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Evaluating sustainable managemnet intreventions in Moroccan ecological accommodations using Analytical Hierarchy Process and Technique for Order Preference by Similarity to Ideal Solution hybrid assessment.

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Abstract

The transition towards sustainable tourism in emerging destinations requires an extensive understanding of how sustainable practices are implemented. This paper examines how combining renewable energy sources and efficiency actions can support the long-term expansion of micro-scale ecological accommodations. Methodologically, this paper adopts a hybrid Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) approach in order to prioritize sustainable interventions according to five criteria and seven sustainable interventions identified from management guideline data provided by Bab Zouina ecolodge in Morocco's Ourika Valley. AHP is used to determine the relative importance of the criteria, while TOPSIS ranks the interventions according to their calculated performance. The results demonstrate how low-complexity and high-impact alternatives such as LED lighting replacement and covered cooking pots outperform high-cost solutions in the emerging context. This study demonstrate the relevance of nmulticrieria decision making frameworks in order to translate enviromental managemnet data into actionable invetsemnet protorties in microscale entities in emerging tourism destinations.

Keywords: renewable energy, sustainable tourism, emerging destinations, ecolodge, energy transition, territorial living laboratory.

Introduction

With a global carbon footprint accounting for 8% of greenhouse gas emissions (Scott, Hall & Gössling, 2019), tourism is one of the highly ranked service industries consuming energy compared to others. As the number of tourists increases and the infrastructure expands, tourism is widely regarded as a significant contributor to the expansion of the economy, particularly in countries located in North Africa such as Morocco. However, environmental challenges, lack of resources, and compatibility with national climate policy are frequently disregarded when this course of action is pursued (Bramwel, 2011; Sharpley, 2022).

Sustainable tourism has seen a paradigm shift in the last 20 years, shifting from fixed ideas about minimizing negative impacts to more fluid models based on governance and systems thinking (Dwyer & Kim, 2003). In these shifting environments, renewable energy has emerged to reduce the environmental impact of the tourism industry by making destinations more competitive (IEA, 2018).

While these tourist sites are advertised for their untouched landscapes and low-carbon appeal, it is challenging to balance their need for growth with the need to protect them (Butler, 1980; Ritchie & Crouch, 2003). In addition, stakeholders are frequently excluded from formal sustainability frameworks and certification systems due to financial, technological, or administrative constraints, creating a significant study gap.

Against this background ,this study aims to develop an illustrative decision support framework that can assist ecolodge managers in identifying sustainable interventions that offer a positive balance between environmental ,economic performance , implementation feasibility and co-benefits. The next section reviews the literature through a progressive shift from emergimg tourism destinations to sustainable tourism and the role of renewable energy in supoooroting more resource-efficient tourism development through a variety of dimensions and indicators assesmnet.The review then introspects the territorial living laboratory perspective as a paradigm for context-sensitive sustainability experimentation.

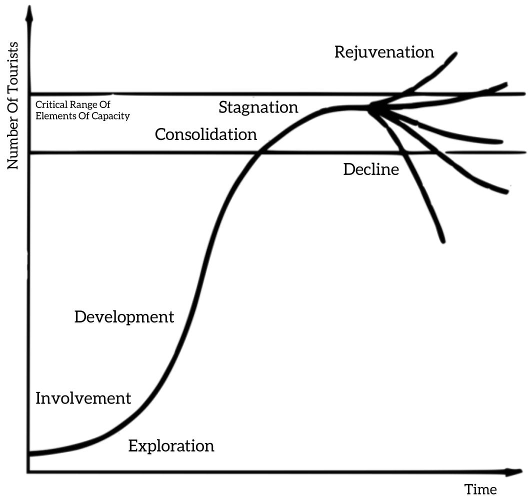
1. Literature review

Within the scope of this literature review, the core concepts highlights the theoretical foundations of sustainable tourism systems and how they have developed toward resilience and performance. It then explores how eco-friendly lodging accommodations contribute to the operationalization of sustainability as territorial living laboratories.

1.1. Emerging Destination

The concept of emerging destinations has been extensively delineated. One of the first was by Butler in his Tourism Area Life Cycle (TALC) Model (Butler, 2006) describing the process by which a touristic area moves from the involvement stage to the rejuvenation or potential decline, where governance systems are formalized and external investments emerge with a noticeable surge of tourists. To visualize Butler's conceptualization, Figure 1 illustrates the classic S-curve of the tourism area life cycle (TALC), delineating how a destination evolves.

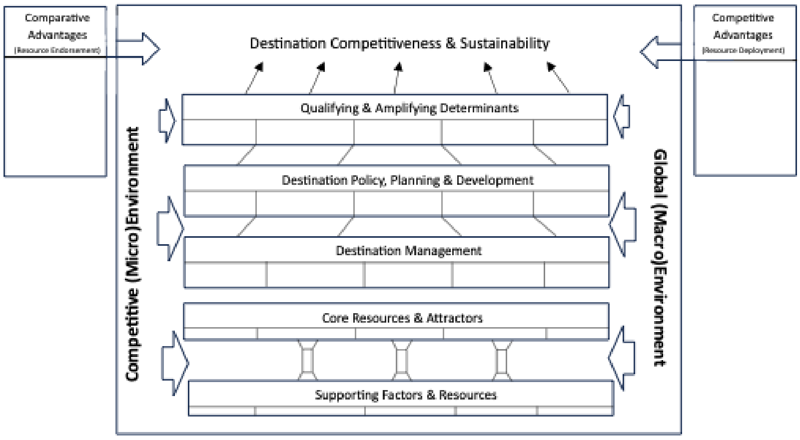
Figure N°1: Tourism Area Life Cycle (TALC) Model



Source: Author's adaptation of Butler, R., *The Tourism Area Life Cycle*, Channel View Publications, Clevedon, United Kingdom, 2006.

