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Innovations in Environmental Risk Assessment and Life Cycle Analysis for Ecotourism Sustainability

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RESUMO

O objetivo desta pesquisa é desenvolver uma estrutura ambiental integrada que combine Avaliação de Risco Ambiental (ERA) e Análise do Ciclo de Vida (LCA) para melhorar a sustentabilidade do ecoturismo. Ela visa unir abordagens teóricas e práticas, incorporando digitalização, tomada de decisão baseada em dados e governança colaborativa no contexto do ecoturismo. Este estudo é qualitativo e temático, combinando um projeto de pesquisa baseado em dados secundários da literatura anterior. O artigo apresenta cinco temas convergentes, dimensões interconectadas, digitalização da ERA, integração da LCA, apoio à tomada de decisões baseada em dados e análise preditiva, governança, colaboração e alinhamento de políticas, e co-benefícios socioambientais e econômicos, e relaciona-os com desenvolvimentos teóricos significativos, como a evolução da Teoria da Sustentabilidade do Ecoturismo Inteligente. Os resultados mostram que as ferramentas de avaliação ambiental, a inovação tecnológica e a colaboração dos formuladores de políticas reforçam a gestão sustentável do ecoturismo. A estrutura sugerida oferece aos gestores de destinos, formuladores de políticas e operadores turísticos uma estrutura sistemática para avaliar e melhorar a sustentabilidade do ecoturismo. Este artigo agregará valor à literatura existente sobre sustentabilidade do ecoturismo, fornecendo uma síntese aprofundada da ERA e da LCA que demonstra como sua combinação contribui para o conhecimento teórico e a implementação prática. Todos os dados utilizados neste estudo foram obtidos de fontes secundárias disponíveis publicamente, e nenhum participante humano ou informação pessoal sensível foi envolvido. A pesquisa desenvolve uma nova estrutura interdisciplinar que facilita soluções adaptativas, baseadas em tecnologia e focadas na governança para o desenvolvimento sustentável do ecoturismo.

Palavras-chave: sustentabilidade do ecoturismo; avaliação de riscos ambientais; análise do ciclo de vida; internet das coisas; inovação em turismo sustentável.

ABSTRACT

The objective of this research is to develop an integrated environmental framework that combines Environmental Risk Assessment (ERA) and Life Cycle Analysis (LCA) to improve ecotourism sustainability. It aims at bridging theoretical and practical approaches by incorporating digitalization, data-driven decision-making, and collaborative governance in the context of ecotourism. This study is qualitative and thematic, merging a research design based on secondary data from previous literature. The paper presents five merging themes, interconnected dimensions, digitalization of ERA, integration of LCA, data-driven decision support and predictive analysis, governance, collaboration and policy alignment, and socio-environmental and economic co-benefits, and relates them to the significant theoretical developments, such as the evolution of the Smart Ecotourism Sustainability Theory. The results show that environmental assessment tools, technological innovation, and policymakers' collaboration reinforce sustainable ecotourism management. The suggested framework offers destination managers, policymakers, and tourism operators a systematic framework to evaluate and improve ecotourism sustainability. This paper adds value to the existing body of literature on ecotourism sustainability by providing an in-depth synthesis of ERA and LCA that demonstrates how their combination contributes to theoretical knowledge and practical implementation. All data used in this study were derived from publicly available secondary sources, and no human participants or sensitive personal information were involved. The research develops a new interdisciplinary framework that facilitates adaptive, technology-based, and governance-focused solutions for sustainable ecotourism development.

Keywords: ecotourism sustainability; environmental risk assessment; life cycle analysis; internet of things; sustainable tourism innovation.

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Introduction

As a phenomenon concerned with protecting the natural environment, cultural authenticity, and the participation of local communities, ecotourism has become a key idea in the creation of sustainable tourism (Wang et al., 2024). The trends in international relations over the last two decades are characterized by the United Nations Sustainable Development Goals and the Paris Climate Agreement, which promote the idea that tourism development should be grounded in the principles of environmental protection and social responsibility (Talukder, 2024a; Candia & Pirlone, 2021). Though the increasing trend of ecotourism has facilitated such a development, the ever-increasing popularity of tourism, in its turn, places more burden on the delicate ecosystem and leads to the displacement of habitats, uneven distribution of resources, and extended carbon footprint (Neger et al., 2025; Zhang and Bin, 2024). To address these issues, managerial interventions are not the only way to overcome them; they also involve developing scientifically based models that reduce environmental and socio-economic impacts.

The current sustainability assessment of the tourism industry is disjointed, focusing only on environmental or socio-economic aspects of ecotourism without considering the entire lifecycle (Duarte et al., 2024). The cause of this disintegration is the low capacity to gauge the long-term sustainability performance. An even more comprehensive and detailed approach to introducing sustainability into the ecotourism industry is to employ Environmental Risk Assessment (ERA) and Life Cycle Analysis (LCA) (Bhattarai, 2017). ERA identifies latent environmental risks and vulnerabilities, whereas LCA assesses the environmental impact throughout the life cycle of a service and its operations. The combination of both methodologies would significantly improve the accuracy of ecotourism sustainability indicators, enable comparison, and make them more relevant to policy development (Sarfraz et al., 2023).

