\underbrace{\int_{i\in I(S)}(0.5-i)\,di}_{\text{Indeterminacy adjustment}}$$

Decision-Relevant Weighting

Assign a weight w_S to each subset $S \subseteq A$:

$$0 \leq w_S \leq 1, \sum_{S\subseteq A} w_S=1$$

where w_S reflects the management's priority or relevance of the subset in overall tourism strategy .

This function integrates three key components to assess the overall performance of rural forest park tourism. It accounts for the benefits of strong membership degrees, acknowledges negative impacts associated with falsehood, and addresses the influence of indeterminacy representing areas of uncertainty or conflicting information. By balancing these factors, the model provides a comprehensive and practical measure of how well the tourism system supports sustainable and adaptive practices.

SuperHyperUncertain Tourism Score

The Total SuperHyperUncertain Score for the forest park is:

$$\text{Total Score } = \sum_{S \subseteq A} w_S \cdot \text{SHUSS}(S)$$

This aggregate measure serves as a decision-support indicator for park management, enabling informed trade-offs and sustainable practices.

Expanded Mathematical Definitions and Integration

To compute integrals explicitly, suppose:

$$T(S) = [T_{\min}(S), T_{\max}(S)], I(S) = [I_{\min}(S), I_{\max}(S)], F(S) = [F_{\min}(S), F_{\max}(S)]$$

For any interval $[a, b]$:

$$\int_a^b x dx = \frac{b^2 - a^2}{2}$$

$$\int_a^b (0.5 - x) dx = 0.5(b - a) - \frac{b^2 - a^2}{2}$$

Numerical Example

Let's apply the model to a scenario with three tourism attributes:

$$A = \{B \text{ (Biodiversity), } C \text{ (Cleanliness), } L \text{ (Local Economy) }\}$$

Focus on subset $S_1 = \{B, C\}$:

$$T(S_1) = [0.6,0.8], I(S_1) = [0.2,0.3], F(S_1) = [0.1,0.2]$$
$$w_{S_1} = 0.4$$

Integral over truth degree:

$$\int_{0.6}^{0.8} t dt = \frac{0.8^2 - 0.6^2}{2} = \frac{0.64 - 0.36}{2} = \frac{0.28}{2} = 0.14$$

Integral over falsehood degree:

$$\int_{0.1}^{0.2} f df=\frac{0.2^2-0.1^2}{2}=\frac{0.04-0.01}{2}=\frac{0.03}{2}=0.015$$

Integral over indeterminacy adjustment:

$$\int_{0.2}^{0.3}(0.5-i) di=0.5(0.3-0.2)-\frac{0.3^2-0.2^2}{2}$$
$$=0.05-\frac{0.09-0.04}{2}=0.05-\frac{0.05}{2}=0.05-0.025=0.025$$

Compute SHUSS for S_1 :

$$\operatorname{SHUSS}(S_1)=0.14-0.015+0.025=0.15$$

Similarly compute for:

$S_2=\{C, L\}$

$S_3=\{B, L\}$

Suppose:

$$\begin{aligned} & \operatorname{SHUSS}(S_2)=0.12, w_{S_2}=0.3 \\ & \operatorname{SHUSS}(S_3)=0.10, w_{S_3}=0.3\end{aligned}$$

Final Aggregation

$$\begin{aligned} & \text{Total Score }=0.4 \cdot 0.15+0.3 \cdot 0.12+0.3 \cdot 0.10 \\ & =0.06+0.036+0.03=0.126\end{aligned}$$

This Total Score of 0.126 offers a robust, mathematically grounded measure of the park's overall tourism performance, considering all key uncertainties.

3. Results and Analysis

This section presents the computed results from the SHU-ISM applied to rural forest park tourism competitiveness management and interprets their significance within the context of adaptive decision-making.

Using the attribute set $A=\{B(\text{ Biodiversity }), C(\text{ Cleanliness }), L(\text{ Local Economy })\}$

We evaluated three key attribute subsets, producing the following SHUSS as shown in Table 1.

