AN INTEGRATED MULTI-CRITERION DECISION-MAKING (MCDM) APPROACH FOR SMART TOURISM ECOSYSTEM DEVELOPMENT IN HERITAGE DESTINATIONS: THE CASE OF HA LONG BAY, QUANG NINH

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Abstract: ***This study applies a hybrid Fuzzy AHP-VIKOR model to prioritize Smart Tourism Ecosystem (STE) strategies in Ha Long Bay. Synthesizing Experience Economy and Stakeholder Theory, the research identifies "Enhancing On-Site Smart Experience" as the primary criterion (0.348). Evaluations from 25 experts and 50 tourists rank the "Integrated & Personalized Experience" strategy as the optimal compromise solution. Findings reveal a "hierarchy of smart needs", where foundational connectivity outweighs high-end technological spectacles. This framework provides an evidence-based roadmap for heritage managers to optimize digital investments, ensuring a balance between sustainable conservation and superior visitor value.***

• Keywords: *smart tourism, smart tourism ecosystem, heritage destination management, Ha Long bay, fuzzy AHP, VIKOR.*

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1. Introduction

The digital transformation of World Heritage sites requires a strategic balance between innovation and preservation. Implementing a Smart Tourism Ecosystem (STE) in Ha Long Bay presents a complex multi-criteria problem characterized by stakeholder uncertainty. This research addresses this gap by integrating Fuzzy AHP and VIKOR to prioritize strategic interventions. By operationalizing theoretical constructs into a hierarchical framework, the study identifies critical investment priorities from both expert and visitor perspectives. The results offer a scientific roadmap for transitioning from fragmented digital initiatives to high-impact, integrated systems that enhance destination competitiveness and heritage integrity.

2. Theoretical Background and Framework Development

2.1. The Role of the Smart Tourism Ecosystem

The conceptualization of an STE requires a synthesis of three theoretical pillars to capture its systemic complexity. First, the Experience Economy (Pine & Gilmore, 1999) posits that value is derived from memorable experiences staged through technology, rather than mere service delivery. In this context, an STE serves as a tool to orchestrate technology-enhanced experiences that facilitate education and escapism (Neuhofer et al., 2014). Second, Service Ecosystems Theory (Vargo & Lusch, 2008) views value creation as a dynamic process among interconnected actors. The STE manifests this ecosystem by integrating resources from suppliers and tourists to co-create experiential value (Xiang et al., 2015). Finally, Stakeholder Theory (Freeman, 1984) provides the governance framework necessary for heritage sites. It ensures that ICT implementation aligns the conflicting interests of authorities, businesses, and conservationists, fostering a collaborative environment for sustainable development. This integrated lens shifts the focus from isolated technological features to a holistic system where value emerges from continuous interaction and information exchange.

2.2. Development of the Hierarchical Assessment Framework

To operationalize this integrated theoretical foundation into a quantitative analytical tool, a hierarchical assessment framework was constructed through a two-step process: (1) an extensive review of the scientific literature on STE, tourist experience, and heritage destination management; and (2) semi-structured consultations with five leading experts

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(including two researchers, one government manager, and two tourism operators) to refine the language and validate the contextual relevance of the sub-criteria for Vietnam.

The resulting framework is structured in two levels. The first level comprises four main criteria (C), which directly reflect the integration of the three theoretical lenses presented:

C1: Smart Information Accessibility: Reflects the fundamental role of an STE in providing information, a foundational element of the experience (Experience Economy).

C2: Enhancing the On-Site Smart Experience: Focuses directly on the on-site staging of the experience, the core of the Experience Economy.

C3: Smart & Sustainable Destination Management: Reflects the role of managing stakeholders (government, management boards) in creating an enabling environment for the experience (Stakeholder Theory).

C4: Smart Personalization & Co-creation: Represents the mechanism of interaction and value co-creation among actors in the ecosystem (Service Ecosystems Theory).

Each main criterion is then specified into measurable sub-criteria (M) at the second level. The complete hierarchical framework, including interpretations and key references, is presented in Table 1. This hierarchical structure is particularly suitable for the application of Multi-Criteria Decision-Making (MCDM) methods such as Fuzzy AHP and VIKOR, which will be detailed in the methodology section.