Although the TALC model effectively traces the chronological evolution of destinations, it does not explicitly address the multi-dimensions of a destination's competitiveness. With regard to it, Ritchie and Crouch's model of destination competitiveness (Ritchie & Crouch, 2003) offers a comprehensive framework including management practices, core resources, and attractions while building the supporting factors such as infrastructure and sustainability. Figure 2 below outlines the structural components of the Calgary Model.

Figure N°2: The Calgary Model of Destination Competitiveness



Source: Author's adaptation of Ritchie, J. R. B. and Crouch, G. I., *The Competitive Destination: A Sustainable Tourism Perspective,* 2003.

While Ritchie and Crouch's model does offer a comprehensive conception of destination competitiveness, it remains theoretical and lacks a full operational structure for empirical implementation. Acknowledging this gap, Lary Dwyer and Chul-Won Kim expanded this model to create a more empirically grounded model where an emerging destination is defined by incorporating both supply-side and demand-side variables using a multi-dimensional lens.

1.2. Sustainable tourism

In academic discourse, "sustainable tourism" refers to a tourism that considers several criteria, including environmental, economic, social and institutional aspects. According to United Nations World Tourism Organization (UNWTO), reducing environmental impact which encompasses emissions, waste and the excessive use of water or energy resources is integrated to build sustainable tourism. Among the most used indicators are the environmental ones, Gossling advocate for using ecological footprint and carbon emissions per tourist as essential indicators for assessing the climate impact of tourism Furthermore, United Nations Environment Program (UNEP) incorporates the proportion of tourism initiatives led by women, youth sand indigenous groups as an indicator of social equity empowerment (Butler, 2006; UNEP, 2026).

1.3. Renewable energy

Over the past decades, scholars have contributed with conceptual frameworks, empirical investigations, and fundamental concepts to better understand the integration of renewable energy into sustainable tourism. A comprehensive literature review was conducted to emphasize on the use of renewable energy tools in the tourism Industry (Becken & Simmons, 2002). Further studies looked at how using green energy, carbon emissions, and economic growth in the industry are all connected in a few countries. Comprehensive research conducted in Egypt, Kenya, and Ethiopia, as stated by Huseynli, demonstrated a correlation between tourism demand and renewable energy sources as well as destination attractiveness and sustainable goals (Michalkó & al., 2012 ; Guo & al., 2019).

1.3.1. Renewable energy's sub-dimensions.

For a comprehensive implementation of renewable energy in tourism, the dimensions are subdivided into sub-dimensions to facilitate its assessment based on monitoring indicators, as shown in Tables 1 and 2.

Table N°1 : Conceptual synthesis of primary and sub-dimensions of renewable energy

Primary dimension	Sub-dimension	Key authors
Technical	- Solar Energy - Wind Energy - Biomass - Geothermal system - Microhydropower - Hybrid system - Grid-tied and off-grid installation	(Ásványi & al., 2019) (Huseynli, 2021)
Operational	- Maintenance of systems - Management of load - Efficiency of storage and battery - Energy autonomy - Smart utilities	(Michalkó & al., 2012) (Guo & al., 2019)
Economic	- Investment cost - Operating cost - Payback period - Return on investment - Cost savings	(Ben Jebli & al., 2019)
Environmental	- Reduction of CO_2 - Decrease in Carbon - Environmental impact - Climate risk mitigation	(Ben Jebli & al., 2019)
Policy and Governance	- Financial incentives - Regulatory frameworks - National subsidies	(Guo & al., 2019) (Huseynli, 2021)
Sector impact	- Tourist awareness and preference - Certification schemes	(Ásványi & al., 2019) (Huseynli, 2021)

Table N°2: Literature-based synthesis of monitoring indicators of renewable energy

Indicator	Description	Dimension	Key authors
Share of renewable energy	Sourced from renewables in total consumption	Technical Operational	(Ásványi & al., 2019) (Huseynli, 2021)
CO_2 emissions	low carbon emissions attributed to renewable use	Environmental	(Ben Jebli & al., 2019)
Payback Period	Timeline to recoup investment from cost savings	Financial	(Ásványi & al., 2019)
Return on investment	Financial gain allocated to renewable energy systems	Fincancial	(Huseynli, 2021)
Number of RE installations	Quantitative assessment of installed systems	Technical	(Michalkó & al., 2012)
Perception index	Assessment of environmental perception and sustainable impact	Sector impact	(Guo & al., 2019) (Huseynli, 2021)

1.4. Territorial Living Laboratories

Territorial Living Laboratories (TLLs) have achieved popularity as an innovative framework for place-based experimentation in sustainability transitions. Based on the larger living laboratories paradigm, which was initially popular in urban and information and communication technologies (ICT) innovation contexts (Ben Jebli & al., 2019) TLLs apply this approach with a focus on local participation, territorial governance, and contextual adaptation. A living laboratory, according to F. Spigarelli is "an open innovation ecosystem working in a territorial setting, combining concurrent research and innovation activities within a public-private-people collaboration." As such, TLLs function as mediating spaces where innovation, policy, and practice intersect, enabling bottom-up contributions to larger sustainability goals, particularly in developing and emerging regions where contextual complexity and environmental challenges are pronounced (Spigarelli,2021).

