Artificial Intelligence and Sustainable Tourism: An Integrated Model for Impact Assessment

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Abstract. In recent years, among the various potential applications of Artificial Intelligence (AI), its ability to serve as a useful tool for data implementation and analysis in various monitoring and impact assessment processes has become increasingly evident. This paper presents an example of AI being used as an integration and support tool for impact assessment in the context of sustainable tourism. In 2023, it is estimated that there were 1.286 billion international tourists worldwide. Specifically, Europe was the most visited region, largely due to domestic demand and travel from the United States. In 2013, the European Commission launched the European Tourism Indicator System (ETIS), consisting of a set of indicators designed to assess tourism sustainability, support destinations, and monitor and measure their performance. This research aims to define an evaluation model that considers these indicators through a weighted system. To determine the specific weight of each indicator and assess the usefulness of AI systems, the paper presents the results of a study aimed at identifying discrepancies and convergences in output data obtained in two ways:

a) Using a traditional model, (stakeholders' consultation).
b) Through AI-based interrogation.

In the proposed case study, a questionnaire will be used and administered to stakeholders in the sector as well as to major AI software systems. The input data will be carefully structured to enable AI to function as a knowledgeable expert in the tourism sector.

Keywords: Artificial Intelligence · Sustainable Tourism · Impact Assessment

1 Introduction

1.1 International Tourism: Trends and Challenges

In 2020, international tourism experienced its worst crisis due to the outbreak of the COVID-19 pandemic. For this reason, the latest reports published by major global agencies monitoring tourist flows refer to annual data compared to the year 2019. According to

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the World Tourism Barometer of the UNWTO, in 2024, 1.4 billion international tourists were recorded, recovering 99% of pre-pandemic levels and marking an 11% increase compared to 2023. Thus, 2024 marks a global recovery in tourist flows, but results vary by region.

Compared to the pre-pandemic period (2019), the Middle East recorded the most significant increase worldwide, with a 32% growth in international arrivals. With 74 million arrivals, Africa saw a 7% increase compared to 2019, driven by increases in Ethiopia (+40%), Morocco (+35%), Tunisia (+9%), and Kenya (+9%). The last region to surpass pre-pandemic levels was Europe, reaching 747 million international arrivals (+1%), mainly supported by strong intra-regional demand. All European countries exceeded 2019 levels, except for Central and Eastern Europe, where many destinations are still affected by the lingering impacts of the Russia-Ukraine conflict [1].

Specifically, 21 European destinations have surpassed 2019 levels. Among the countries that recorded the highest increases, one country saw a remarkable 80% rise in international arrivals in the first 10–12 months of 2024, followed by Andorra (+35%), Malta and Serbia (+29%), Portugal (+18%), Denmark (+17%), Greece and Turkey (+14%), and Spain (+10%). The Americas recovered 97% of pre-pandemic arrivals, with the Caribbean and Central America already surpassing 2019 levels, thanks to strong outbound travel from the United States [1].

In addition to the growth of international tourism, 2024 set record levels for total tourism-related export revenues (including transport and accommodation), reaching $1.9 trillion, approximately 3% more than in 2019. According to the latest estimates, in the first nine to eleven months of 2024, several destinations reported significant revenue growth. Specifically, El Salvador tripled its earnings, recording a 206% increase, followed by Saudi Arabia with a 148% increase, Albania (+136%), Serbia (+98%), and Canada (+70%). This trend is also confirmed among the world's major tourist destinations; for example, the United Kingdom saw a 40% revenue increase, Spain 36%, France 27%, and Italy 23%.

According to the first forecasts for international tourist arrivals in 2025, these levels are expected to grow between 3% and 5% compared to 2024, assuming a continued recovery in Asia and the Pacific. Confirming these expectations, the latest United Nations Tourism Confidence Index (UN TCI) predicts "better" or "much better" prospects for 2025 compared to 2024 for approximately 64% of respondents. Specifically, the TCI aims to assist governments, business leaders, and other decision-makers worldwide in shaping tourism policies [2].