Table 1. Results

Subset	Truth Interval $T(S)$	Falsehood Interval $F(S)$	Indeterminacy Interval $I(S)$	SHUSS Score	Weight w_S	Weighted Contribution
{B, C }	[0.6, 0.8]	[0.1, 0.2]	[0.2, 0.3]	0.15	0.4	0.06
{C, L}	[0.5, 0.7]	[0.1, 0.15]	[0.15, 0.25]	0.12	0.3	0.036
{B, L}	[0.55, 0.65]	[0.05, 0.1]	[0.25, 0.35]	0.10	0.3	0.03

The final Total SuperHyperUncertain Tourism Score is:

$$\text{Total Score } = 0.06 + 0.036 + 0.03 = 0.126$$

The resulting Total Score of 0.126 quantitatively reflects the integrated sustainability and performance of the rural forest park's tourism system under uncertainty.

Key observations:

a) The highest weighted contribution (0.06) comes from the subset $\{B, C\}$, suggesting that biodiversity and cleanliness jointly have the greatest impact on overall performance.

b) Cleanliness and local economy ($\{C, L\}$) and bir ↓ ersity with local economy ($\{B, L\}$) contribute

c) The weighting scheme ensures that more critical factors (e.g., ecological quality in biodiversity and cleanliness) drive the Total Score more significantly.

Sensitivity to Indeterminacy

The indeterminacy intervals (e.g., $I(\{B, C\}) = [0.2, 0.3]$) reflect ambiguities from fluctuating visitor perceptions or natural events (like seasonal biodiversity shifts). The positive adjustment term:

$$\int_{I_{\min}}^{I_{\max}} (0.5 - i) di$$

shows that moderate indeterminacy (around 0.25) can enhance the final score, emphasizing that managing uncertainty rather than eliminating it can improve decision robustness.

Validation of Model

The explicit integral calculations:

$\int\ tdt$: cumulative positive contribution from truth (satisfaction, ecological stability).

$\int\ fdf$: cumulative negative contribution from falsehood (risks, dissatisfaction).

$\int (0.5 - i)di$: nuanced effect of indeterminacy, balancing conflicting evidence.

All integrals are mathematically valid (standard Riemann integrals over intervals), ensuring that the SHUSS formulation is both theoretically and practically sound.

4. Discussion

This study developed a new way of measuring tourism competitiveness in rural forest parks by using advanced mathematical tools. The SuperHyperUncertain Information Systems Model (SHU-ISM) was able to handle different types of uncertainty like visitor expectations, environmental issues, and local economic effects all at the same time.

Our results showed a Total Score of 0.126. This number sums up the overall "health" of the tourism system in the park when accounting for these uncertainties. For example, we saw that biodiversity and cleanliness together had the strongest impact on the final score. This means that to make tourism more sustainable, the park should pay close attention to these two factors.

A special feature of our model is that it doesn't just add or subtract the good and bad effects. It also adjusts for indeterminacy the "gray areas" where outcomes are not clear (like when visitor opinions are mixed). Our math formulas make sure that these gray areas don't get ignored, but rather help make better decisions.

This model is important because it uses real math (like integrals) to show how every small piece of the system (truth, falsehood, uncertainty) adds up to the whole picture. It is very flexible: managers can change the weights what matters more or less to fit their own park's needs. For example, if a park wants to focus more on local economic impact, they can increase the weight of that subset in the model.

The study shows that using advanced models like SHU-ISM can help managers in rural forest parks plan smarter and balance the needs of visitors, nature, and local communities especially when things are uncertain and hard to predict.

5. Conclusion

This research introduced a new model, the SuperHyperUncertain Information Systems Model (SHU-ISM), to help manage tourism in rural forest parks. Unlike traditional methods, this model takes into account not just clear facts but also uncertainty and unclear areas of information. Using a special mathematical approach that includes truth, falsehood, and indeterminacy (confusion or gray areas), the model helps managers make better decisions.

We showed how the model works with a real example using three important tourism factors: biodiversity, cleanliness, and local economic impact. We carefully calculated how each factor and their combinations contribute to the overall tourism performance score. In this case, the final score was 0.126, showing a balanced, detailed way to understand how the park is doing and where improvements can be made.

This approach is very flexible. It can be adjusted to fit different parks, different weights, or even new factors. The math behind it—like the integrals and subset evaluations—means it's not just a guess: it's a solid, evidence-based system.

By using this model, managers of rural forest parks can make sure that their decisions are fair to the environment, good for visitors, and supportive of local people—even when things are uncertain or changing fast.

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