

Article

A Systematic Framework for Identifying, Validating, and Evaluating Ecotourism Sustainability Indicators: A Case Study of AlUla, Saudi Arabia

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Abstract

Assessing sustainability in ecotourism destinations remains challenging due to the multi-dimensional interactions among environmental, socio-cultural, educational, and managerial factors. Existing assessment approaches often focus on isolated sustainability aspects and lack a systematic procedure for identifying, validating, and quantitatively evaluating sustainability indicators. To address this gap, the framework sequentially applies the Ecotourism Opportunity Spectrum (ECOS) model for indicator identification, Delphi for expert validation, and Confirmatory Factor Analysis (CFA) for statistical verification before Sustainability Index development in AlUla, Saudi Arabia. The results collected 25 Ecotourism sustainability indicators grouped into five dimensions: nature, environmental education/protection, sustainability, socio-cultural benefits, and tourist satisfaction from the literature. A two-round Delphi process involving 110 experts achieved more than 80% expert agreement across all indicators, while CFA confirmed the reliability and validity of the proposed framework. A Sustainability Index was subsequently developed, resulting in an overall Sustainability Index score of 52.40 on the normalized 0–100 scale. The findings highlight the strengths of environmental education and protection while identifying opportunities for improvement in sustainability and nature-related dimensions. This study develops and validates a systematic sustainability assessment framework for AlUla, Saudi Arabia, as the empirical study context, providing policymakers, tourism planners, and destination managers with a practical tool for evaluating and monitoring sustainable ecotourism performance. Although developed and tested in AlUla, the methodological process may provide a basis for assessment in other ecotourism destinations, subject to context-specific indicator adaptation and local validation.

Keywords: ecotourism; sustainability; indicators; evaluation; index



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1. Introduction

Despite the close association between ecotourism and sustainable development, assessing whether ecotourism destinations actually achieve sustainability remains methodologically challenging. Existing studies employ diverse environmental, socio-cultural, economic, and management indicators, but their selection and validation vary considerably across destinations and assessment frameworks [1–3]. This fragmentation limits comparability and makes it difficult to determine which indicators provide a reliable basis for evaluating destination-level sustainability. Consequently, a structured process is still needed to link indicator identification, expert validation, statistical verification, and quantitative assessment within a coherent framework.

Ecotourism sustainability indicators are measurable attributes used to evaluate how effectively a destination maintains environmental integrity, socio-cultural well-being, educational benefits, responsible management, and sustainable visitor experiences [4–6]. In this context, a comprehensive sustainability assessment involves evaluating these interconnected dimensions simultaneously rather than examining individual aspects of sustainability in isolation. These indicators reflect destinations' ability to preserve natural and cultural resources while supporting local communities, environmental awareness, visitor satisfaction, and long-term sustainability. Accordingly, the framework incorporates visitor-related perspectives through sustainability-related aspects of visitor experiences and tourist satisfaction, including accessibility, nature-based activities, habitat quality, and visitor protection. The framework does not seek to comprehensively measure all dimensions of visitor behavior, but rather focuses on visitor-related conditions that contribute to sustainable ecotourism development [7–9]. Developing and managing sustainable ecotourism destinations requires comprehensive evaluation of sustainability indicators [10,11]. Measuring comprehensive ecotourism opportunities can help identify sustainable opportunities, establish benchmarks, and monitor the success of sustainability initiatives [10,11].

Ecotourism sustainability indicators are essential for systematically evaluating the environmental, socio-cultural, and managerial sustainability of tourism destinations. These indicators provide structured evidence of destinations' sustainability performance and support decision-making by tourism planners, policymakers, and stakeholders [5,10–12]. They also help identify strengths and weaknesses in sustainability practices while supporting long-term destination management and monitoring [11,13].

Sustainability indicators provide efficient information to the administrative, human resource, land management, and programming sectors to predict problems, highlighting their value [11]. By identifying issues, they enable speedy government and industry response, contributing to UN Sustainable Development Goals 8 and 11 [14]. Sustainability indicators help stakeholders prioritize ecotourism destinations and identify strong and weak regions [5,10–12]. Thus, researchers, industry practitioners, and local government authorities can use them to explore the opportunities and maximize the destination's potential to attract tourists during peak times without harming the site's environment and culture.

Approaches to Evaluating Ecotourism Sustainability Indicators

Researchers have utilized different analytical methodologies to evaluate Ecotourism sustainability indicators. For instance, using landscape assessment methodologies, Priskin [15] proposed several methods for measuring ecotourism opportunities based on scenic quality or attractiveness. The first, known as the landscape consensus, involves experts assessing a site's scenic worth using fieldwork, aerial photography, and other sources. This procedure was used to determine Areas of Outstanding Natural Beauty (AONB) in England [16]. A second model, according to Litton (1968) [17], is descriptive landscape studies, in which

some or all of the landscape's entities are inventoried and described. Litton created and implemented an assessment system based on landform and land use in California, creating six categories based on landforms and seven on the degree of land use, ranging from wild to urbanized. He also created maps and assigned numerical values to each category. A third method is landscape preferences, which is used by Shafer Jr et al. [18]. Based on interviews and photographs, this methodology identifies the environmental elements deemed appealing by both professionals and visitors. In addition, Boyd and Butler [7] formulated the Ecotourism Opportunity Spectrum (ECOS) model, which provides a framework for evaluating ecotourism opportunities based on natural and cultural resources, management contexts, and tourist experiences. Various sustainability assessment approaches have been applied to examine environmental, socio-cultural, economic, and managerial dimensions influencing ecotourism sustainability [19,20]. Researchers such as Barzekar, Aziz, Marianpan and Ismail [1] and Ashok et al. [21] employed the Delphi method, a consensus-building technique involving structured inquiries directed at a panel of experts, to conduct sustainability assessments of ecotourism. These methodologies illustrate that several instruments have been utilized to measure ecotourism opportunities. Nevertheless, most of these studies measured ecotourism opportunities qualitatively, with few quantitative studies.

Moreover, understanding ecotourism opportunities benefits both visitors and tourism industry experts when evaluating potential destinations [11]. Visitors often rely on general perceptions of a destination, increasingly shaped by search engine results, whereas industry professionals use data and quantitative methods [10,22]. Few academics, such as Baral, Stern and Hammett [10] and Adeleke [23], have studied quantitative measurements or index development. Nonetheless, these traditional methods of evaluating ecotourism opportunities, whether via search engines, indices, or scales, merely offer a coarse-grained overview of the extent of opportunities available in an ecotourism destination.

Although previous studies have proposed various frameworks and indicators for ecotourism sustainability assessment, most have focused on specific dimensions or specialized aspects of sustainability, such as environmental conservation, socio-cultural impacts, visitor experiences, or destination management. This focus reflects the inherent complexity of sustainability assessment, where individual dimensions are often examined separately to allow for more detailed evaluation. Consequently, existing approaches often treat indicator identification, validation, and quantitative assessment as distinct processes rather than integrating them into a single methodological framework. Therefore, an opportunity remains to develop a structured framework that systematically combines indicator identification, expert validation, and quantitative evaluation while acknowledging the multi-dimensional nature of ecotourism sustainability. Accordingly, this study aims to develop and examine a systematic framework for assessing ecotourism sustainability indicators in AIUla, Saudi Arabia.