However, as industry experts highlight, economic difficulties and geopolitical risks (in addition to ongoing conflicts) represent a set of factors that could jeopardize these forecasts. Balancing growth and sustainability will be crucial in 2025, as highlighted by two main trends identified: the search for sustainable practices and the discovery of lesser-known destinations [1].

1.2 Aim and Scope of Study

The expansion of the Internet, coupled with the emergence of Artificial Intelligence (AI) and autonomous mobility [3], is significantly influencing many sectors, including tourism, by offering substantial opportunities. Although tourism is known as an

interdisciplinary field, research methodologies have long been constrained by classical approaches [4].

As reported by Ciano, Alderighi, and Ferrara in the era of digitalization, data appears in new unstructured forms [5]. This, together with traditionally structured datasets, has led to the rise of Big Data. Consequently, thanks to advancements in computing and, above all, the rapid development of algorithms, advanced analytical tools and methods have emerged, enabling more accurate and in-depth insights, including those related to urban policy, planning, design, and the management of urban transformation, and ultimately, systemic approaches to decision-making support [6].

In recent years, some of these new methods have been applied to the study and forecasting of tourism, such as route optimization, predictive and forecasting analysis, alert and monitoring systems, and much more [7]. Tourism is, therefore, an extremely complex and multidimensional sector, making it an ideal field for the application of Artificial Intelligence systems. The use of AI could be beneficial in investigating both tourism supply and demand, including marketing strategies, managing overtourism [7] and, most importantly, designing policies focused on sustainable tourism.

Since providing a comprehensive review of all significant proposals and projects on AI applications in the tourism sector is complex, an excerpt from the guidelines provided by Ciano, Alderighi, and Ferrara on possible applications is presented below:

"Innovative tourism strategies can only be designed with new visions and ideas. Creativity techniques can then be applied by considering insights obtained from the analysis of large datasets. Alternatively, new ways to visualize them could be used; among the latest principles of the circular economy, sustainable development, and environmental economics can inspire governments, destination managers, local tourism entities, and tourism stakeholders in general. [6]."

To determine the specific weight of each indicator and assess the usefulness of AI systems, the paper presents the results of a study aimed at identifying discrepancies and convergences in output data obtained in two ways:

a) Using a traditional model, (stakeholders' consultation).
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In the proposed case study, a questionnaire will be used and administered to stakeholders in the sector as well as to major AI software systems. The input data will be carefully structured to enable AI to function as a knowledgeable expert in the tourism sector.

2 Literary Review: Tools and Methods for Impact Assessment of Tourists Flows

For the analysis of sustainable tourism, there are no sources providing references for assigning weight values.

De Marchi et al. introduce the Tourism Sustainability Index (TSI), which provides a scalable and georeferenced assessment of tourism sustainability based on ETIS criteria, focusing on tourist satisfaction through sentiment analysis [8].

Liu et al. present a comprehensive analysis of regional tourism sustainability using the TOPSIS method to evaluate the level of sustainable tourism development in the Yangtze River region [9]. They establish a system of scientific indicators to assess economic, social, resource-related, and environmental aspects of tourism, offering insights into the coordination between tourism and various factors in the region.

Troise et al. propose an interpretative model that uses multiple case studies to assess sustainable tourism initiatives, highlighting stakeholder approaches and tourists' perceived quality [10].

Park & Yoon focus on developing indicators for evaluating sustainable rural tourism, emphasizing the importance of these indicators in measuring progress and enhancing community capacity development [11].

Epifani introduces the Sustainable Tourism Assessment Index (STAI), a synthetic index designed to assess a destination's preparedness for sustainable tourism development trajectories with a holistic approach [12].

Budeanu discusses the impacts and responsibilities of sustainable tourism from the perspective of tourism operators, emphasizing the need for a preventive approach to mitigate the consequences of rapid tourism growth [13].

Weiler et al. conduct a bibliometric analysis of trends and research models in sustainable tourism, highlighting the evolution of theoretical and methodological approaches over time [14].

In conclusion, the assessment of tourism is crucial for ensuring long-term sustainability and the positive impacts of tourism activities on destinations and communities.