2. Conceptual research gap

Table 3 consolidates how scholars provide rich foundations across a variety of concepts while highlighting the gap of a systematic framework connecting all variables across emerging and underexplored tourism destinations.

Table N° 3. Critical synthesis of conceptual gaps in literature

Concept	Key scholars	Critical analysis
Emerging destination	- Richard Butler - Ritchie and Crouch - Dwyer and Chul-Won - Richard Sharpley - Dimitrios Buhalis	The literature conceptualizes tourism destinations as evolving systems progressing through identifiable stages and shaped by competitiveness, governance, and development dynamics. However, the models remain largely descriptive, offering limited adaptation to micro-level ecological accommodations.
Sustainable Tourism	- Stefan Gössling - UNWTO	Sustainable tourism is framed as a multi-dimensional concept, yet treated with insufficient attention to processes through which sustainability gets implemented in practice.
Renewable Energy	- Ásványi & al. - Bano & al. - Huseynli - Michalkó & al. - Huseynli - Guo & al.	This stream identifies key dimensions along with measurable indicators yet ,research often remains fragmented on isolated indicators without merging them in a broader territorial logic.
Territorial Living Laboratory	- Koen Ballon - Dimitri Schuurman - Yuliya Voytenko	TLLs are conceptualized as place-based innovation ecosystems but remain insufficiently connected to how these mechanisms translate into concrete operational improvements.

3. Cconceptual model

The conceptual framework of this paper highlights the dynamic interactions between important factors that impact sustainable hospitality in ecolodge settings, with a particular emphasis on the function that renewable energy plays in this context, outlined in Figure 3.

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Figure N°3: Conceptual model linking the selected variables

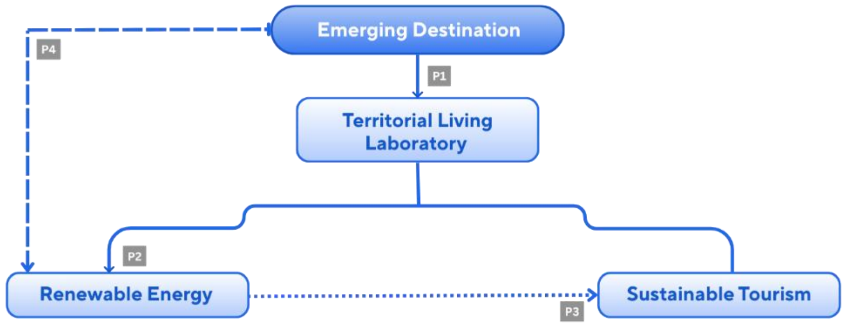

Table N° 4. Analytical synthesis of the paper's conceptual model

Variable	Type	Conceptual links
Emerging destination	Moderating Variable	The dynamic between emerging destinations and TLLs , as expressed in P1, mirrors how the destination characteristics influence the fucntioning of living laboratories as they emerge to adress limited maturity and resource constraints by enabling context specific innovation.
Sustainable Tourism	Dependent Variable	The dynamic between renewable energy and sustainable tourism, as expressed in P3, projects the positve impact of its adoption on developing resilient touristic destinations through resource efficiency and environmental performance.
Renewable Energy	Mediating Variable	The link between emerging destination and renewable energy, as expressed in P4, reflects how contextual factors like infrastructure and financial capacity of a destination, may either facilitate or constrain the implementation of renewable energy, thereby affecting the overall sustainability outcome.
Territorial Living Laboratory	Independent Variable	The dynamic between TLLs and renewable energy, as reflected in P2, demonstrates how these laboratories facilitate the integration of renewable practices through adapted local solutions.

4. Methodology

This paper is framed as a conceptual contribution to the complexity of sustainable transitions in hospitality, following a quantitative and deductive mode of reasoning,centered around ecolodge operations in which the co-existence of multiple and frequently conflicting decision criteria is clearly recognized.

As highlighted in the preceding literature, while considerable focus has been directed towards the role of renewable energy in mitigating the ecological footprint of tourism, less emphasis has been placed on how decision-makers can systematically prioritize among multiple options at the operational level. To address such complexity, an analytical approach combining quantitative indicators and qualitative dimensions is crucial. In this regard, such methods have been widely adopted in sustainability-related research as tools to initiate complex decision & evaluation processes. Among these methods, the analytical hierarchy process (AHP), which was introduced by Saaty, has been widely used to figure out how important different assessment criteria are through structured pairwise comparisons, allowing subjective judgments to be formalized into a consistent weighting matrix (Saaty,1980).