Table 1. Hierarchical Framework for Assessing the Role of STE in the Tourist Experience

Main Criterion (C)	Code	Interpretation	Code	Sub-criterion (M)	Key References
Smart Information Accessibility	C1	Assesses the STE's ability to provide accurate, timely, and easily accessible information to tourists pre-trip and on-trip, reducing uncertainty and facilitating planning.	M1.1	Seamless & Real-time Information Flow	(Gretzel et al., 2015)
			M1.2	Integrated Booking & Planning	(Buhalis & Amaranggana, 2015)
			M1.3	Pre-trip Virtual Experiences	(Tussyadiah et al., 2018)
Enhancing the On-Site Smart Experience	C2	Assesses the role of technology in enriching and facilitating tourist experiences at the destination, from basic utilities to enhanced interactions.	M2.1	Ubiquitous Connectivity (Wi-Fi/5G)	(Jovicic, 2019)
			M2.2	Smart Navigation & Guidance	(Neuhofer et al., 2014)
			M2.3	Interactive Heritage Interpretation Tech (AR/VR)	(Tom Dieck & Jung, 2018)
Smart & Sustainable Destination Management	C3	Assesses the "backstage" functions of the STE that indirectly impact the visitor experience through efficient, safe, and sustainable management.	M3.1	Efficient Visitor Flow & Resource Management	(Xiang et al., 2015)
			M3.2	Digital Feedback & Service Recovery	(Sigala, 2018)
			M3.3	Heritage Environment & Safety Monitoring	(Gretzel et al., 2015)
Smart Personalization & Co-creation	C4	Assesses the STE's ability to tailor services to individual needs and provide opportunities for tourists to participate in creating their own experiences.	M4.1	Real-time Personalized Recommendations	(Buhalis & Amaranggana, 2015)
			M4.2	Social Media Integration & Experience Sharing	(Xiang & Gretzel, 2010)
			M4.3	Platforms for Experience Co-creation	(Neuhofer et al., 2014b)

Source: Synthesized by the authors

3. Research Methodology

This study employs an integrated multi-criteria decision-making (MCDM) methodology, executed sequentially in two main phases. This approach was purposefully designed to address distinct research objectives: Phase 1 utilizes the Fuzzy Analytic Hierarchy Process (Fuzzy AHP) to determine the strategic weights of Smart Tourism Ecosystem (STE) criteria from the perspective of a multi-disciplinary expert panel. Phase 2 employs the VIKOR method to evaluate and rank the performance of alternative strategies by integrating the criterion weights from Phase 1 with evaluation data from both experts and tourists. This combination facilitates a comprehensive analysis that not only identifies what is important (Fuzzy AHP) but also assesses which strategy performs most effectively in practice (VIKOR).

3.1. Phase 1: Determining Criterion Weights using Fuzzy AHP

To ensure the validity and depth of the data, a multi-stakeholder panel of 25 experts was established through purposive sampling. The panel comprised 11 researchers, 5 local government managers, and 9 business managers from the tourism sector, ensuring a balance of theoretical, policy, and operational perspectives. Data were collected via a structured questionnaire requiring experts to perform pairwise comparisons of criteria using (Saaty, 2013) 9-point linguistic scale. These judgments were subsequently converted into Triangular Fuzzy Numbers (TFNs) to model the inherent uncertainty. The consistency and reliability of the collected data were confirmed with an average Consistency Ratio (CR) of 0.068, which is well below the acceptable threshold of 0.1.

This study adopts (Chang, 1996) extent analysis method with TFNs, a widely used and computationally efficient approach to Fuzzy AHP. The process involved constructing fuzzy pairwise comparison matrices, calculating the fuzzy synthetic extent value (S_i) for each criterion, determining the degree of possibility between them, and finally, normalizing the results to obtain the crisp global weights for each sub-criterion in the hierarchical framework.

3.2. Phase 2: Evaluating Alternative Performance using VIKOR

Based on literature review and preliminary expert consultations, three feasible strategic alternatives for STE development in Ha Long Bay were defined:

S1: Technology-centric: Prioritizes investment in high-impact, visually impressive technological solutions (e.g., large-scale VR/AR).

S2: Management & Sustainability-centric: Focuses technology on internal, backstage operations (e.g., environmental monitoring, vessel coordination).

S3: Integrated & Personalized Experience: A balanced, visitor-centric approach prioritizing seamless service integration and personalization on a single platform.