The relevance of the research can be justified by the apparent gap in the literature on both theoretical sustainability frameworks and their implementation in ecotourism management (Jain, 2024). Ecotourism destinations have not been thoroughly studied in recent years due to their inconsistent nature and the scope of their lifecycle impacts and technological advantages (Miralles et al., 2023). Also, new opportunities to improve sustainability assessment and decisions are premised on the additional evolution of digitalization, AI, remote sensing, and data analytics (Rawat et al., 2023). The research is hence guided by the need to understand how a healthy environmental system, facilitated by technological advancement, can ensure that ecotourism is proactively and informedly sustained. The research highlights the need for integrated assessment instruments, as ecotourism is facing mounting pressure and environmental governance challenges. It would be more effective to emphasize that the study fills a significant gap by bringing ERA and LCA together through technological innovation. The idea of introducing a single, innovation-based sustainability framework is unique, making the research a new contribution to the field of environmental management and ecotourism.

Although some studies have separately examined ERA and LCA, the integration concept has not been applied to the ecotourism scenario in many of them (Candia and Pirlone, 2021). The existing literature is concentrated on sustainability from either an environmental or managerial perspective. In most cases, it fails to integrate lifecycle effects, risk analysis, and governance dynamics. In addition, it does not present any studies based on the secondary data synthesis approach and thematic conglomeration to establish cross-functional relationships among environmental assessment, sustainability management, and digital innovation. The current study fills this gap by developing an analytical model that bridges theory and practice through the synthesis of evidence.

Research Objectives

The main objective of this study is to develop a Smart Ecotourism Sustainability Framework that integrates ERA and LCA to evaluate and improve the sustainability performance of ecotourism destinations. The specific objectives are:

A. To analyse secondary data and use a thematic merging approach to synthesize the theoretical gaps that guide sustainable ecotourism practices.

B. To develop a Smart Ecotourism Sustainability Framework that incorporates technological innovation to manage ERA and LCA.

C. To combine ERA and LCA into a single system for evaluating the environmental, socio-economic, and governance aspects of ecotourism sustainability.

Theoretical Overview

This theoretical background suggests that the ERA and LCA theories should be examined for their applicability to sustainable ecotourism practices (Herrero et al., 2025). It also examines how such structures influence the identification of potential environmental risks and the measurement of the environmental impact of the ecotourism activity lifecycle during planning and post-use phases (Reda and M'Bark, 2023). Additionally, the interdependence of climate change and ecotourism is another factor that should be understood to find the most effective way of adaptation and introduce new, innovative, and sustainable technologies that would allow for maintaining the business plan in the long term (Neger et al., 2025; Talukder, 2024b). The theoretical contribution of the study enables a more comprehensive approach to interdependent and interrelated risks, thereby challenging traditional linear risk assessment systems and introducing a dynamic systems model to assess their effects (Lawrence et al., 2020). The fact that system transition theory and resource dependence theory offer macro- and micro-level perspectives, respectively, on systemic and resource-based alterations towards a sustainable tourism transition to combat energy poverty, a driver of sustainable development, also supports this opinion. Thus, the researcher would like to study ERA and LCA to enhance the long-term sustainability of ecotourism.