In this study, ecotourism opportunities are conceptualized as sustainability-related attributes that support the long-term development of ecotourism destinations. Therefore, the objective is not merely to assess landscape characteristics or tourism attractiveness, but to evaluate the environmental, socio-cultural, educational, managerial, and visitor-related conditions that contribute to sustainable ecotourism development. In this context, the ECOS model serves as a framework for organizing and assessing these sustainability-oriented opportunities through a structured set of indicators.

Although previous studies have used Delphi to develop ecotourism sustainability frameworks, such as [1,21], they commonly emphasize indicator identification or expert validation rather than linking these stages with statistical verification and quantitative index development. This study's scientific contribution is therefore to connect ECOS-based indicator identification, Delphi-based contextual validation, CFA-based measurement ver-

ification, and index development within one sequential assessment process, reducing the methodological fragmentation identified in previous approaches.

While previous studies have discussed many indicators individually, this research contributes by integrating indicator identification, expert validation, statistical verification, and quantitative assessment within a single framework. This integration reduces fragmentation between indicator selection and evaluation and provides a transparent procedure for developing sustainability assessments across multiple dimensions.

2. Materials and Methods

This study employs a threefold methodology: first, to collect Ecotourism sustainability indicators; second, to validate the sustainability of the collected indicators; and third, to evaluate these sustainability indicators and develop a sustainability index. A case study is considered appropriate for these types of studies. It enables an in-depth, context-specific examination of multidimensional sustainability indicators within their real-world destination setting, making it appropriate for evaluating the environmental, socio-cultural, managerial, and tourism characteristics [11,24]. Hence, AIUla provides a suitable context for developing and testing a sustainability assessment framework within a rapidly evolving ecotourism destination. In addition, AIUla is simultaneously implementing environmental conservation, heritage protection, and sustainability initiatives. These characteristics provide an appropriate setting for evaluating sustainability indicators within an emerging ecotourism context.

2.1. Research Context

In recent years, Saudi Arabia has worked to expand international tourism, positioning itself as a destination rich in cultural heritage, historical significance, and natural splendor [25,26]. AIUla, situated along the ancient Incense Road in northwest Medina province, about 200 km from the Red Sea, exemplifies a distinctive blend of cultures and traditions [27–31]. The city consists of five historically significant districts: Old Town AIUla, Jabal Ikma, Dadan, the Nabataean region, and Hegra (Figure 1). Each neighborhood exemplifies distinct phases of the city's cultural evolution, ranging from Old Town AIUla's pivotal role in the 12th-century incense trade to the archaeological site of Dadan, the capital of the Lihyanite and Nabataean kingdoms; the distinctive rock-cut tombs of the Nabataeans; the prehistoric rock inscriptions at Jabal Ikma; and Hegra, a UNESCO World Heritage site in Saudi Arabia [27–31].

AIUla helps in examining the socio-economic dynamics of rural communities in Saudi Arabia because of its considerable cultural and historical importance [29,32,33]. The region has a semi-arid Mediterranean climate characterized by hot summers and moderate, precipitation-rich winters [34,35]. The geography, characterized by arid rocky landscapes and sporadic watercourses, supports local agriculture despite the absence of permanent streams [34,35]. The economy primarily relies on agriculture and animal husbandry [33,34]. The region's diverse geography, including mountains, deserts, and oases, offers numerous adventure tourism activities, including hiking, ziplining, and exploring unique rock formations [29,36].

AIUla's biodiversity markedly elevates its ecotourism potential, featuring 58 plant species and a variety of wildlife, including the rare Arabian leopard, Nubian ibex, and Idmi gazelles [29,36]. Cultural history is vital to AIUla's tourism appeal, encompassing historic buildings, traditional architecture, and events such as the Winter at Tantora Festival and the AIUla Dates Festivals [37,38].

Nonetheless, AIUla's potential as a tourism destination has traditionally been hindered by insufficient infrastructure and stringent visa rules [29,33,35]. The initiation of

Saudi Vision 2030 in 2016, aimed at diversifying the economy and promoting sustainable tourism, has garnered considerable attention in the area [29]. The Royal Commission for AlUla (RCU) was established to safeguard the region's natural and cultural assets while fostering sustainable tourism development [39,40]. The Commission aims to attract two million visitors by 2035, transforming AlUla into the world's largest living museum and a leading global destination for heritage, nature, and culture tourism [29,30].

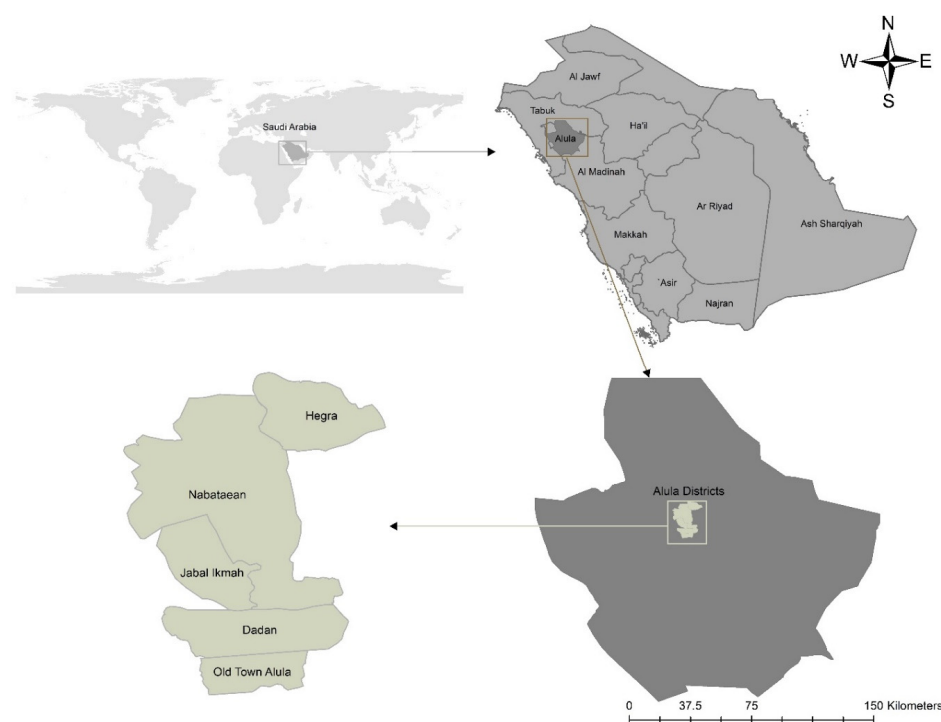


Figure 1. AlUla and its districts in Saudi Arabia (Adopted from Sahahiri, et al. [32]).

To further justify the selection of AlUla as the empirical case study, Table 1 summarizes publicly available tourism development milestones and reported visitor figures since the launch of Saudi Arabia's tourism sector in 2019. Complete annual visitor data for the early development period is not publicly reported in the available sources; therefore, the table reports verified milestones and available visitor numbers from official and published sources. The available data show a clear growth trajectory since the COVID-19 period, with visitor arrivals rising from 185,000 in 2022 to approximately 265,000 in 2023 and 286,259 in 2024. This trend supports the need to develop a sustainability assessment framework for AlUla, a rapidly emerging destination for sustainable tourism, culture, and heritage experiences.

Table 1. Reported visitor trends in AlUla since 2019.

Year	Tourism Development Milestone/Reported Visitors	Reference/Source
1990	AlUla recognized for its rich archaeological and cultural heritage.	Hariri-Rifai (1990) [37]
2008	Heritage resources, including the Hijaz Railway, highlighted AlUla's tourism potential.	Orbaşlı & Woodward (2008) [38]
2019	Saudi Arabia officially opened AlUla to international tourists	Arab News (2019) [41]
2020, 2021	COVID-19 disrupted tourism activities in AlUla	

Table 1. Cont.