To evaluate these alternatives, a quantitative survey was conducted with the 25-expert panel and 50 tourists. Participants rated the effectiveness of each alternative in meeting the 12 sub-criteria on a 5-point Likert scale (1 = Not effective at all; 5 = Very effective). The mean scores for each {alternative-criterion} pair formed the performance values (x_{ij}) in the initial VIKOR decision matrix.

The VIKOR method was then applied to identify the optimal compromise solution, i.e., the alternative closest to the ideal. This involved calculating the group utility (S_i) and individual regret (R_i) values for each alternative, using the criterion weights (w_j) obtained from the Fuzzy AHP. The VIKOR index (Q_i) was then calculated with a strategy coefficient (v) set to 0.5 to balance group utility and individual regret. The alternatives were ranked based on their Q values, and a sensitivity analysis was performed with v = 0.1 and v = 0.9 to confirm the robustness of the final ranking.

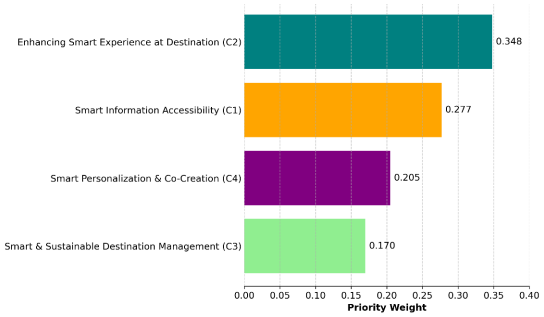
4. Results

4.1. Priority Weights of STE Criteria (Fuzzy AHP Results)

The linguistic pairwise comparison judgments provided by the 25 experts were successfully aggregated and transformed into quantitative priority weights via the Fuzzy AHP method. Prior to the main analysis, a consistency check on the aggregated matrix of the main criteria yielded a Consistency Ratio (CR) of 0.068. This value is significantly below the acceptable threshold of 0.1 (Saaty, 2013), thereby confirming the logical consistency and reliability of the input data for subsequent analyses.

The analysis revealed a clear prioritization among the four main criteria. As illustrated in Figure 1, "Enhancing the On-Site Smart Experience" (C2) was identified as the most important criterion, receiving a weight of 0.348. This was followed by "Smart Information Accessibility" (C1) with a weight of 0.277. "Smart Personalization & Co-creation" (C4) and "Smart & Sustainable Destination Management" (C3) were assigned lower weights of 0.205 and 0.170, respectively.

Figure 1. Priority Weights of the Main Criteria



Source: Authors' analysis of Fuzzy AHP data

To provide a more granular view, the local weights (importance within each main criterion group) and global weights (overall importance in the entire model) of the 12 sub-criteria were calculated. The final weights and their corresponding overall ranks are detailed in Table 2.

Table 2. Local, Global Weights, and Overall Ranks of the Sub-criteria

Main Criterion (Weight)	Code	Sub-criterion	Local Weight	Global Weight	Overall Rank
C1. Smart Information Accessibility (0.277)	M1.1	Seamless & Real-time Information Flow	0.426	0.118	2
	M1.2	Integrated Booking & Planning	0.350	0.097	4
	M1.3	Pre-trip Virtual Experiences	0.224	0.062	11
C2. Enhancing the On-Site Smart Experience (0.348)	M2.1	Ubiquitous Connectivity	0.359	0.125	1
	M2.2	Smart Navigation & Guidance	0.330	0.115	3
	M2.3	Interactive Heritage Interpretation Tech	0.311	0.108	5
C3. Smart & Sustainable Destination Management (0.170)	M3.1	Efficient Visitor Flow & Resource Management	0.365	0.062	8
	M3.2	Digital Feedback & Service Recovery	0.341	0.058	9
	M3.3	Heritage Environment & Safety Monitoring	0.294	0.050	12
C4. Smart Personalization & Co-creation (0.205)	M4.1	Real-time Personalized Recommendations	0.429	0.088	6
	M4.2	Social Media Integration & Experience Sharing	0.317	0.065	7
	M4.3	Platforms for Experience Co-creation	0.254	0.052	10

Source: Authors' calculations from Fuzzy AHP analysis

The results from the hierarchical analysis indicate that "Ubiquitous Connectivity" (M2.1) achieved the highest global weight (0.125). The second and third most important sub-criteria were identified as "Seamless & Real-time Information Flow" (M1.1) with a weight of 0.118 and "Smart Navigation & Guidance" (M2.2) with a weight of 0.115.