Below is a summary table listing additional authors who have used methods and tools to evaluate tourism in different application fields (Table 1).

Table 1. Reference papers

Paper	Objective	Method/Tool
Chen, C. L., & Bau, Y. P. (2016). Establishing a multi-criteria evaluation structure for tourist beaches in Taiwan: A foundation for sustainable beach tourism. Ocean & Coastal Management, 121, 88–96. [15]	Identify the factors influencing beach environments and establish a multi-criteria evaluation framework for tourist beaches; Inform beach managers on where and how to invest resources to achieve sustainable beach tourism	Critical review of the literature on beach quality criteria. Interviews with experts to identify the factors related to a highly frequented tourist beach. The fuzzy Analytical Hierarchy Process (AHP), a decision-making method based on pairwise comparisons between criteria, was then used to construct a three-level evaluation framework with associated criteria and weights for beach managers

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Table 1. (*continued*)

Paper	Objective	Method/Tool
Hatipoglu, B., Ertuna, B., & Salman, D. (2019). Corporate social responsibility in tourism as a tool for sustainable development: An evaluation from a community perspective. *International Journal of Contemporary Hospitality Management*, *31*(6), 2358–2375	Analyze corporate social responsibility (CSR) programs in tourism as a tool for sustainable development within the CSR program of a multinational company in Turkey	Qualitative research on a single company, including content analysis of corporate documents, participant observations, questionnaires for tourism project coordinators, and follow-up interviews with company directors and project managers
Cernat, L., & Gourdon, J. (2011). Is the concept of sustainable tourism sustainable? Developing the Sustainable Tourism Benchmarking Tool	Provide a unified methodology to assess the sustainability of tourism, based on a set of quantitative indicators	The Sustainable Tourism Benchmarking Tool (STBT) will provide a set of benchmarks to assess the sustainability of tourism activities in various countries A model development procedure is proposed: identifying the dimensions (economic, socio-ecological, infrastructural) and indicators, scaling method, graphical representation, and evaluation in three Asian countries
Montis, A. D., Deplano, G., & Nijkamp, P. (2007). Multicriteria evaluation and local environmental planning for sustainable tourism. In *Advances in modern tourism research: Economic perspectives* (pp. 207–232). Heidelberg: Physica-Verlag HD	Decision-making process of a hypothetical institutional entity interested in developing an objective and standardized procedure for evaluating the spatial dimension of sustainable tourism development	The methodology belongs to the family of multicriteria tools and was developed by integrating the regime method with AHP (Analytic Hierarchy Process)
García-Melón, M., Gómez-Navarro, T., & Acuña-Dutra, S. (2012). A combined ANP-delphi approach to evaluate sustainable tourism. *Environmental Impact Assessment Review*, *34*, 41–50	The evaluation of sustainable tourism strategies promoted by stakeholders in National Parks	Methodology based on the Analytic Network Process and a Delphi-type evaluation procedure. The approach aims to engage stakeholders in a participatory process and consensus building

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Paper	Objective	Method/Tool
Blancas, F. J., Lozano-Oyola, M., González, M., & Caballero, R. (2018). A dynamic sustainable tourism evaluation using multiple benchmarks. *Journal of cleaner production*, *174*, 1190–1203	Designing more effective benchmarking practices among different tourist destinations Differentiated evaluation based on the type of territory to define a comprehensive benchmarking practice	Creation of a composite vector indicator defined through two components: one dynamic, to grade the evolution of the destination in relation to its sustainability; the other static, to contextualize its position relative to other territories, evaluating the status achieved in the social, economic, and environmental parameters that influence the level of sustainability
Rita, S. E., Ferreira, F. A. F., & Rosa, L. (2019). A socio-technical approach to the assessment of sustainable tourism: Adding value with a comprehensive process-oriented framework [J]. *Journal of Cleaner Production*, *236*(5), 117487–17489	Create a system for evaluating sustainable tourism by providing a rational and transparent basis for the selection and weighting of evaluation criteria	A technique that combines the use of cognitive maps with Choquet integral (CI), developed through group meetings with a panel of tourism experts
Punzo, G., Trunfio, M., Castellano, R., & Buonocore, M. (2022). A multi-modelling approach for assessing sustainable tourism. *Social Indicators Research*, *163*(3), 1399–1443	Build and validate a composite sustainable tourism indicator (SusTour-Index), which recognizes the economic, environmental, and social dimensions as the three main interconnected aspects of sustainable tourism	The SusTour-Index is composed of 75 elementary indicators, appropriately structured into pillars and sub-pillars within each dimension: economic (34), environmental (21), and social (20) A multi-model approach verifies the hierarchical structure of the SusTour-Index by combining various weighting and aggregation methods within each dimension of sustainability to select the most appropriate model once the uncertainty analysis has been conducted