While AHP provides a strong model to measure criteria's quality, it doesn't on its own offer a complete framework for ranking multiple alternatives based on their performance across criteria. Due to this, the technique for order preference by similarity to ideal solution (TOPSIS), originally laid out by Hwang & Yoon was specifically designed to evaluate and rank alternatives by measuring their relative proximity to an ideal solution representing optimal performance and a negative ideal solution representing the least desirable scenario (Hwang & Yoon,1981).

In recognition of the complementary strengths of these two approaches and to further develop a decision support framework for optimizing sustainability actions in operations, this research paper adopts an AHP-TOPSIS hybrid model where AHP is used for criterion weights and TOPSIS to rank alternatives accordingly. Crucially, the data used to construct the decision matrix are derived from an internal environmental management guideline, “Le guide de bonne gestion environmentale en Hôtellerie," developed through a collaborative initiative involving Sustainable Business Associates and academic contributors from l'école hôtelière de Lausanne, which offers operational data and recommended practices in hospitality. It has been applied and disseminated within professional hotel networks with the backing of the Moroccan ministry of tourism and handicrafts, solidifying its positioning in the Moroccan industry.

Instead of relying on a conventional sample, this study adopts a case-based unit of analysis, as the set comprises seven sustainability interventions relevant to ecolodge operations: solar thermal systems, geothermal solutions, covered cooking pots, refrigeration optimization, LED replacement, energy monitoring, and water-flow regulators.

The suggested hybrid model is not designed to offer empirically validated results of sustainability performance, nor does it depend on statistically representative datasets. The selected data are used in an illustrative case assessment to demonstrate the application of structured decision-making models in translating theoretical sustainability goals into actionable decision support tools relevant to emerging destinations.

5. Illustrative case study

Following the methodological positioning outlined above, the implementation of this AHP-TOPSIS hybrid model requires the construction of a decision matrix. This involves the definition of decision alternatives, the identification of evaluation criteria, the classification of criteria according to their nature, and the conversion of both quantitative and qualitative data into a unified decision matrix.

5.1. Definition of decision alternatives

Following the methodological positioning outlined above, the implementation of this hybrid model requires the construction of a decision matrix. This involves the definition of decision alternatives, the identification of evaluation criteria, the classification of criteria according to their nature, and the conversion of both quantitative and qualitative data into a unified decision matrix.

To construct the decision model, the initial stage is to list the set of best sustainable practices to be assessed. The input data were compiled from the guideline and organized in raw dataset, taking into consideration factual statements, meaning, that alternatives were defined as actionable, operational or technological interventions (Belton,2002) .However, contextual consumption shares were retained as supporting evidence but not modelled as alternatives as they are considered indicators showing where intervention matters most. Accordingly, the following alternatives were chosen for assessment, as shown in Table 5.

Table N° 5. Selected sustainable alternatives

Code	Sustainable Alternative	Description
A1	Solar thermal system	Installation of solar panels to facilitate hot water production and reduce dependence on traditional energy sources
A2	Geothermal heating	Usage of ground-source energy for heating and cooling purposes
A3	Covered cooking pots	Boiling water in covered pots to reduce energy consumption in kitchen operations
A4	Refrigeration placement optimization	Positioning of refrigeration units away from heating-emitting equipment to improve energy efficiency
A5	LED lighting replacement	Substitution of traditional lighting systems with energy-efficient LED technologies
A6	Energy monitoring system	Implementation of monitoring systems to track and optimize energy consumption
A7	Water flow regulators	Installation of flow control devices to reduce water consumption in daily operations

5.2. Definition of evaluation criteria

In such contexts, criteria represent the attributes used to assess the performance of alternatives that aligns with the overall decision goal. Based on raw data, five evaluation criteria were considered, as shown in Table 6.

Table N° 6. Criteria and sub-dimensions used in the analysis

Code	Criterion	Dimension
C1	Energy-saving potential	Environmental Performance
C2	Water-saving potential	
C3	Payback period	Economic feasibility
C4	Complexity implementation	Implementation Feasibility
C5	Operational co-benefits	Operational Value

Energy-saving potential was considered the most critical criterion, as the study focuses on energy transition in hospitality operations. Likewise, saving potential was assigned significant importance due to water scarcity concerns in emerging touristic destinations.

Further, the payback period reflects the economic feasibility of interventions, while implementation complexity captures practical deployment constraints. While operational co-benefits represent additional advantages such as improved monitoring, environmental branding, and operational efficiency.

5.3. Polarity of evaluation criteria

In line with the standard TOPSIS method, all evaluation criteria must be expressed according to a unified polarity framework, distinguishing between benefit criteria to be maximized and cost criteria to be minimized (Saaty,1977) where the model compares each alternative to an ideal best or ideal worst solution. Based on this classification on Table 7, the criteria retained in this study are defined as follows:

Table N° 7. Classification of criteria based on polarity

Code	Criterion	Dimension
C1	Energy-saving potential	Environmental Performance
C2	Water-saving potential	
C3	Payback period	Economic feasibility
C4	Complexity implementation	Implementation Feasibility
C5	Operational co-benefits	Operational Value

Benefit criteria are to be maximized, as higher values indicate improved performance, whereas cost criteria are to be minimized, as lower values are preferred.

5.3.1. Ordinal evaluation scales for qualitative criteria

To construct the decision model, the matrix should involve the integration of both quantitative and qualitative data. While certain criteria are expressed using measurable indicators associated directly with performance levels of each sustainability intervention on an ecolodge level derived from the guideline, others require transformation into numerical values such as complexity and co-benefits. Ordinal scales were developed to standardize judgement across alternatives and were based on the characteristics of each intervention as described in the selected guideline.

