USING THE FUZZY ANALYTIC HIERARCHY PROCESS TO EVALUATE CIRCULAR ECONOMY APPLICATION IN COMMUNITY - BASED TOURISM DEVELOPMENT: A CASE STUDY OF MOC CHAU, SON LA

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Abstract: ***This study investigates the integration of circular economy (CE) principles into community-based tourism (CBT) in Moc Chau, Vietnam, employing the Fuzzy Analytic Hierarchy Process (FAHP). Through expert elicitation from 25 diverse stakeholders, the research identifies and prioritizes key factors for CE implementation in CBT. FAHP analysis reveals "Waste and pollution reduction," "Natural resource preservation," and "Generation of local economic and social value" as paramount. The findings offer a robust evaluation framework and actionable recommendations for advancing sustainable CBT via CE, contributing to theoretical understanding and practical application in developing tourism contexts.***

• Keywords: *circular economy, community-based tourism, sustainable development, FAHP method, Moc Chau, Son La.*

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1. Introduction

Tourism, a significant global economic sector, faces increasing pressure regarding sustainability due to its environmental and social impacts. Community-based tourism (CBT), emphasizing local community involvement and cultural preservation, has emerged as a promising alternative (Okazaki, 2008), though it can still pose environmental challenges, particularly in developing destinations (Kontogeorgopoulos et al., 2015). The circular economy (CE), focused on minimizing waste and optimizing resource utilization, is recognized as a potential solution for sustainability in tourism (Ellen MacArthur Foundation, 2015).

1. Which CE principles are most important for application in CBT in Moc Chau?

2. What are the main barriers and opportunities for implementing CE in the CBT context in Moc Chau?

3. How can the FAHP method provide an effective evaluation framework to support decision-making regarding CE application in CBT?

The paper is structured as follows: section 2 presents a theoretical overview of CE, CBT, and their interrelationship, as well as the theoretical basis of the FAHP method. Section 3 describes the research methodology, including the FAHP procedure and data collection. Section 4 presents the FAHP analysis results. Section 5 discusses the findings, offering theoretical and practical implications. Section 6 concludes and suggests directions for future research.

2. Literature review

2.1. Circular economy (CE)

The circular economy (CE) is an economic paradigm aimed at maximizing resource value retention, thereby minimizing waste and regenerating natural systems (Ellen MacArthur Foundation, 2015). Diverging from the linear "take-make-dispose" model, CE emphasizes closing material and energy loops through core principles: designing out waste and pollution, keeping products and materials in use, and regenerating natural capital. CE is widely recognized as instrumental in achieving Sustainable Development Goals (SDGs), particularly SDG 12 and SDG 13 (United Nations, 2015).

2.2. Community-based tourism (CBT)

Community-based tourism (CBT) empowers local communities with ownership and control over tourism development, ensuring their participation and benefit (Goodwin & Santilli, 2009). CBT prioritizes the preservation of local culture and environment alongside socio-economic advantages for the community (Ashley et al., 2001). Key tenets include genuine community participation, equitable benefit distribution, and a strong focus on cultural and environmental integrity. Consequently, CBT is viewed as a potent vehicle

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for sustainable tourism in rural and remote regions, contributing to poverty alleviation and conservation (Scheyvens, 1999).

2.3. Interconnection between CE and CBT

CE and CBT are inherently complementary in advancing sustainable tourism (Tukker, 2015). CE offers a strategic framework and practical tools for minimizing CBT's environmental footprint and optimizing resource efficiency. Conversely, CBT's community-centric approach facilitates the grassroots implementation of CE initiatives (Font & McCabe, 2017). The application of CE within CBT can manifest in diverse areas such as integrated waste management (Pham et al., 2019), renewable energy adoption (Buckley, 2012), sustainable water practices (Gössling et al., 2012), development of circular products and services (Lewandowski, 2016), and fostering multi-stakeholder collaboration (Kirchherr et al., 2017).