(*continued*)

Table 1. (*continued*)

Paper	Objective	Method/Tool
Wang, S. H., Lee, M. T., Château, P. A., & Chang, Y. C. (2016). Performance indicator framework for evaluation of sustainable tourism in the Taiwan coastal zone. *Sustainability*, *8*(7), 652	The evaluation of coastal tourism performance, using a framework of indicators to facilitate sustainable development and improve the effectiveness of coastal resource utilization	Through a literature review and expert surveys using the fuzzy Delphi method (FDM) and fuzzy analytic hierarchy process (FAHP), this study constructs a performance indicator framework and identifies key factors influencing the sustainable development of coastal tourism in Taiwan
De Marchi, D., Becarelli, R., & Di Sarli, L. (2022). Tourism sustainability index: measuring tourism sustainability based on the ETIS toolkit, by exploring tourist satisfaction via sentiment analysis. *Sustainability*, *14*(13), 8049	Measuring the sustainability of tourism and developing a composite indicator based on the use of sentiment analysis techniques to assess e-reputation and tourist satisfaction, combining this analysis with other open data sources	Starting with the ETIS and developing new TSI indicators

3 Materials and Methods

3.1 Weighing ETIS Indicators: AI and Stakeholders Consultation

The weighting process of the ETIS sustainability indicators adopted in this study is based on a participatory approach that combines stakeholder involvement with the use of Artificial Intelligence (AI). The goal is to achieve a balanced assessment that integrates both the subjective perceptions of stakeholders and a quantitative analysis based on predictive models. The process unfolds through six key stages, outlined below (Fig. 1).

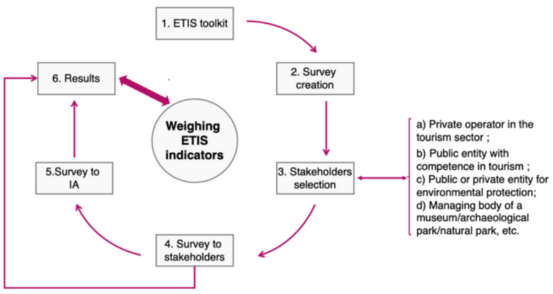

Fig. 1. Weighing ETIS indicators (Source: created by the authors)

Initially, the ETIS toolkit, a tool developed by the European Commission to measure the sustainability of tourism in various destinations, was studied. This phase allowed for the identification of the 43 sustainability indicators to be assessed, covering economic, social, cultural, and environmental aspects. Subsequently, a structured questionnaire was developed, consisting of 43 questions, corresponding to the 43 ETIS indicators. Each participant was asked to assign a score from 1 to 5, using an ascending importance scale, where 1 indicated minimal importance and 5 indicated maximum importance. The questionnaire was created using the Google Forms platform, ensuring easy and intuitive access for participants and facilitating data collection and analysis.

The next phase involved the selection of stakeholders, divided into four main categories: (a) private tourism operators, (b) public tourism bodies, (c) public and/or private environmental protection bodies, and (d) park management organizations or archaeological site authorities. The questionnaire was distributed to representatives from each category, ensuring broad participation and collecting various perspectives on the importance of each indicator. At the same time, AI was involved to perform an autonomous assessment of the indicators. The AI model was trained to "simulate" each stakeholder category, replicating their viewpoint and assigning a score to each indicator based on available data and the specific criteria of the relevant sector. This process provided an additional weighting based on objective analysis, mitigating the subjectivity of human assessments. The data collected from both the stakeholders and the AI were then analyzed and compared to determine the final weight of each indicator. Finally, the results obtained were used to define a ranking of the most relevant indicators, contributing to an improvement in the monitoring and evaluation system for sustainable tourism.