As shown in Table 8, implementation complexity is assessed using a five-point ordinal scale representing increasing levels of operational effort and financial investment required for implementation.

Table N° 8. Ordinal scale to assess implementation complexity

Score	Description
1	Behavioural adjustment requiring no major investment
2	Simple intervention requiring minor technical adjustment
3	Moderate intervention requiring installation effort
4	Upgrade requiring major infrastructure adaptation
5	Complex system integration requiring significant investment

Along with it, operational co-benefits are evaluated using a three-level ordinal scale reflecting the extent to which each intervention generates additional operational advantages beyond its primary environmental impact, as shown in Table 9.

Table N° 9. Ordinal scale to assess operational co-benefits

Score	Description
1	Low operational co-benefits
2	Moderate operational co-benefits
3	High operational co-benefits

Meanwhile, the payback period represents an evaluation criterion for which quantitative insights are partially available. As explicit values are reported for certain interventions, such as LED lighting replacement, energy monitoring systems, and water flow regulators, other measures are described qualitatively without precise recovery data.

To ensure the completeness and comparability of the decision matrix, a structured transformation of the payback criterion into an ordinal evaluation scale was adopted.

The definition of scale levels was guided by the distribution of observed values in the dataset. In particular, the available payback values (10 and 25 days) were used as reference points to define the lower range of the scale, distinguishing between very short and short recovery periods, as shown in Table 10.

Higher scale levels were then defined to represent progressively longer payback durations associated with more capital-intensive interventions, such as renewable energy systems. This approach ensures that the payback criterion is evaluated consistently across all alternatives and avoids introducing unsupported numerical assumptions to the illustrative study.

Table N° 10. Ordinal scale to assess payback period

Score	Payback category	Interpretation
1	Energy-saving potential	Environmental Performance
2	Water-saving potential	
3	Payback period	Economic feasibility
4	Complexity implementation	Implementation Feasibility
5	Operational co-benefits	Operational Value

The following payback scores, in Table 11, are provided to sustainable alternatives that have been documented in the guideline.

Table N° 11. Ordinal scale of payback period for documented alternatives

Code	Alternative	Category	Score	Payback [days]
A5	LED lighting replacement	Short	2	25
A6	Energy monitoring system	Short	2	25
A7	Water flow regulators	Very short	1	10

The listed payback scores, in Table 12, are provided to sustainable alternatives lacking numerical values.

Table N° 12. Ordinal scale of payback period for non-quantifiable alternatives

Code	Alternative	Category	Score
A3	Very short	1	1
A4	Very short	1	1
A1	Long	4	4
A2	Very long	5	5

Together, these tables clarify how the payback criterion is harmonized across alternatives, ensuring a comparable decision matrix while avoiding unsupported numerical Data.

5.4. Decision matrix of sustainability alternatives

Following the definition of alternatives, evaluation criteria, and their respective polarity, this section consists of constructing the decision matrix representing the performance of each alternative with respect to each evaluation criterion. In the present illustrative study, the values included in the decision matrix are derived from the illustrative data provided in the

Guideline. Quantitative criteria, are directly expressed using indicative numerical values and qualitative criteria, are evaluated using the predefined ordinal scoring scales described in the previous section. Zero values were retained where they represent the actual absence of impact of a given alternative on a specific criterion while reflecting a realistic performance difference across interventions.Notably, the energy saving associated with LED lighting was estimated by comparing conventional bulbs (60W) with LED bulbs (11W).
The percentage reduction in energy consumption was calculated as:

$$ES = \frac{P_{conv} - P_{LED}}{P_{conv}}$$

The resulting matrix provides a unified representation of both quantitative and qualitative performance indicators, as shown in Table 13.

Table N° 13. Source-based performance matrix of sustainability alternatives

Code	C1	C2	C3	C4	C5
A1	40	0	4	4	4
A2	12	0	5	5	3
A3	73	0	1	1	3
A4	30	0	1	2	3
A5	82	0	2	2	4
A6	0	0	2	3	5
A7	0	50	1	1	4

5.5. Criterion weights using the analytical hierarchy process

To figure out how important each assessment criteria is, the analytical hierarchy process is applied, which relies on pairwise comparisons to transform qualitative judgments into quantitative priority weights (Saaty,1980).Based on Saaty's fundamental scale of nine main levels of importance (1, 3, 5, 7, 9), as well as intermediate values (2, 4, 6, 8) that stand for compromise judgments between adjacent levels, each criterion is compared to all the others to see how they affect sustainability performance. The scale adopted in the illustrative study is shown in Table 14.

Table N°14. Fundamental scale for pairwise comparison in AHP

Level	Interpretation
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values

5.5.1. Pairwise comparison matrix

The analytical hierarchy process relies on a reciprocal property to keep the pairwise comparison matrix consistent, ensuring that each element a_{ij}satisfies the condition $a_{ij} = 1/a_{ji}$.When a criterion is considered more important than another, a value larger than 1 is allocated according to the intensity of preference. It follows that the reciprocal of the value is used when a criterion is judged to be less important. The resulting matrix is presented in Table 15.