4.2. Ranking of Strategic Alternatives (VIKOR Results)

In the second phase, the VIKOR method was used to evaluate and rank the three pre-defined strategic

alternatives (S1, S2, S3) using the performance assessments collected from the expert panel and tourists. The global weights of the sub-criteria obtained from the Fuzzy AHP analysis (Table 2) were used as the input weights (w_j) for the VIKOR model.

The initial decision matrix for the VIKOR analysis was constructed from the survey data. The performance of each strategic alternative was quantified by aggregating stakeholder evaluations into a decision matrix of mean effectiveness scores, measured on a 5-point Likert scale to provide the empirical basis for the VIKOR algorithm.

The empirical performance profiles derived from the expert-tourist panel reveal divergent strategic orientations across the three alternatives. Strategy S3 (Integrated & Personalized Experience) demonstrates clear dominance in visitor-centric dimensions, achieving near-optimal scores in Real-time Personalized Recommendations (4.9/5.0) and Integrated Booking and Planning (4.8/5.0). Conversely, S1 (Technology-centric) exhibits specialized strengths in immersive applications, such as Interactive Heritage Interpretation (4.8) and Pre-trip Virtual Experiences (4.7), yet lacks the operational depth required for sustainable site management. Strategy S2 (Management-centric) is characterized by a 'backstage' orientation, excelling in Environmental Monitoring (4.9) and Visitor Flow Management (4.8), but fails to provide the high-touch personalization required to satisfy modern visitor expectations. This divergence underscores S3 as the most robust and balanced approach, effectively bridging the gap between backstage operational efficiency and frontstage experiential value.

Data from Table 2 were integrated into the VIKOR algorithm. The resulting values for group utility (S), individual regret (R), and the VIKOR index (Q) for each alternative were calculated. The final compromise ranking is presented in Table 3.

Table 3. Decision Matrix: Average Performance Scores from Evaluations (x_{ij})

Code	Sub-criterion	S1: Technology-centric	S2: Management-centric	S3: Integrated & Personalized Experience
M1.1	Seamless & Real-time Information Flow	3.8	3.5	4.6
M1.2	Integrated Booking & Planning	3.5	3.2	4.8
M1.3	Pre-trip Virtual Experiences	4.7	2.8	3.5
M2.1	Ubiquitous Connectivity	4.2	4.0	4.5
M2.2	Smart Navigation & Guidance	4.1	3.6	4.7
M2.3	Interactive Heritage Interpretation Tech	4.8	3.1	4.2
M3.1	Efficient Visitor Flow & Resource Management	3.4	4.8	4.1
M3.2	Digital Feedback & Service Recovery	3.9	4.2	4.4
M3.3	Heritage Environment & Safety Monitoring	3.2	4.9	3.8
M4.1	Real-time Personalized Recommendations	4.0	3.3	4.9
M4.2	Social Media Integration & Experience Sharing	4.3	3.7	4.5
M4.3	Platforms for Experience Co-creation	3.9	3.5	4.6

Source: Authors' calculations from survey data

The VIKOR analysis identified Alternative S3 "Integrated & Personalized Experience" as the optimal compromise solution, achieving the lowest Q value of 0.000. Alternative S1 "Technology-centric" was ranked second with a Q value of 0.675, followed by Alternative S2 "Management-centric" with a Q value of 1.000. Alternative S3 also satisfied the conditions of acceptable advantage and stability in decision-making, confirming its position as the most robust strategic choice.

4.3. Sensitivity Analysis of the VIKOR Ranking

To validate the resilience of the compromise solution and mitigate potential bias from the strategy coefficient (v), a sensitivity analysis was conducted by recalculating the VIKOR index across diverse decision-making scenarios. The parameter v, representing the weight of maximum group utility versus minimum individual regret, was adjusted from the balanced consensus baseline (v=0.5) to extreme scenarios emphasizing individual regret (v=0.1) and group utility (v=0.9). The results demonstrate that the strategic rank order (S3 > S1 > S2) remains invariant across all tested values of v. This stability confirms that the 'Integrated & Personalized Experience' strategy (S3) is consistently the optimal choice, as its superiority is independent of the decision-maker's strategic preference. Such consistency reinforces the reliability of the proposed roadmap, ensuring that the prioritization of an integrated ecosystem remains valid regardless of varying management perspectives on utility and regret.