4 Results

Regarding the results of the weighting process, the data collected show significant differences between the assessments provided by AI and those given by stakeholders.

As seen in Fig. 2, private tourism operators (category a) attributed greater importance to economic indicators and destination management, while environmental and cultural aspects were rated with slightly lower scores. This result is consistent with their role in the sector, which focuses on profitability and efficient resource management. The AI, when queried as stakeholders in category a), instead assigned a balanced weight to all four macro-categories of indicators (destination management, social aspects and cultural impacts, economic aspects, and environmental aspects), giving similar scores across them.

On the other hand (Fig. 3), public tourism authorities (category b) placed greater emphasis on destination management and social and cultural aspects, reflecting their responsibility in ensuring balanced and sustainable tourism growth. Environmental aspects, while considered important, received a lower rating compared to the other areas. The results from the AI, again, provided a more balanced view, although indicators related to destination management were still considered more relevant than others.

The comparative analysis between the AI ratings and those of the stakeholders in category c, namely public and private environmental protection bodies, highlights key differences in the priorities assigned to sustainability indicators. The AI assigned a

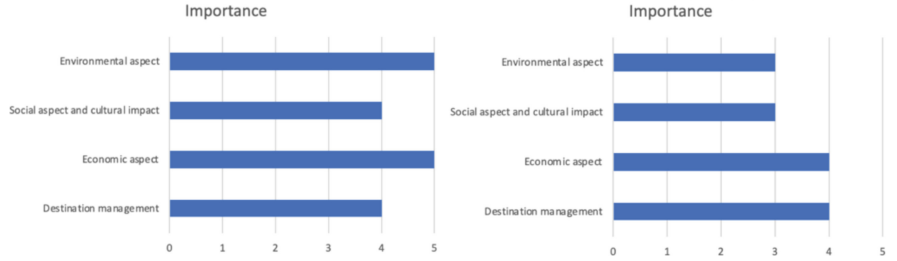

Fig. 2. Degree of preference among indicators – AI cat. a) and stakeholders cat.a) (from left to right) (Source: created by the authors)

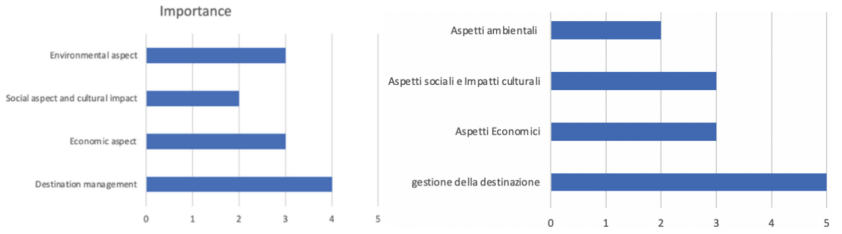

Fig. 3. Degree of preference among indicators – AI cat. b) and stakeholders cat. b) (from left to right) (Source: created by the authors)

balanced evaluation across the four macro-categories, with a slight preference for environmental aspects and destination management. However, the stakeholders placed significant emphasis on environmental aspects, giving them the highest rating among all categories. This result aligns with the mission of the organizations involved, which prioritize environmental protection in their activities. Additionally, compared to the AI, the stakeholders assigned a slightly lower rating to the economic aspects, considering them less relevant than the other dimensions of sustainability (Fig. 4).