Table N°15. Pairwise-based comparison matrix

Code	C1	C2	C3	C4	C5
C1	1	3	2	4	5
C2	1/3	1	2	3	4
C3	1/2	1/2	1	2	3
C4	1/4	1/3	1/2	1	2
C5	1/5	1/4	1/3	1/2	1

5.5.2. Derivation of criteria weights

In order to derive the priority weights, the pairwise comparison matrix is normalized by dividing each element by the sum of its respective column. The normalization process transforms the original comparison values into comparable proportions and makes it possible to calculate the priority vector associated with each criterion, as shown in Table 16.

Table N°16. Sum of derived criteria weights

Code	C1	C2	C3	C4	C5
Sum	2.283	5.083	5.833	10.500	15.000

5.5.3. Normalized pairwise-based comparison matrix for criteria

The resulting pairwise comparison matrix is normalized by dividing each value by the total of its associated column, as shown in Table 17.

Table N°17. Normalized pairwise-based comparison matrix for criteria

Code	C1	C2	C3	C4	C5	Weights
C1	0.438	0.590	0.343	0.381	0.333	0.417
C2	0.146	0.197	0.343	0.286	0.267	0.247
C3	0.219	0.098	0.171	0.190	0.200	0.175
C4	0.110	0.066	0.086	0.095	0.133	0.098
C5	0.088	0.049	0.057	0.048	0.067	0.061

5.6. Consistency verification

The analytical Hierachy Process (AHP) has the dual benefit of generating criterion weights and enabling verification of the logical coherence of the pairwise comparisons.Therefore, a consistency test is required to ensure subjective assessements of relative importance are not contradictory. Following saaty's original procedure , this verification is performed through the maximum eigenvalue ($\lambda_{\max}$), the consistency index (CI) , and the consitency ratio (CR).

5.6.1. The maximum eigenvalue.

The value $\lambda_{\max}$ indicates the extent to which the pairwise comparison approches perfect consistency. To estimate it, the normalized matrix is multiplied by the criteria weight in order to obtain the wighted sum, as shown in table 18. Each element of this vector is then, divided by the corresponding criterion weight leading to the consistency vector, presented in table 19.

Table N°18. Weighted sum of the normalised matrix model

Code	Weighted Sum
C1	2.215
C2	1.281
C3	0.891
C4	0.497
C5	0.315

Table N°19. Resulting consistency vector for each criterion

Code	Consitency value
C1	5.311
C2	5.186
C3	5.091
C4	5.071
C5	5.163
Average $\lambda_{\max}$	5.164

5.6.2. The consistency index

The consistency index quantifies the extent to which the comparison matrix deviates from ideal consistency, where n is the number of criteria, calculated as:

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

For the obtained matrix, $\lambda_{\max} = 5.164$, resulting into a consistency index of $CI = 0.041$

5.6.3. The random index

The random index (Saaty,1977) is a benchmark statistic representing the average consistency index of random generated pairwise comparison calculated upon the size of the matrix, as shown in Table 20.

Table N°20. Random index (RI) values for AHP consistency assessment

Size (n)	1	2	3	4	5	6	7	8
R1	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41

5.6.4. The consistency ratio

The consistency ratio compares how inconsistent the matrix is with how inconsistent a random matrix is expected to be, for an acceptable ratio of less than 0.10, computed as follows:

$$CR = \frac{CI}{RI}$$

For the obtained random index, RI = 1.12 , resulting into a consistency ratio of

$$CR = 0.036$$

The resulting consistency ratio of 0.036 is less than 0.10, confirming acceptable consistency and reliability of the derived criteria.

5.7. The technique for order preference by similarity to ideal solution

Following the validation of criteria weights, the technique for order preference by similarity to ideal solution (TOPSIS), is applied to rank sustainability alternatives based on geometric distance from a positive ideal solution as the best possible performance and a negative ideal solution as the worst possible performance (Hwang,1981).Its implementation in the current illustrative case follows a sequence of steps.The decision matrix is normalized to eliminate differences in measurement scales across criteria. It is then weighted using weights derived from AHP.

Subsequently, the positive and negative ideal solutions are identified according to the polarity of each criterion. The distance of each alternative is then computed through a relative closeness coefficient for each sustainable alternative, enabling their ranking based on their overall performance.

5.8. The normalisation of the weighted decision matrix

5.8.1. Normalisation of the decision matrix

The matrix combines heterogenous forms of data, such as ordinal scores and percentages which makes the normalization process of utmost significance, converting all values into

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dimensionless quantities and keeping criteria with wider numerical ranges from exerting disproportionate influence on the final ranking.Each criterion is subjected to vector normalisation, as shown in Table 21, where r_{ij} denotes the normalised value and x_{ij} represents the value of alternative i under criterion j with m as number of alternatives, applied as follows:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Table N°21. Normalised decision matrix

Code	C1	C2	C3	C4	C5
A1	0.330	0.000	0.521	0.504	0.400
A2	0.099	0.000	0.651	0.630	0.300
A3	0.602	0.000	0.130	0.126	0.300
A4	0.247	0.000	0.130	0.252	0.300
A5	0.676	0.000	0.260	0.252	0.400
A6	0.000	0.000	0.260	0.378	0.500
A7	0.000	1.000	0.130	0.126	0.400

Table 21 displays the normalized decision matrix highlighting the relative performance of each sustainable alternative, following standardisation. Once criterion's polarity is taken into consideration, alternatives with higher normalised values on benefit criteria indicate stronger positive contributions compared to lower normalized values on cost criteria.