Year	Tourism Development Milestone/Reported Visitors	Reference/Source
2022	185,000 visitors.	Arab News (2014) [42]
2023	Approximately 265,000 visitors; RCU also reported more than 265,000 guests, over 40% higher than 2022.	RCU Annual Report (2023) [43] RCU Annual Report (2024) [44]
2024	286,259 travelers; UNESCO Courier also reports 286,000 arrivals.	[45,46]
2030 target	1.1–1.2 million annual visitors	[43,47]

Despite the region’s evident tourism potential, investigations into the socioeconomic conditions and issues facing rural populations, such as land tenure, resource management, and access to services, remain insufficient [34,48]. Although AIUla supports broader cultural and heritage tourism, its diverse desert, mountain, and oasis landscapes, biodiversity and wildlife, protected areas, conservation initiatives, and environmental restoration programs make ecotourism particularly relevant. Unlike tourism, which is often considered a visitor activity primarily, ecotourism directly connects these nature-based assets with conservation, environmental education, local benefits, and responsible destination management, while complementing AIUla’s cultural heritage resources (Figure 2). Ecotourism in the region has several challenges, including insufficient infrastructure and fluctuating market demands [34,48]. Analyzing AIUla’s emerging tourism sector could provide insights into sustainable management practices, stakeholder collaboration, and systemic resilience.



Figure 2. Representative views of AIUla’s cultural and natural landscape. Source: Authors’ photographs.

2.2. Identifying Ecotourism Opportunity Indicators

To identify ecotourism opportunity indicators, this study uses the ECOS framework established by Boyd and Butler [7]. ECOS offers a wide-ranging framework for evaluating tourism and for effective destination organization. The model's efficacy has been empirically evaluated in numerous studies in which ECOS was used to identify ecotourism opportunities and conduct qualitative evaluations of destination potential [3,24,49]. It comprises eight components for identifying ecotourism opportunities in a specific destination, as seen in Figure 2. However, the framework can be functional in numerous circumstances with some adjustments [7]. Consistent with this flexibility, we identified five dimensions from Sahahiri et al. [50] and 32 candidate indicators (Table 1) through a targeted review of established ecotourism, sustainability, and indicator-assessment literature [4,8,50–55]. We considered studies and indicators addressing environmental, socio-cultural, educational, managerial, or visitor-related aspects of ecotourism sustainability. The retained indicators conceptually aligned with the ECOS framework and were relevant to AIUla's environmental, cultural, and tourism context, and excluded indicators lacking clear contextual applicability. This screening produced 25 indicators for subsequent Delphi validation. Seven candidate indicators (N7, N8, N13, N18, N19, N25, N31) were excluded during pre-Delphi screening because they lacked sufficient relevance or applicability to AIUla's environmental, cultural, and tourism context, leaving 25 indicators for expert validation.

Additionally, the indicators were conceptualized as destination-level sustainability attributes rather than individual behavioral constructs. Consequently, indicators referring to local communities and visitors represent collective conditions that support sustainable ecotourism development and were not intended to compare the attitudes of these stakeholder groups separately. Likewise, environmental education and protection were combined within one dimension because environmental awareness, interpretation, and educational initiatives are closely linked to conservation behavior and environmental protection outcomes in ecotourism destinations [9,53].

The indicators were developed to provide a strategic assessment of destination-level sustainability rather than detailed evaluations of individual tourism services or facilities. Accordingly, indicators such as accommodation opportunities were designed to assess the overall availability and adequacy of tourism services within the destination rather than specific service attributes. These indicators identify strategic strengths and deficiencies that can guide destination managers and policymakers in prioritizing planning, resource allocation, and sustainable tourism interventions.

The tourist satisfaction dimension focuses only on sustainability-related conditions that influence visitor experiences, including accessibility, nature-based activities, habitat quality, and visitor protection, rather than attempting to measure all determinants of tourist satisfaction comprehensively (Table 2).

Table 2. Dimensions and indicators collected by ECOS.

Dimensions	Indicators	Scale Source/Context
Nature (D1)	Topography (N1)	Priskin (2001) [15]
	Appropriate natural phenomenon (N2)	Priskin (2001) [15]
	Wildlife saturation (N3)	Lindsey et al. (2007) [56]
	Protected sites (N4)	Ocampo et al. (2018) [2]
	Preparation to conserve nature (N5)	Buckley (2009) [54]
	Preparation to conserve culture (N6)	Kiper (2013) [57]
	Biodiversity conservation initiatives (N7)	Ocampo et al. (2018) [2]
	Ecological landscape connectivity (N8)	Ocampo et al. (2018) [2]

Table 2. Cont.

Dimensions	Indicators	Scale Source/Context
Environmental education/ protection (D2)	Environmental protection consciousness among local communities (N9)	Bowles and Ruhanen (2018) [9]
	Environmental education (N10)	Zeppel (2008) [58]
	Ecotourism consciousness among local communities and visitors (N11)	The International Ecotourism Society (2020) [53]
	Infrastructural Services (N12)	Ocampo et al. (2018) [2]
	Visitor environmental interpretation programs (N13)	Ballantyne et al. (2011) [59]
	Accommodation opportunities for ecotourists (N14)	Ashok et al. (2017) [21]
	Government planning to promote tourism (N15)	Ocampo et al. (2018) [2]
Sustainability (D3)	Water accessibility and conservation strategies (N16)	Ocampo et al. (2018) [2]
	Practices to protect the natural environment (N17)	Kiper (2013) [57]
	Renewable energy utilization in tourism facilities (N18)	Ocampo et al. (2018) [2]
	Waste management and recycling practices (N19)	Ocampo et al. (2018) [2]
	Practices to support sustainable long-term economic growth (N 20)	Ashok et al. (2017) [21]
Socio-cultural benefits (D4)	Planning to conserve historical heritage sites (N21)	Kiper (2013) [57]
	Protection and promotion of local heritage (N22)	Ashok et al. (2017) [21]
	Impact assessment indicator (N23)	Boyd and Butler (1996) [7]
	Health facilities (N24)	Ocampo et al. (2018) [2]
	Local community participation in tourism planning (N25)	Ashok et al. (2017) [21]
	Educational opportunities (N26)	Ashok et al. (2017) [21]
	Employment opportunities (N27)	Ocampo et al. (2018) [2]
	Local business promotion opportunities (N28)	Ashok et al. (2017) [21]
Tourist satisfaction (D5)	Resilient habitat (N29)	Buckley (2009) [54]
	Nature-based activities (N30)	Boyd and Butler (1996) [7]
	Accessibility and quality of ecotourism services (N31)	Baral et al. (2012) [10]
	Tourist protection (N32)	Asmelash and Kumar (2020) [60]

2.3. Validating Ecotourism Opportunities' Sustainability

Following identification, validating the sustainability of the collected ecotourism opportunity indicators was essential. This refers to the ability to accommodate tourism without negatively impacting the environment, local communities, or their cultural heritage [4,61]. Therefore, this phase validated sustainability through the Delphi technique, which is a structured method for collecting and combining expert opinions on a specific problem or topic [62,63]. It is a recognized method for reaching expert agreement on complex issues. Its ability to obtain structured feedback from a diverse group of specialists and expand the range of indicators and dimensions is what led to its selection [21,62,64].