2.4. Fuzzy analytic hierarchy process (FAHP) method

The Fuzzy Analytic Hierarchy Process (FAHP) integrates Saaty's Analytic Hierarchy Process (AHP) (1980) with Zadeh's fuzzy set theory (1965) to form a robust multi-criteria decision-making (MCDM) tool. This approach excels at managing uncertainty and linguistic vagueness in expert judgments by employing fuzzy numbers, while retaining AHP's hierarchical problem structuring (Kahraman et al., 2014).

Key FAHP stages include: constructing a decision hierarchy; developing fuzzy pairwise comparison matrices from expert assessments using a fuzzy scale; calculating fuzzy weights for criteria and alternatives; performing consistency checks to ensure judgment reliability; and finally, defuzzifying these weights for a crisp ranking.

FAHP's capacity to handle imprecise data has led to its wide application in fields like environmental management and strategic decision-making (Chan & Kumar, 2007; Büyüközkan & Güleryüz, 2016). In tourism, it is notably used for evaluating sustainability, selecting destinations, and assessing policy effectiveness (Boley et al., 2017; Pulido-Fernández & Lozano-Oyola, 2021).

3. Research methodology

3.1. Case study and expert selection

This research employs a case study methodology, focusing on Moc Chau, Son La, Vietnam. Moc Chau was selected because it is a developing CBT destination with significant potential for CE application but also faces numerous challenges.

To collect data, we selected 25 experts from five different stakeholder groups:

Tourism Specialists (5): Researchers, lecturers, and tourism consultants with experience in CBT and CE. Local Leaders (5): Representatives of local authorities (district, commune level) responsible for tourism management and socio-economic development. Tourism Business Managers (5): Owners or managers of CBT businesses in Moc Chau (hotels, homestays, restaurants, travel agencies). Tourists (5): Tourists who have experienced CBT in Moc Chau and are interested in sustainable tourism. Local Residents (5): Representatives of local communities involved in CBT activities or affected by tourism.

Selecting experts from different groups aimed to ensure diversity and comprehensiveness in the evaluation, gathering different perspectives on CE application in CBT.

3.2. FAHP procedure and data collection

This study follows the steps of the FAHP method as presented in section 2.4. The FAHP hierarchical structure was constructed with the overall goal of "Evaluating CE Application in CBT in Moc Chau." The main criteria were identified based on CE principles and the CBT context, including:

- Waste and pollution reduction (WP): Focusing on activities to reduce waste generation from tourism and environmental pollution (air, water, soil). (Zaman & Lehmann, 2011).

- Natural resource preservation (NR): Ensuring the sustainable and efficient use of natural resources (water, energy, land, biodiversity). (Holden, 2008).

- Generation of local economic and social value (ESV): Enhancing economic benefits for local communities, creating jobs, developing skills, and preserving culture. (Murphy & Murphy, 2004).

- Awareness raising and participation (ARP): Raising awareness of CE and sustainable CBT among tourists, local communities, and stakeholders, encouraging their participation in CE activities. (Moscardo, 2008).

Table 1: Triangular Fuzzy number (TFN) scale and meaning

Fuzzy Scale	TFN	Meaning
Equally Important	(1, 1, 1)	Two factors are of equal importance.
Slightly More Important	(3, 5, 7)	One factor is slightly more important than the other.
Much More Important	(5, 7, 9)	One factor is much more important than the other.
Extremely More Important	(7, 9, 9)	One factor is extremely more important than the other.
Intermediate Values	(2, 4, 6, 8)	Intermediate values between the above levels (when necessary).
Reciprocal	(1/9, 1/7, 1/5, 1/3, 1) to (1, 1/3, 1/5, 1/7, 1/9)	Used when comparing in reverse (e.g., if A is more important than B, then B is less important than A).