5.8.2. Weighted normalised decision matrix

Following normalisation, the matrix is built upon multiplying each normalised value by the corresponding criterion weight derived from the Analytical Hierarchy Process, such that more weighted criteria have greater influence on the final ranking, where $w_j$denotes the weight of criterion j and v_{ij}represents the weighted normalised value of alternative i under criterion j, computed as follows:

$$v_{ij} = w_j \times r_{ij}$$

The resulting weighted normalised decision matrix is presented in table 22.

Table N°22. The weighted normalised decision matrix

Code	C1	C2	C3	C4	C5
A1	0.138	0.000	0.092	0.049	0.025
A2	0.041	0.000	0.115	0.062	0.019
A3	0.251	0.000	0.023	0.012	0.019
A4	0.103	0.000	0.023	0.025	0.019
A5	0.282	0.000	0.046	0.025	0.025
A6	0.000	0.000	0.046	0.037	0.031
A7	0.000	0.248	0.023	0.012	0.025

Table 22 displays a balanced and context sensitive representation of sustainable alternatives, serving as a strong foundation for subsequent identification of the ideal solutions and their final ranking. Further, switching to LED lighting and covered cooking pots exhibit strong weighted constributions under the energy-saving criterion while water flow regulators dominate the water saving criterion.Conversely, alternatives with higher payback scores or higher implementation complexity display lower performance under cost criteria.

5.1. Determination of separation distances and relative closeness coefficient

According to TOPSIS's geometric interpretation, the ideal solution refers to a hypothetical reference point representing the best achievable performance across criteria.

Theoretically, an alternative is considered preferable when it's the closest to the positive ideal solution (defined as the highest value) while being farthest from the ideal negative one (defined as the lowest value), observed for each criterion computed as follows:

5.1.1. Positive Ideal Solution

$A^{+} = \{v_1^{+}, v_2^{+}, \dots, v_n^{+}\}$

$$v_j^{+} = \begin{cases} max_i \, v_{ij} & \text{for benefit criteria} \\ min_i \, v_{ij} & \text{for cost criteria} \end{cases}$$

5.1.2. Negative Ideal Solution

$A^{-} = \{v_1^{-}, \dots, v_n^{-}\}$

$$v_j^{-} = \begin{cases} min_i \, v_{ij} & \text{for benefit criteria} \\ max_i \, v_{ij} & \text{for cost criteria} \end{cases}$$

Following the weighted normalised matrix, the positive and negative ideal solution vectors are obtained, respectively as follows:

$A^{+} = \{0.282, 0.248, 0.244, 0.127, 0.310\}$

$A^{-} = \{0.000, 0.000, 0.122, 0.063, 0.018\}$

5.1.3. Separation distances from ideal solution

Following the ideal solutions, the relative position of each alternative is assessed through separation distances using Euclidean distance metric, where n is the number of evaluation criteria, S_i^{+} is the distance from the positive ideal solution and S_i^{-} is the distance from the negative ideal solution, computed as:

$$S_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2}$$

$$S_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2}$$

The resulting separation distances are presented in table 23.

Table N°23. Euclidean relative distance metric

Code	S_i^+	S_i^-
A1	0.298	0.140
A2	0.362	0.041
A3	0.250	0.274
A4	0.306	0.147
A5	0.249	0.293
A6	0.377	0.078
A7	0.282	0.271

The occurring separation distances of LED lighting replacement (A5) and covered cooking pots (A3) exhibit relatively small distances from the positive ideal solution comparatively with larger distances from the negative ideal one. Conversely, geothermal heating (A2) displays the largest distance from the positive ideal and the smallest distance from the negative ideal, suggesting a weaker performance within the considered criteria framework.

5.1.4. Relative closeness to ideal solution

The relative closeness coefficient C_i ,bounded between 0 and 1 converts the separation distances into a unified performance indicator, used to compute the final ranking as follows:

$$C_i = \frac{S_i^-}{S_i^+ + S_i^-}$$

The resulting relative closeness Coefficients are presented in table 24.

Table N°24. Euclidean relative distance metric

Code	Sustainable alternative	C_i	Rank
A5	LED lighting replacement	0.54	1
A3	Covered cooking pots	0.52	2
A7	Water flow regulators	0.49	3
A4	Refrigeration placement optimisation	0.32	4
A1	Solar thermal system	0.31	5
A6	Energy monitoring system	0.17	6
A2	Geothermal heating	0.10	7

6. Results and Discussion

6.1. Results Analysis

According to the AHP-TOPSIS hybrid model, a significant share of energy used in hospitality operations comes from cooking practices and relative behavioural adjustments like adopting covered pots when boiling, which can result in considerable energy savings without requiring major infrastructural upgrades. Similarly, water flow regulators and LED lighting replacement achieved a high ranking due to their respective capacity to drastically cut water use and substitute traditional lighting systems with low investment costs and quick payback times.Given that international guests often consume significantly more water and energy than locals, installing flow regulation and energy-efficient LED devices can be a scalable way to lessen the water strain and energy consumption on nearby ecosystems.Across from it, geothermal heating system received the lowest assessment. Despite its potential to contribute to energy transition in the long run, putting it into action typically requires higher capital investment, significant technical infrastructure and specialized expertise.