This study employed the Delphi method to validate the sustainability of the collected indicators. The multidisciplinary panel comprised 110 experts: 56 academics, 18 architects, 17 hospitality and tourism professionals, 14 engineering specialists, and five geologists. Purposive selection required relevant academic qualifications and more than five years of professional experience, supported by research publications or involvement in ecotourism and sustainability projects. Before rating the indicators, panel members received a brief explanation of the study objective, the meaning of sustainability in the context of ecotourism, and the indicator dimensions under evaluation. The experts were also informed that the indicators were intended to represent destination-level strategic sustainability attributes rather than detailed operational performance measures. The Delphi method was

used because the indicators were compiled from previous studies and required contextual validation for AIUla rather than direct adoption. A four-point relevance scale was adopted because the Delphi process aimed to evaluate the content validity and relevance of the proposed sustainability indicators rather than measure attitudes or behavioural preferences. Four-point relevance scales are widely recommended in content validity assessment because they facilitate clear judgments regarding item relevance and support the calculation of expert agreement while avoiding ambiguous middle categories [65,66]. Previous Delphi studies have adopted four-point relevance scales to evaluate the content validity of proposed items and to distinguish clearly between relevant and irrelevant indicators during expert assessment [21,65,66]. The objective of the present study was not to measure individual attitudes or preferences, but rather to obtain expert agreement regarding the relevance and sustainability of the proposed indicators. Therefore, a four-point relevance scale was adopted to support the systematic assessment of indicator relevance during the Delphi process. Experts were also invited to comment on the clarity and relevance of the indicators and to suggest refinements where necessary. The objective of the Delphi process was to establish expert agreement regarding the relevance and suitability of the proposed sustainability indicators rather than to measure individual attitudes or preferences.

Moreover, researchers propose using 2–4 rounds of the Delphi method [67,68]. Thus, this study used two rounds. The first-round questions included a list of 25 ecotourism opportunity indicators and were sent to 125 panel members. Participants were asked to indicate their level of agreement with the sustainability of each indicator using a 4-point Likert scale ranging from strongly agree (1) to strongly disagree (4) [62,69]. The experts were asked to rate “each indicator’s relevance to sustainability.” This round involved 110 experts whose concise and organized responses were prepared for the second questionnaire. The final panel of 110 experts surpasses typical Delphi study sample sizes and offers a wide range of multidisciplinary expertise relevant to ecotourism sustainability assessment [1,2].

The second round commenced one month after the initial one, involving re-contact with the 110 members. All participants from the first round responded, showing ongoing interest. The questions aimed to validate the relevance and consistency of the sustainability indicators across five dimensions. A 4-point scale rated each indicator’s importance, from highly relevant (1) to highly irrelevant (4). Participants also estimated the availability of each validated indicator in AIUla, assigning a score from 0 to 100. These expert scores provided the quantitative data for further statistical analysis and sustainability index development. They reflected expert judgments on how accessible each indicator was in AIUla, Saudi Arabia.

Since the study relied on expert evaluations gathered via a two-round Delphi method, the potential impact of common method variance (CMV) was deemed minimal. The primary goal was to reach expert consensus on the importance and accessibility of sustainability indicators, not to analyze causal links between behavioral constructs. Harman’s single-factor test was used as an initial check for common method variance [70,71]. The findings indicated that the first unrotated factor accounted for less than 50% of the overall variance, suggesting that common method variance probably did not significantly impact the results. Nevertheless, Harman’s single-factor test is merely a diagnostic tool and does not eliminate or completely address common method bias.

Additionally, this research considered consensus on the sustainability of each indicator to be achieved if it received >80% agreement [72–74]. A strong consensus enhances the validity of the results and facilitates the development of widely accepted and effective sustainability indicator frameworks.

2.4. Evaluating the Ecotourism Opportunities Indicators

In this phase, the research used CFA to evaluate the reliability and validity of the construct derived from the dimensions and indicators. The CFA model included five latent dimensions and twenty-five observed indicators, which were validated through the Delphi process. The analysis used expert evaluation data collected during the second Delphi round to assess whether the observed indicators adequately represented their respective sustainability dimensions and to verify the internal consistency of the proposed framework. CFA was adopted because of its extensive use in the scholarly literature to examine the validity and reliability of hypothesized relations between the inputs [75–77]. This research applied multiple fit indices as recommended by various scholars [10,60,77–79]: Chi-square, Goodness of Fit Index (GFI), *p*-value, Root Mean Square Residual (RMR), Adjusted Goodness of Fit Index (AGFI), Normed Fit Index (NFI), Root Mean Square Error of Approximation (RMSEA), Incremental Fit Index (IFI), Tucker–Lewis Index (TLI), and Comparative Match Index (CFI).

Subsequent to the CFA, the index was constructed by normalizing the indicator scores (Equation (1)) of 25 sustainability indicators. This study used the Min-Max Normalization method. This is a straightforward and efficient method for normalizing data to a uniform scale. It facilitates the comparison of values from disparate sources by normalizing the data to a uniform range [80,81]. This technique transforms values to a range of 0 to 1, which is advantageous for specific algorithms, particularly in index calculation methodologies where the variable range must be confined to 0 to 1, enabling the final index value to be converted to a scale of 0 to 100 [82,83]. Subsequently, after normalization, the dimension score has measured by calculating the average score of the indicators Equation (2). This score has then averaged once again to determine the dimension score Equation (3), whose average value reflected the EOI score of AIUla Equation (4).

$$N_{\text{normalized}} = \frac{N - N_{\text{minimum}}}{N_{\text{maximum}} - N_{\text{minimum}}} \quad (1)$$

Here,

N = Indicators.

The rescaled indicator values are then used to create dimension scores ranging from 0 to 100.

The dimension score was calculated as the arithmetic mean of the normalized indicators within each dimension (Equation (2)), following the Opportunity Index methodology described by Opportunity Nation [13] and Rackers et al. [84]. Consistent with this approach, equal weighting was applied so that each indicator contributed equally to its respective dimension, avoiding additional subjective assumptions about the relative importance of individual indicators.

$$D_{\text{score}} = \frac{N_1 + N_1 \dots \dots \dots N_{25}}{\text{Total number of counts}} \quad (2)$$

Here,

D = Dimension.

Following the same Opportunity Index approach [13,84], the final Sustainability Index for AIUla was calculated as the arithmetic mean of the five dimension scores (Equation (3)), thereby assigning equal weight to each dimension. Sensitivity was tested by varying each dimension weight from 20% to 10% and 30% while proportionally redistributing the remaining weight across the other dimensions.

$$\text{Sustainability Index} = \frac{D_1 + D_1 \dots \dots \dots D_n}{\text{Total number of counts}} \quad (3)$$

So, the index was calculated by the following formula (Equation (4)):

$$\text{Sustainability Index} = \frac{1}{D_t} \sum_{j=1}^{D_t} \left(\frac{1}{n_j} \sum_{i=1}^{n_j} N_{ij(\text{norm})} \right) \quad (4)$$

For explanation:

$N_{ij(\text{norm})}$ = normalized score of indicator i under dimension j .

n_j = number of indicators within dimension j .

D_t = total number of dimensions.

3. Results

3.1. Collecting Ecotourism Opportunities Indicators

The screening process retained 25 of the 32 candidate sustainability indicators across five dimensions: nature (6), environmental education/protection (6), sustainability (3), socio-cultural benefits (7), and tourist satisfaction (3) (Table 3).

Table 3. The final list of collected ecotourism sustainability indicators.