To develop fuzzy pairwise comparison matrices, we used expert survey questionnaires. The questionnaire

was designed based on the triangular fuzzy number (TFN) scale (Table 1). Experts were asked to compare the relative importance of the criteria in pairs, using fuzzy language and scales. For example, the question "Compare the importance of the criterion "Waste and Pollution Reduction" versus the criterion "Natural Resource Preservation" in applying CE to CBT in Moc Chau?" and experts would choose a value on the fuzzy scale ("Slightly more important," corresponding to TFN (3, 5, 7)).

Survey data were collected in October 2024 through face-to-face interviews and online questionnaire distribution.

3.3. FAHP data analysis

Survey data from 25 experts were aggregated and processed according to the following steps:

- Constructing an aggregated fuzzy pairwise comparison matrix: The pairwise comparison matrices of individual experts were aggregated into an aggregated fuzzy pairwise comparison matrix using the geometric mean operation for each fuzzy element (Buckley, 1985).

- Calculating fuzzy weights: We used Chang's Extent Analysis Method (1996) to calculate fuzzy weights for each criterion from the aggregated fuzzy pairwise comparison matrix. This method is considered effective and widely used in FAHP.

- Consistency checking: Calculating the Consistency Ratio (CR) for the aggregated fuzzy pairwise comparison matrix to ensure consistency in expert assessments. A CR value < 0.1 is considered acceptable (Saaty, 1980). In case CR > 0.1, data should be reviewed, and further information collection or adjustment of expert assessments may be required.

- Defuzzifying fuzzy weights: Using the centroid (center of area) defuzzification method to convert fuzzy weights into crisp weights.

- Ranking criteria: Ranking the criteria in descending order of crisp weights to determine the priority level of each criterion in applying CE to CBT in Moc Chau.

- FAHP data analysis was performed using specialized software (e.g., MATLAB, Fuzzy AHP software) and/or manual calculation using Excel.

4. Results

4.1. Aggregated fuzzy pairwise comparison matrix and consistency check

Table 2 presents the aggregated fuzzy pairwise comparison matrix for the criteria, aggregated from the assessments of 25 experts.

The Consistency ratio (CR) calculated for this matrix is 0.07, less than 0.1, indicating that the matrix has acceptable consistency.

Table 2: Aggregated fuzzy pairwise comparison matrix

Criteria	WP	NR	ESV	ARP
WP	(1, 1, 1)	(2.57, 4.23, 6.32)	(3.16, 5.10, 7.41)	(4.00, 6.24, 8.66)
NR	(0.16, 0.24, 0.39)	(1, 1, 1)	(2.00, 3.46, 5.20)	(3.00, 4.89, 7.00)
ESV	(0.13, 0.20, 0.32)	(0.19, 0.29, 0.50)	(1, 1, 1)	(2.00, 3.46, 5.20)
ARP	(0.12, 0.16, 0.25)	(0.14, 0.20, 0.33)	(0.19, 0.29, 0.50)	(1, 1, 1)

Note: WP - Waste and Pollution Reduction, NR - Natural Resource Preservation, ESV - Generation of Local Economic and Social Value, ARP - Awareness Raising and Participation.

4.2. Fuzzy weights and crisp weights

Table 3 presents the fuzzy weights and crisp weights (after defuzzification using the centroid method) for each criterion.

Table 3: Fuzzy weights and crisp weights of criteria

Criteria	Fuzzy Weights	Crisp Weights	Rank
WP	(0.40, 0.61, 0.83)	0.61	1
NR	(0.23, 0.35, 0.52)	0.37	2
ESV	(0.15, 0.24, 0.38)	0.26	3
ARP	(0.09, 0.16, 0.28)	0.18	4

4.3. Ranking of criteria

Based on the crisp weights, the criteria are ranked in descending order of priority as follows:

1. Waste and Pollution Reduction (WP) (0.61)

2. Natural Resource Preservation (NR) (0.37)

3. Generation of Local Economic and Social Value (ESV) (0.26)

4. Awareness Raising and Participation (ARP) (0.18)

5. Discussion

The FAHP analysis prioritizes "Waste and Pollution Reduction" (WP) as the paramount criterion for applying CE to CBT in Moc Chau. This underscores the critical need to address significant environmental pressures common in developing tourism destinations. Prioritizing interventions such as plastic waste minimization, robust solid waste management, and effective wastewater and air pollution control is therefore essential, a stance strongly supported by existing CE and sustainable tourism literature (Zaman & Lehmann, 2011; Pham et al., 2019).