5. Discussion

5.1. Synthesis and Interpretation of Key Findings

This study's findings provide a multi-dimensional perspective on the strategic implementation of a Smart Tourism Ecosystem (STE) in a World Heritage destination. Two key insights emerge from the analysis.

First, the research reveals a "hierarchy of smart needs" where foundational, experience-enabling factors are prioritized over high-end experiential technologies. While the main criterion "Enhancing the On-Site Smart Experience" (C2) was ranked highest (weight: 0.348), a more granular analysis shows that "enabling" sub-criteria such as "Ubiquitous Connectivity" (M2.1, rank 1) and "Seamless Information Flow" (M1.1, rank 2) significantly outperform direct "experiential" technologies like AR/VR (M2.3, rank 5). This suggests that for visitors in a heritage context like Ha Long Bay, the primary value of an STE is not in technological spectacle, but in its ability to remove friction and uncertainty. This finding refines existing visitor-centric theories (Pine & Gilmore, 1999) by demonstrating that fulfilling basic digital needs for connectivity and information is a prerequisite for any higher-order smart experience.

Second, the results unequivocally support an integrated, visitor-centric strategy over technology- or management-focused approaches. The VIKOR analysis identified the "Integrated & Personalized Experience" strategy (S3) as the optimal compromise solution. This indicates that the value of an STE is derived not from isolated technologies, but from their seamless integration into a cohesive tourist journey on a unified platform. Such an approach respects the heritage context by positioning technology as an "invisible" enabler that enhances the core experience, rather than as an attraction that might overshadow the heritage itself. This underscores the principle that in heritage tourism, technology should serve the destination, not become the destination.

5.2. Theoretical Contributions

This study contributes to the literature on smart tourism and heritage management through three primary avenues. First, it operationalizes the abstract concept of a Smart Tourism Ecosystem (STE) into a quantitative, hierarchical, and testable framework, bridging the gap between theory and managerial application in sensitive heritage contexts. Second, it refines technology acceptance theory in tourism by empirically demonstrating the primacy of foundational "enabling" factors (e.g., connectivity, information) over high-end experiential technologies. This suggests that successful STE implementation in developing destinations should adopt a "bottom-up" logic, prioritizing the perfection of basic digital infrastructure before deploying more complex applications. Finally, the study validates the efficacy of a hybrid Fuzzy AHP-VIKOR model that integrates multi-stakeholder data (experts and tourists), offering a robust methodological template for addressing complex strategic planning problems in tourism.

5.3. Practical and Managerial Implications

The findings yield three actionable implications for managers of Ha Long Bay and similar heritage destinations. First, a strategic reorientation of investment toward foundational digital infrastructure is imperative. The prioritization of "Ubiquitous Connectivity" (M2.1) confirms that a robust connectivity backbone is a non-negotiable prerequisite for any smart tourism initiative. Destination managers must prioritize the deployment of high-speed Wi-Fi and stable 5G coverage across key visitor areas. Second, the development of a single, integrated destination portal is essential. The high importance assigned to seamless information and integrated booking functions underscores the need for a unified mobile application and web portal that consolidates e-ticketing, real-time information, and interactive navigation, thereby eliminating the current information fragmentation. Finally, investment should favor non-intrusive heritage interpretation technologies. The significance of interactive interpretation (M2.3) should be addressed through low-impact solutions, such as developing Augmented Reality (AR) features within the official application, rather than through large-scale physical installations that could disturb the natural landscape.

5.4. Limitations and Future Research Directions

This study's conclusions should be considered in light of two primary limitations, which also define an agenda for future research. First, the external validity is constrained by the study's focus on the Vietnamese context, and caution is advised when generalizing the findings to heritage sites in different socio-economic regions. Second, the use of a small, non-probabilistic tourist sample (n=50) means the ranking of strategies should be interpreted as an indicative outcome rather than a definitive, population-level conclusion. Future research should aim to validate this framework using large-scale, probabilistic sampling across diverse heritage contexts (e.g., natural vs. cultural sites) to test the stability and generalizability of the identified priorities.

Conclusion: This research demonstrates that a well-designed Smart Tourism Ecosystem is critical for enhancing the visitor experience at heritage destinations while respecting their integrity. By prioritizing foundational visitor needs connectivity and information and adopting an integrated, personalized strategy, destination managers can leverage technology to create superior experiential value. The findings provide an evidence-based roadmap for Ha Long Bay to harness the potential of smart tourism, reinforcing its role as a competitive and responsible steward of a global heritage.

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