Dimensions	Indicators
Nature (D1)	Topography (N1) Appropriate natural phenomenon (N2) Wildlife saturation (N3) Protected sites (N4) Preparation to conserve nature (N5) Preparation to conserve culture (N6)
Environmental education/ protection (D2)	Environmental protection consciousness among local communities (N7) Environmental education (N 8) Ecotourism consciousness among local communities and visitors (N9) Infrastructural Services (N10) Accommodation opportunities for ecotourists (N11) Government planning to promote tourism (N12)
Sustainability (D3)	Water accessibility and conservation strategies (N13) Practices to protect the natural environment (N14) Practices to support sustainable long-term economic growth (N 15)
Socio-cultural benefits (D4)	Planning to conserve historical heritage sites (N16) Protection and promotion of local heritage (N17) Impact assessment indicator (N18) Health facilities (N19) Educational opportunities (N20) Employment opportunities (N21) Local business promotion opportunities (N22)
Tourist satisfaction (D5)	Resilient habitat (N23) Nature-based activities (N24) Tourist Protection (N25)

3.2. Validating Ecotourism Indicators' Sustainability

After collecting 25 indicators using the ECOS model, the study assessed their sustainability using the Delphi method. In the first Delphi round, the expert panel received a list of 25 sustainability indicators. All experts responded to all 25 questions, indicating their awareness of these indicators. Their ratings for each indicator demonstrated over 80% agreement, combining “agree” and “strongly agree,” as illustrated in Figure 3. This strong consensus indicates that the chosen indicators are reliable and broadly accepted as components of sustainable ecotourism in AIUla.

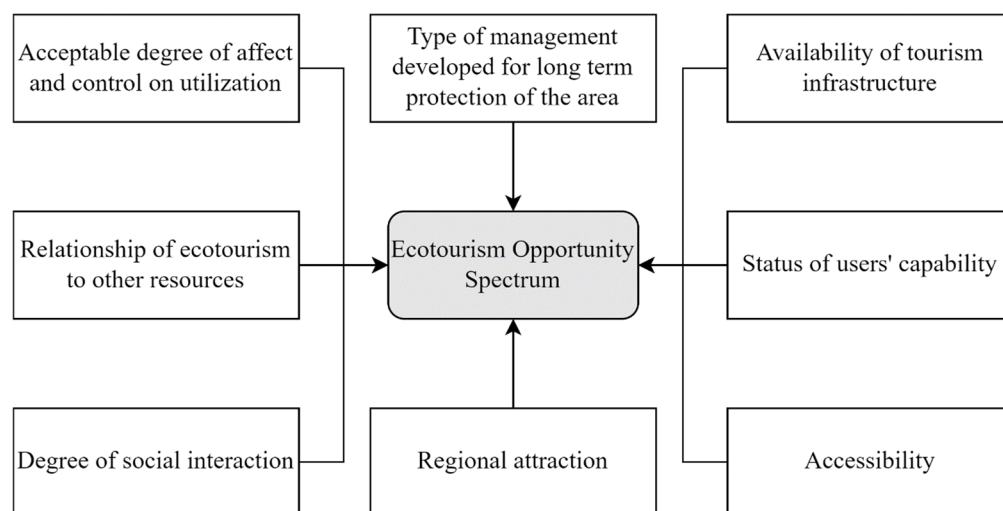


Figure 3. Ecotourism Opportunity Spectrum (ECOS) model (Adopted from Boyd and Butler [7]).

In the second Delphi round, the confirmed list of 25 sustainability indicators was sent again to the expert panel for further assessment of their relevance to the five dimensions. All 110 Round 1 experts participated again in Round 2, and their responses were included in the subsequent analysis.

The second Delphi round achieved over 80% agreement on all indicators. The combined responses of “highly relevant” and “somewhat relevant” showed ongoing consensus among the expert panel. Figure 4 presents the final validated framework consisting of 25 indicators and their corresponding expert relevance levels.

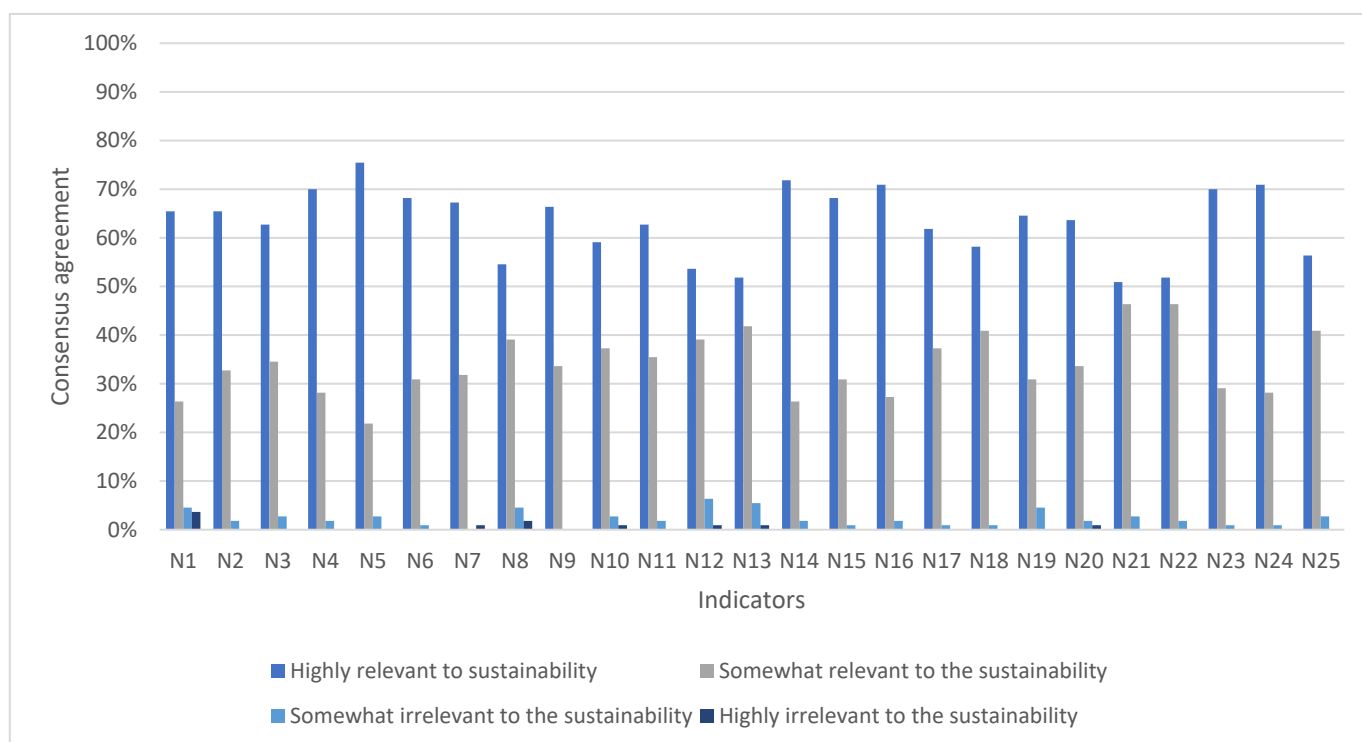


Figure 4. The list of consented sustainable ecotourism opportunity indicators.