Ranking second, "Natural Resource Preservation" (NR) reflects the intrinsic dependence of Moc Chau's CBT on its natural capital, including landscapes, biodiversity, and water resources. Sustainable utilization and protection of these assets are vital for the long-term viability of CBT. This advocates for solutions like renewable energy integration, sustainable water stewardship, biodiversity conservation, and the promotion of ecotourism, aligning with established research on sustainable resource management in tourism (Holden, 2008; Gössling et al., 2012).

The third-ranked criterion, "Generation of Local Economic and Social Value" (ESV), indicates that despite CE's environmental focus, experts highly value the socio-economic co-benefits for local communities.

This positions CE not merely as an environmental corrective but as a holistic tool for sustainable socio-economic development. Consequently, fostering local circular products and services, creating green employment, supporting community-based enterprises, and ensuring equitable benefit distribution are crucial, consistent with CBT principles and research on CE's socio-economic contributions (Murphy & Murphy, 2004; Kirchherr et al., 2017).

Finally, "Awareness raising and participation" (ARP), though ranked fourth, remains integral to successful CE implementation. Effective stakeholder engagement, achieved through targeted education, communication, and training for all actors (tourists, communities, businesses, authorities), alongside active community involvement in the planning, implementation, and monitoring of CE initiatives, is indispensable. This finding resonates with studies emphasizing the foundational role of awareness and participation in sustainable tourism development (Moscardo, 2008).

5.1. Theoretical implications

This study contributes to the theory of CE and CBT by providing a specific evaluation framework for applying CE in the CBT context. The use of the FAHP method allows for a systematic and comprehensive evaluation of critical factors, while also addressing uncertainty and ambiguity in expert assessments. The research also clarifies the relationship between CE and CBT, showing that CE can be an effective tool to enhance the sustainability of CBT.

5.2. Practical implications

These findings inform actionable strategies for CE integration in CBT for Moc Chau and analogous destinations. Key recommendations include: (1) Prioritizing comprehensive waste and pollution mitigation (plastics, solid waste, wastewater, air emissions) within tourism; (2) Investing in natural resource preservation via ecotourism, renewable energy, sustainable water management, and biodiversity conservation; (3) Stimulating development of circular tourism products/services (recycled goods, local/green experiences); (4) Strengthening stakeholder awareness and participation through targeted education and empowered community involvement in CE initiatives; and (5) Promoting multi-stakeholder collaboration for knowledge and resource exchange to advance circular CBT.

5.3. Limitations and future research directions

Future research could expand the expert sample, compare results across different CBT destinations, and combine FAHP with other quantitative methods to verify and supplement the results. Research could also focus on evaluating the economic, social, and environmental effectiveness of implementing CE initiatives in CBT in practice.

6. Conclusion

This study has used the FAHP method to evaluate critical factors in applying CE to CBT in Moc Chau, Son La, Vietnam. The results indicate that "Waste and pollution reduction" is the most important criterion, followed by "Natural resource preservation," "Generation of local economic and social value," and "Awareness raising and participation." The study provides a useful evaluation framework and practical recommendations to promote sustainable CBT development based on CE principles. The research findings have significant implications for policymakers, tourism businesses, and local communities in developing and implementing specific strategies and actions to integrate CE into CBT, contributing to the sustainable development of the tourism industry and local communities.

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