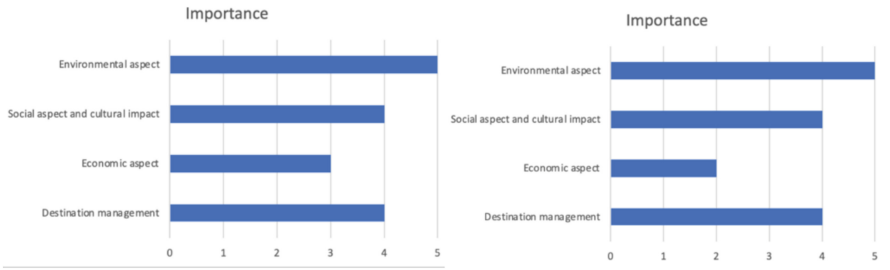

Fig. 4. Degree of preference among indicators – AI cat. c) and stakeholders cat. c) (from left to right) (Source: created by the authors)

Regarding category d, which includes the managers of nature parks or archaeological sites, some specificities are evident in the responses. The AI assigned a uniform evaluation to the indicators, with similar scores across all aspects of sustainability. However, stakeholders in category d gave the highest score to destination management, recognizing its crucial role in the preservation and enhancement of natural and cultural heritage. Environmental and social aspects were also rated highly, while economic aspects received slightly lower consideration. This reflects the nature of the institutions involved, which prioritize heritage conservation over economic performance [19] (Fig. 5).

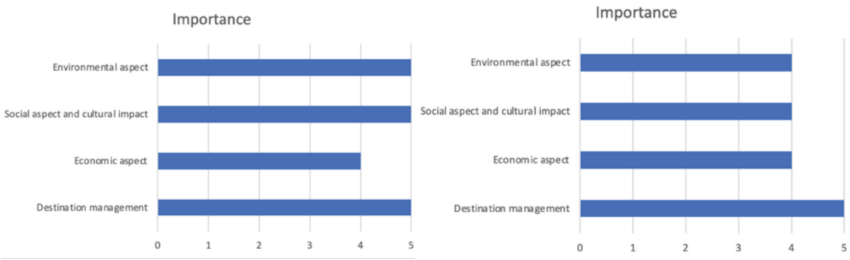

Fig. 5. Degree of preference among indicators – AI cat. d) and stakeholders cat. d) (from left to right) (Source: created by the authors)

5 Discussion and Conclusion

The analysis of the collected data highlights a general trend in the priorities perceived by the various actors involved. The AI, regardless of the stakeholder category "interpreted," showed a uniform distribution of weights across the four macro-categories, demonstrating a balanced approach based on historical data and analytical models. "Real" stakeholders, on the other hand, tended to highlight different preferences depending on their category of involvement.

For instance, destination management received high scores from both private tourism operators and public tourism entities, emphasizing its central role in the planning and management of tourism activities. In contrast, environmental aspects received lower scores from private operators compared to public entities and environmental organizations, highlighting the need for policies that encourage sustainability without compromising economic competitiveness.

Another significant difference concerns social and cultural aspects, which were rated more highly by public entities than by private operators. This suggests that public institutions perceive a key role in ensuring the respect of local traditions and the well-being of host communities, while tourism operators tend to focus more on economic profitability and operational management.

These results underline the importance of continuous dialogue between all actors in the tourism sector to define shared and sustainable strategies.

In summary, the weighting process of the ETIS indicators has allowed for highlighting the priorities and divergences among the various stakeholders, providing a solid

foundation for developing more effective and sustainable tourism policies. The combined use of empirical data and human evaluations represents an innovative approach to improving tourism governance and promoting more responsible development of tourist destinations.

The integration between the judgment of stakeholders and the evaluations provided by AI has enabled a more comprehensive and multidimensional view of sustainable tourism.

Finally, below are listed the strengths and weaknesses of the research, as well as possible future developments.

1) The focus on AI is timely and aligns with ongoing trends making the research applicable to current challenges
2) the effectiveness of AI assessments depends on the quality and comprehensiveness of the underlying algorithms and data. Any inherent limitations in these algorithms could impact the validity of the AI-generated results
3) the reliance on existing tools like the ETIS toolkit may limit the exploration of innovative or emerging sustainability metrics that could provide additional insights
4) train the AI models on more comprehensive datasets and refining how they simulate different stakeholder views.

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