3.3. Confirmatory Factor Analysis and Developing a Sustainable Index

The objective of the CFA was to evaluate whether the twenty-five validated indicators adequately represented the five proposed sustainability dimensions. Before the CFA,

Harman's single-factor test was performed and indicated that common method bias was not a significant concern in the dataset. Using the expert evaluation data obtained during the second Delphi round, CFA was applied to examine the reliability and validity of the relationships between observed indicators and their corresponding latent dimensions. This step was undertaken to statistically verify the structure of the proposed sustainability framework before developing the sustainability index.

The model fit was evaluated using several statistical metrics based on indicator and dimension data. Figure 5 presents the standardized factor loadings for all 25 indicators, which predominantly exceed 0.30; indicators were specified to load on their theoretically assigned dimensions, with no cross-loadings estimated. We further assessed measurement-model quality using multiple model-fit, reliability, and validity measures [85,86]. In Table 4, the chi-square-to-degrees-of-freedom ratio remained below 5, indicating substantial model fit. Model-fit evidence was mixed rather than uniformly satisfactory: CFI (0.92), TLI (0.91), and RMSEA (0.074) met commonly applied criteria, whereas AGFI (0.78), NFI (0.89), and IFI (0.89) were marginal or slightly below conventional thresholds. The CFA results should therefore be interpreted as indicating an acceptable, but not unequivocally strong, overall model fit.

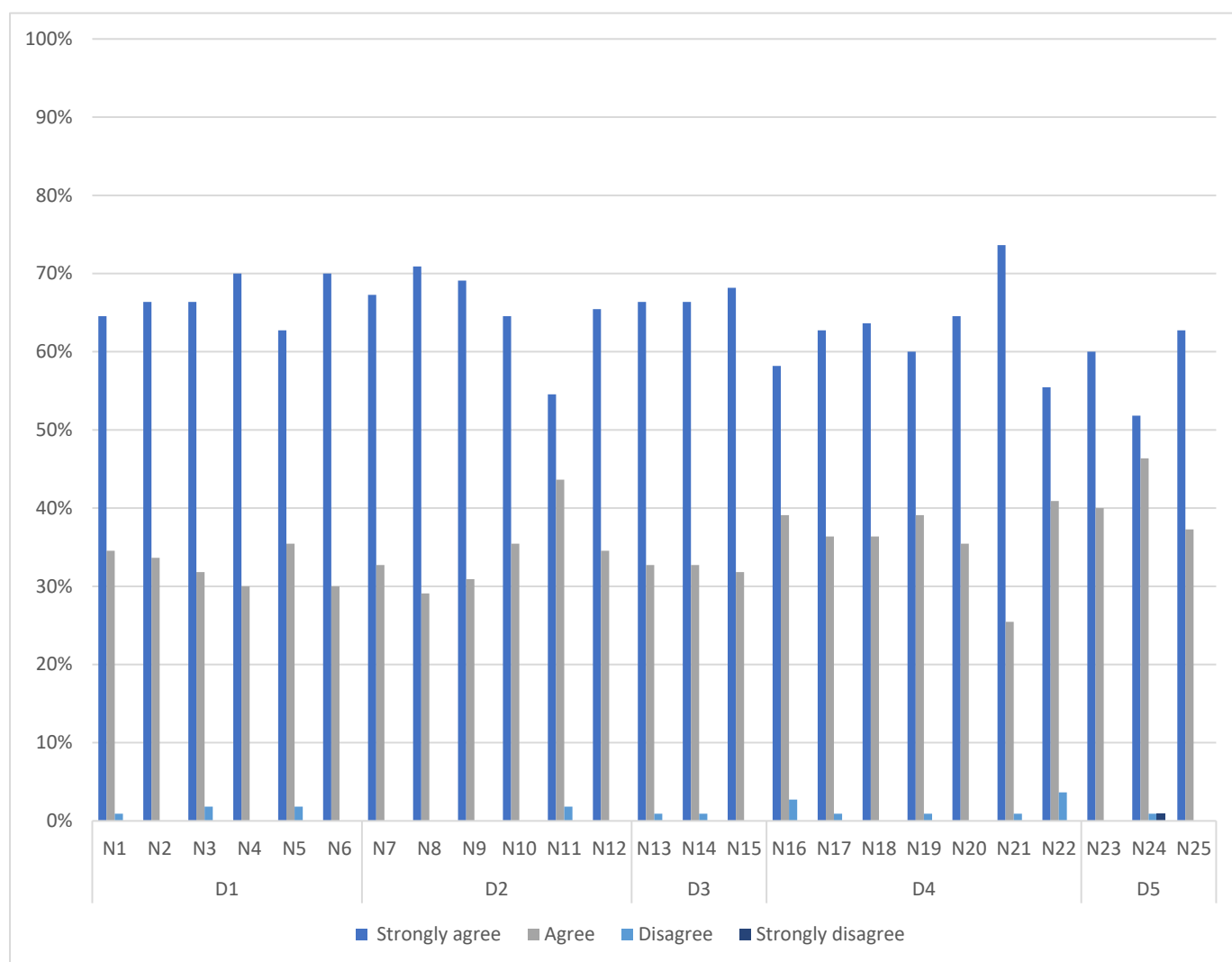


Figure 5. The 25 sustainable ecotourism opportunity indicators.

Table 4. Model fit indices of indicators with cut-off values.

Measures (Goodness of Fit for the Modified Research Model)	Cut-Off Values	References	Round 1 (D1–D5)
Chi-square: χ^2/df	Below 5	[77,78]	1.6
P	Below 0.05	[77,79]	0.01
GFI	Above 0.9 or close to 0.8	[60,78]	0.8
AGFI	Above 0.9 or close to 0.8	[60,78]	0.78
RMR	Below 0.5	[10,77]	0.2
RMSEA	Below 0.08	[10,77]	0.074
NFI	Above 0.9	[77,78]	0.89
CFI	Above 0.9	[77,79]	0.92
IFI	Above 0.9	[60,78]	0.89
TLI	Above 0.9	[60,78]	0.91

The reliability and validity assessments indicate that the model demonstrates strong reliability and validity, as outlined in Table 5. Cronbach’s Alpha values, which evaluate the internal consistency of items within each dimension, remain at 0.905, reflecting high reliability. Similarly, the Composite Reliability (CR) value, another measure of internal consistency, is 0.9, further confirming the reliability of the constructs. The Average Variance Extracted (AVE) values, which assess convergent validity, remain at 0.72, indicating that a substantial proportion of variance is shared among items within each dimension. These results validate the robustness of the measurement instruments employed, ensuring the reliability and validity of the data used in the analysis.

Table 5. Reliability and validity test for indicators.

Measures	Cut-Off Values	References	Round 1
Cronbach’s Alpha	Above 0.7	[77,79]	0.9
Composite reliability (CR)	Above 0.9	[77,79]	0.90
Average variance extracted	Above 0.5	[77,79]	0.72

The final Sustainability Index score for AIUla was 52.40 under equal weighting. Sensitivity analysis produced scores ranging from 51.10 to 53.71 when individual dimension weights were varied between 10% and 30%, indicating that the overall assessment remained relatively stable under alternative weighting assumptions. These results show moderate levels of sustainable ecotourism opportunity indicators. Looking further at the EOI components, in the first dimension (D1), “nature,” AIUla received a score of 47.54. In the second dimension (D2), “environmental protection/preservation,” AIUla received a score of 62.82; 46.88 for the third dimension (D3), “sustainability,” 56.80 for the fourth dimension (D4), “socio-cultural benefits,” and for the fifth dimension (D5) “, tourist satisfaction”, AIUla gained a score of 47.98. The second dimension received the highest score, indicating the region’s greatest potential is in environmental protection. This study’s results indicate a moderate to high potential for ecotourism in the region. While calculating the indicator scores in AIUla, the Infrastructural Services (N10) 78.70 in D2 received the highest score, followed by the Educational Opportunities (N20) 74.70 and Employment Opportunities (N21) 74.37 in D4. Figure 6 shows the indicator index values across five districts of AIUla.