These factors lessen its relative attractiveness when compared to lower cost efficiency alternatives.Considering the overall findings, it becomes apparent that operational efficiency measures and low-cost technological upgrades should be prioritized as first stages in the transition to a more sustainable model while remaining affordable for small and medium-sized ecological accommodations.

6.2. Managerial Implications

From a wider territorial perspective, the findings reinforce the role of ecological accommodations as sustainable living laboratories within emerging touristic destinations. Ultimately, this conceptual research paper's matrix helps ecolodge managers choose sustainable initiatves that balance environmental effectiveness, economic feasibility and operational practicality. Such hybrid models are particularly relevant for sustainability projects to be successful in emerging tourism destinations where initiatives must align with both ecological challenges and managerial realties.

Conclusion

Despite the contributions of this research paper, numerous limitations should be acknowledged.

The analysis relies on an illustrative case study based on The AHP-TOPSIS hybrid model using raw data derived from an existing operational guideline. While these insights provide a useful foundation for demonstrating the applicability of the resulting framework, they do not originate from large scale measurements across multiple hospitality entities.

Therefore, the numerical results of this paper should be considered as illustrative rather than definitive assessments of sustainability performance. Furthermore, the resulting pairwise comparisons were constructed to reflect general priorities in hospitality management. However, in practice, criteria may vary depending on contextual factors such as entity's size, geographical conditions, local constraints and the financial capacity of tourism operators.

All considered, the hybrid model put forth in this conceptual paper demonstrates the potential of multi-criteria decision-making methods to support sustainability-oriented decision processes in hospitality management. Future studies could enhance the framework's robustness through empirical case studies of ecolodge operators and other releavnat stakeholders, testing the crietria abd their relative importance across different destinations and contetxs and conducting sensitivity analyses to examine. The robustness of rankings under sereval scenarios. enabling the decision support model to be validated, refined and transferable under real-life scenarios.

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NOMENCLATURE

For clarity, the main symbols, subscripts, superscripts and abbreviations used in this conceptual research paper are summarized in the nomenclature below.

Symbols

P_{conv}	power of conventional bulb	[W]
P_{LED}	power of conventional bulb	[W]
ES	energy saving percentage	
C_i	consistency index	
CR	consistency ratio	
R_i	random index	
S_i^+	euclidean distance from the positive ideal solution	
S_i^-	euclidean distance from the negative ideal solution	
A^+	positive ideal solution vector	
A^-	negative ideal solution vector	
v_j^-	negative ideal value for criterion j	
v_j^+	positive ideal value for criterion j	
w_j	weight of criterion j	
v_{ij}	weighted normalised value of alternative i under criterion j	
r_{ij}	normalised value of alternative i under criterion j	
x_{ij}	normalised value of alternative i under criterion j	
m	number of alternatives	
λ_{max}	maximum eigenvalue.	

Subscripts and superscripts

i	alternative index
j	criterion index
+	positive ideal solution
−	negative ideal solution
i	alternative index
j	criterion index
+	positive ideal solution

Abbreviations

AHP analytical Hierarchy Process

TOPSIS technique for order preference by similarity to ideal solution

TLLs territorial living laboratories

APPENDICES

To ensure transparency and reproducibility of the results, the detailed input data used in the hybrid AHP-TOPSIS illustrative model are provided in this appendix.

Table A1. Ecolodge energy consumption

Energy usage category	Share of Consumption
Water heating	19
Kitchen operations	17
HVAC system	16
Lighting	15
Laundry	9
Plugs and other technical services	24

Table A2. Comparative energy consumption in operations

Lighting technology	Power consumption [W]	Efficiency indicator
Traditional incandescent bulb	60	Baseline
LED efficient bulb	11	Up to 12 longer lifespans

Table A3. Summarised energy efficiency measures in operations

Energy efficiency measure	Indicator [%]	Description
Solar Thermal system	40	Using Panels to reduce consumption of hot water production
Geothermal Heating	12	Using heat from the ground for building's heating and cooling
Cooking Pot	73	Boiling water in a covered pot (127 kWh) compared to uncovered (480 kWh)
Refrigeration optimisation	30	Placing refrigerators near heat sources

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Table A4. Ecolodge's economic viability of sustainability measures

Sustainability measure	Investment cost	Annual net savings	Payback period [days]
LED lighting optimisation	28.047	407.516	25

Table A5. Ecolodge Water Consumption

Indicator	Consumption [Liters]
Average daily water consumption per guest	300

Table A6. Ecolodge's water conservation measures

Water saving device	Average saving [%]	Payback period [days]
Flow regulator installation	50	10

Table A7. Summarised sustainability measures

Measure	Dimension	Impact type
Solar thermal system	Energy	Impact type
Geothermal heating	Energy	Low-consumption heating
Efficient cooking practices	Energy	Low-carbon heating
Refrigeration optimisation	Energy	Behavioural efficiency
LED lighting	Energy	Operational efficiency
Energy monitoring system	Energy	Energy efficiency
Water flow regulators	Water	Management optimisation