Figure 7 presents the principal tourism and ecotourism locations within the AIUla study area, rather than separate cities. These locations represent key natural, cultural, and heritage settings associated with tourism development in AIUla and illustrate their spatial distribution within the study area.

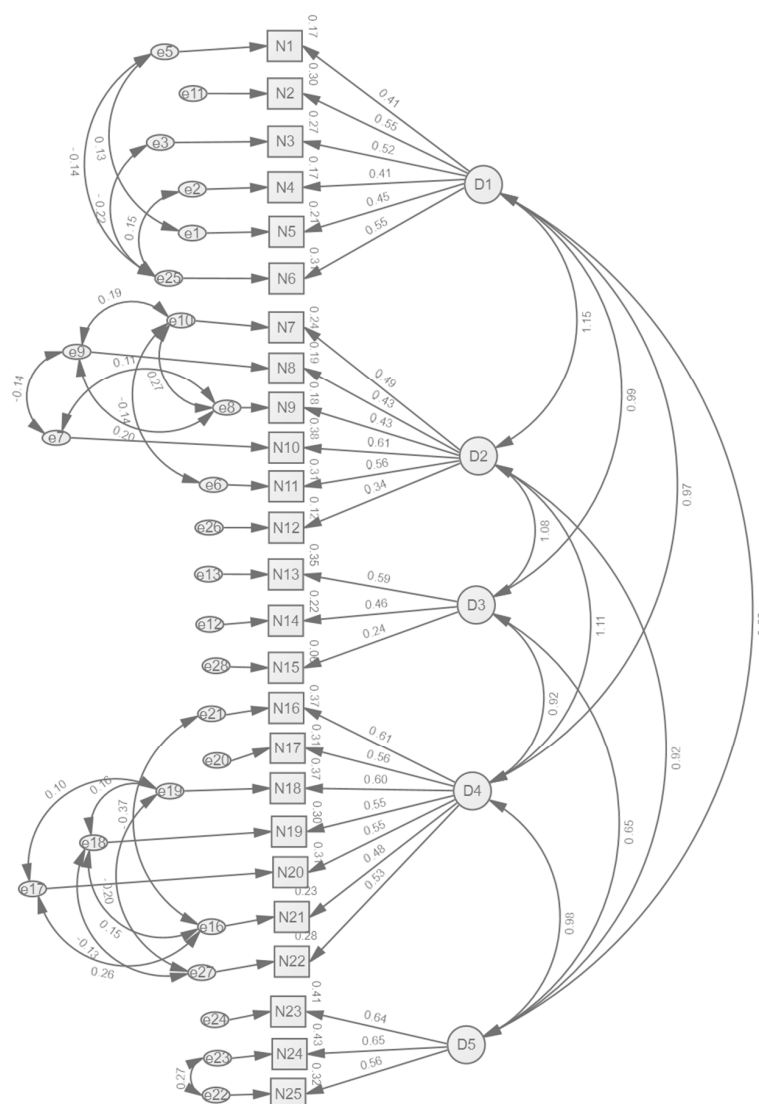


Figure 6. The measurement model for the dimensions and indicators.

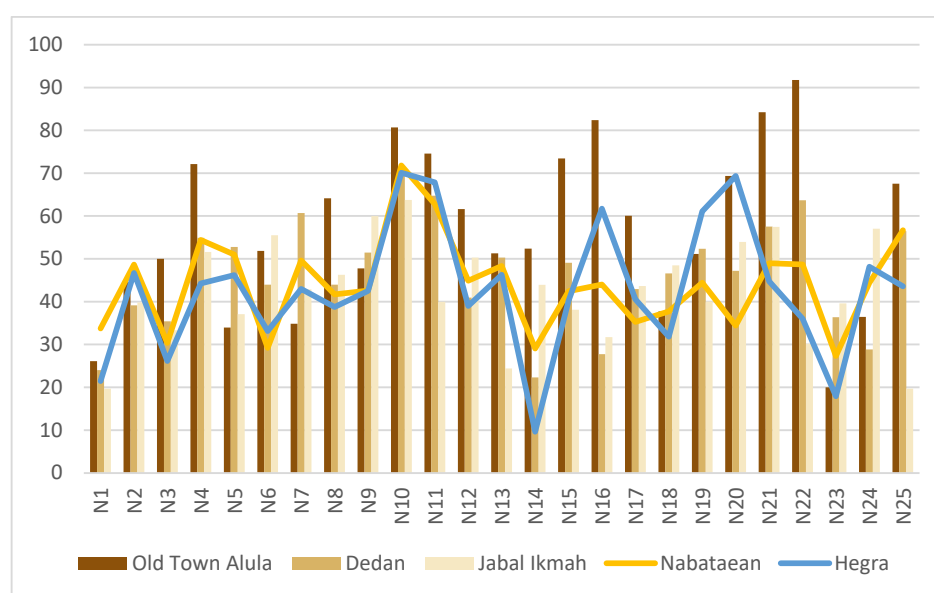


Figure 7. District-wise index values for the 25 sustainability indicators.

4. Discussion

This research provides a systematic framework for identifying, validating, and evaluating Ecotourism sustainability indicators for AIUla, leading to the development of a sustainability index framework. The findings highlight the multidimensional nature of sustainable ecotourism systems, demonstrating interrelationships among ecological, socio-cultural, educational, and managerial dimensions. The ECOS model facilitated the systematic identification and classification of Ecotourism sustainability indicators under five major dimensions, accompanied by 25 sustainability indicators. The nature dimension emerged as the most significant, highlighting the essential role of natural assets and their preservation in ecotourism development.

This finding supports previous assessments in which natural resources and conservation constitute core components of ecotourism sustainability [8,55]. However, in AIUla, nature received a relatively low index score (47.54), indicating a gap between its recognized importance and current sustainability performance. This contrasts with environmental education/protection (62.82), suggesting that conservation awareness and supporting services are comparatively stronger than the assessed condition of nature-related indicators.

In the second stage, the research aimed to validate the sustainability and relevance of the ecotourism indicators through the Delphi method. The strong consensus among experts confirmed that these indicators reflect well-recognized and sustainable facets of ecotourism development. This result demonstrates the effectiveness of the ECOS framework in integrating sustainability considerations during the early stages of indicator identification, rather than introducing sustainability only during later validation stages. The indicator relevance values and sustainability outcomes reported in this study should be interpreted within AIUla's specific environmental, cultural, and managerial context.

The primary contribution of the proposed framework is not the introduction of entirely new sustainability indicators and the application of the Delphi technique, but the systematic integration of indicator identification by ECOS, sustainability validation by Delphi, statistical testing by CFA, and quantitative evaluation. Existing studies generally focus on indicator identification, expert validation, or quantitative evaluation as separate processes, with limited integration of these stages within a unified sustainability assessment framework [1,2,21,77]. In contrast, the proposed framework links these stages within an integrated methodological structure, providing a more transparent and reproducible approach for sustainability assessment.

The sustainability index score for AIUla was calculated as 52.40 on the normalized 0–100 scale. This score indicates the balanced yet evolving condition of ecotourism in AIUla and highlights the need for focused initiatives to address deficiencies while capitalizing on its advantages. Environmental education/protection earned the highest score (62.82), underscoring its vital importance to AIUla's ecotourism potential. This corresponds with current research highlighting the importance of incorporating environmental consciousness and protective strategies into tourism operations [58,59]. The socio-cultural benefits dimension was ranked second (56.80), followed by tourist satisfaction (47.98), the nature dimension (47.54), and sustainability (46.88). The comparatively lower scores within the nature and sustainability dimensions indicate the need for stronger conservation strategies, environmental management policies, and long-term sustainability planning to achieve more balanced ecotourism development.

The strong performance of the environmental education and protection dimension reflects AIUla's increasing emphasis on conservation awareness, environmental education, and sustainable tourism management practices. These initiatives align with global trends in sustainable tourism, emphasizing the amalgamation of environmental education and conservation methods to attain enduring sustainability objectives [14,53]. The

results underscore that environmental education not only promotes sustainability but also enriches the visitor experience by cultivating a greater appreciation for natural and cultural resources.

Among the evaluated sustainability indicators, infrastructural services (N10) achieved the highest score, highlighting their essential function in facilitating sustainable tourism within the environmental education and protection framework. Infrastructure development improves accessibility, enriches visitor experiences, and supports the sustainability of tourism activities, corroborating previous research highlighting the significance of well-developed infrastructure in tourism planning [58,59]. Additional high-scoring indicators included educational opportunities (N20) (74.70) and job opportunities (N21) (74.37) within the socio-cultural benefits dimension, signifying AIUla's commitment to promoting community engagement and socio-economic advancement through tourism.

The relatively lower performance in the nature and sustainability dimensions (47.54 and 46.88, respectively) indicates opportunities for improvement. Managerial priorities should reflect the observed dimension scores, particularly the comparatively lower performance of sustainability (46.88), nature (47.54), and tourist satisfaction (47.98). Resources and monitoring efforts should therefore prioritize the indicators within these dimensions, while maintaining the comparatively stronger environmental education and protection performance (62.82) and socio-cultural benefits (56.80).

The findings underscore the multidimensional characteristics of sustainable ecotourism development in AIUla, particularly emphasizing strengths in environmental education and infrastructure. Addressing the highlighted deficiencies in sustainability and ecological aspects is crucial for realizing the region's full potential as a premier ecotourism destination. The sustainability index framework developed in this study provides a reproducible, systematic approach to assessing ecotourism potential across regions and offers valuable insights for policymakers, stakeholders, and researchers pursuing sustainable tourism goals.

This study contributes to ecotourism sustainability research by providing a systematic framework for identifying, validating, and quantitatively evaluating Ecotourism sustainability indicators. The research uses the ECOS model to systematically identify sustainability-oriented ecotourism indicators across multiple dimensions, avoiding the inefficiencies of conventional approaches that rely on iterative refinement. The development of the sustainability index provides an innovative, quantitative instrument for evaluating ecotourism potential and ensuring adherence to sustainability standards across various dimensions. The study's findings have practical significance for policymakers, tourism planners, and stakeholders by highlighting key strengths, such as environmental education and infrastructure services, while identifying areas for improvement, including sustainability and nature protection. Because the framework was empirically evaluated only in AIUla, its applicability to other destinations cannot yet be established. However, the assessment procedure may provide a methodological basis for future testing in other ecotourism settings, subject to context-specific indicator adaptation and local validation.

The proposed sustainability framework provides practical guidance for tourism managers, destination planners, and policymakers by identifying strengths and weaknesses across key sustainability dimensions. The Sustainability Index can support priority setting, resource allocation, and monitoring of sustainability performance over time. In the case of AIUla, the findings indicate that greater attention should be directed toward strengthening nature conservation and long-term sustainability initiatives while maintaining the strong performance achieved in environmental education and protection. The framework may also help destination managers evaluate the effectiveness of sustainability strategies and inform evidence-based tourism planning.

5. Conclusions

This case study identified 25 validated sustainability indicators across five dimensions, producing an overall Sustainability Index score of 52.40 for AIUla. These findings showed that sustainable ecotourism assessment requires a comprehensive, evidence-based approach that goes beyond evaluating natural attractions and incorporates broader interactions among tourism development, environmental conservation, community participation, and visitor experiences. The findings also support the robustness of the developed sustainability index and its applicability for evaluating ecotourism sustainability in emerging tourism destinations.

The Sustainability Index score of 52.40 represents AIUla's combined performance across the five assessed dimensions on the normalized 0–100 scale. Environmental education/protection recorded the highest dimension score (62.82), indicating the strongest relative performance, followed by socio-cultural benefits (56.80). In contrast, tourist satisfaction (47.98), nature (47.54), and particularly sustainability (46.88) performed comparatively poorly, identifying these dimensions as priority areas for improvement. Thus, the index should be interpreted comparatively across dimensions rather than through predefined categorical thresholds. These findings emphasize that sustainable ecotourism development requires balanced progress across all sustainability dimensions rather than concentrating on tourism growth alone. Regarding the study's contribution to other destinations, indicators related to conservation, environmental education, community participation, employment, waste management, and tourist satisfaction are broadly transferable. Indicators concerning archaeological heritage, water availability, desert ecosystems, and associated tourism services reflect AIUla's particular environmental and socio-cultural context. Accordingly, application to other destinations should retain the general assessment procedure while adapting context-specific indicators through local expert validation.

Despite these contributions, the study has several limitations. First, the initial indicators were derived from the ECOS framework and a targeted literature review, and contextual screening may have excluded potentially relevant indicators. Second, although the Delphi panel was large and multidisciplinary, purposive expert selection may introduce selection bias and may not fully represent all stakeholder perspectives. Third, the framework was evaluated only in AIUla, limiting direct generalizability to destinations with different environmental, cultural, and socio-economic conditions. Fourth, the CFA was reported primarily at the aggregate level; therefore, dimension-specific reliability and discriminant-validity statistics were unavailable, limiting a detailed assessment of individual dimensions. Finally, Harman's single-factor test provides only a diagnostic assessment of common method variance and cannot quantify or correct potential bias; moreover, the questionnaire did not include a marker variable. Future research should therefore test the framework across diverse destinations, broaden stakeholder representation, examine alternative indicator sets, report dimension-level measurement properties, and incorporate marker-variable or other advanced approaches to assess common method bias.

While the proposed methodological framework can be replicated at other ecotourism destinations, the indicators, their scores, and sustainability index values are expected to vary with local conditions and destination-specific contexts. Future research should therefore apply the framework in different geographical settings, incorporate longitudinal assessments, and explore integrating spatial, environmental, and real-time tourism datasets to further strengthen sustainability evaluation processes. Overall, the findings show that sustainable ecotourism assessment requires systematically validated, multidimensional, and quantitatively measurable approaches that support adaptive, long-term tourism planning. The proposed sustainability framework provides a foundation for advancing sustain-

able ecotourism evaluation and offers practical guidance for improving the sustainability performance of emerging tourism destinations.

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Institutional Review Board Statement: Ethical review and approval were waived for this study because, in accordance with the institutional policies of King Abdulaziz University and national research regulations, formal ethics committee or IRB approval was not required for this low-risk, non-interventional study [87]. Nonetheless, the study adhered strictly to the Declaration of Helsinki (1975, revised in 2013), with special attention to voluntary participation, informed consent, anonymity, and data confidentiality.

Informed Consent Statement: Informed consent for participation was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in this study are included in the article.

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