Figure 01 below presents one of the proposed theoretical models, which clearly links the concepts of ecotourism to the strategic integration of ERA and LCA to achieve more sustainable outcomes. This framework is interested in the integrated analysis of environmental effects, including resource extraction and the ultimate disposal of products, within the context of complex interactions among tourism activities, the local community, and ecosystems (Shekhar, 2024). The framework also involves applying indigenous knowledge systems through the Two-Eye Seeing approach, which makes environmental management interventions and the mitigation of ecotourism risks culturally sensitive and inclusive (Akalibey et al., 2024). The integrated scheme has become a focal point of research on the ripple effect of climate change, as it encompasses the complexity of interactions and feedback loops between natural and anthropogenic systems (Lawrence et al., 2020). Besides this, there is the problem of environmental poverty, which persists particularly in the developing world; eradicating it is a focal point of environmental sustainability. The effects of poverty on the environment often act as a barrier to the introduction of environmentally friendly policies and the mitigation of environmental disasters (Neger et al., 2025). Sustainability in ecotourism has been used to address high energy poverty. Sound policy frameworks and technological advancements have catalyzed this, consequently enhancing the environment's resilience. It is therefore worth noting that effective tourism planning policies and practices, such as resource conservation, waste management, and community involvement, can help mitigate the negative environmental impacts of tourism and prevent environmental degradation.
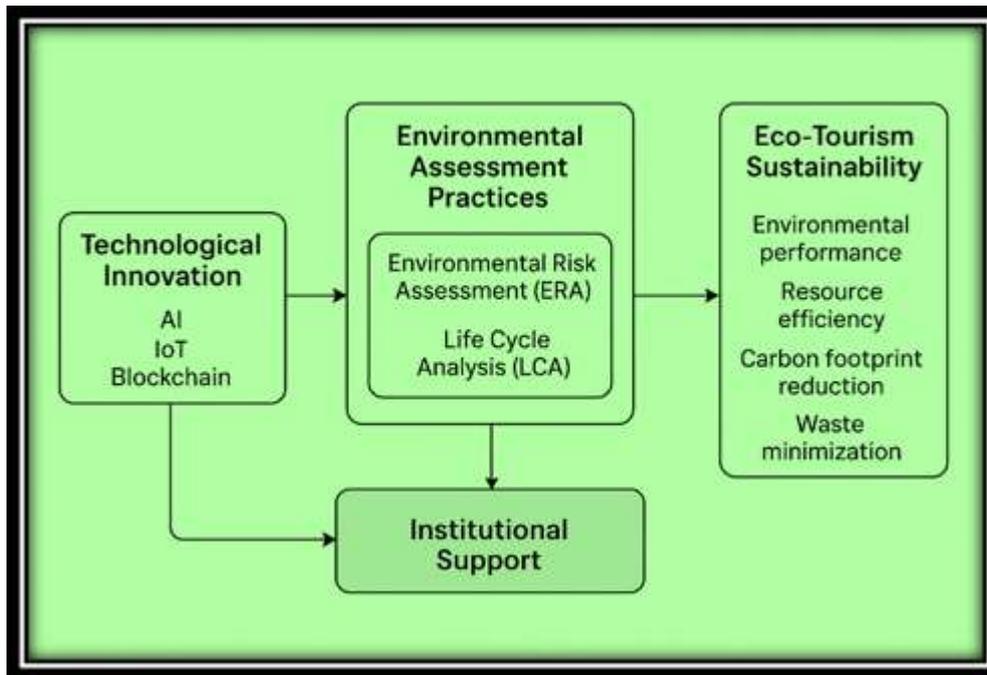
Figure 01: Theoretical Framework for Innovations in ERA and LCA for Ecotourism Sustainability. Source: Author Compilations

As Figure 01 shows, technological innovations (AI, IoT, and Blockchain) enable environmental assessment (ERA and LCA), which can be further extended to improve ecotourism sustainability outcomes. The same links are also facilitated by institutional support that enhances the integration of technology in sustainable environmental management systems.

Literature review

With the implementation of the ERA and LCA, the ecotourism business has been critically assessed in light of gaps in the literature and future research perspectives. This implies that novel approaches might involve socio-economic measures and policies, as well as technological and environmental considerations, to achieve sustainable industrial operations (Firoozi et al., 2025). It has a sustainable form of ecotourism, grounded in the conservation of social and environmental resources. By taking this measure, it is necessary to harmonize them with sound tourism policies to ensure that business operations are conducted efficiently without unnecessarily complicating things; on the other hand, tourism practitioners would be more conscious of their role in environmental stewardship (Talukder, 2025a). In the fields of energy consumption, waste management, and real-time environmental control, which technological advancements can offer, these measures are the required solutions to improving the sustainability of tourist destinations' performance. The rationale for such concerted efforts is the conceptualization of multifaceted interactions among these factors, which can mitigate short-term environmental impacts and address socio-economic outcomes that, in turn, can affect the overall sustainability of ecotourism (Neger et al., 2025). So, it must also be prepared to accommodate the possibility of stable regulatory principles that can facilitate the change process, since highly sustainable practices can be introduced on a large scale in the ecotourism business. In addition, collaboration with local communities and the active participation of traditional environmental knowledge can help such structures become more efficient. This can be considered an unsold contribution to the sustainable use of resources and biodiversity.

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Ecotourism sustainability

To compare traditional tourism and ecotourism, it can be stated that this type of tourism is characterized by its non-distorting nature, its training of local people to become economically self-sufficient, and its provision of education and experiences that enable them to meet the needs of tourists (Rawat et al., 2023). It is an active initiative that reduces the environmental footprint, promotes cultural respect, and enhances the overall sustainability of destinations by preserving natural resources and supporting the well-being of local inhabitants (Jain, 2024). It also plays a significant role in mitigating the negative impacts of climate change on tourism and enhancing the resilience of local ecosystems. Additionally, it enables communities to access sustainable energy (Rawat et al., 2023). It helps restore natural balance, conserve resources, and attract environmentally conscious consumers, thereby reducing disturbance to the habitat and enhancing biodiversity (Perovic et al., 2025). Additionally, the policies of sustainable tourism can be considered within the framework of sustainable development, and neglecting environmental problems, including greenhouse gas emissions, can threaten this so, that the most significant element of the process of sustainable tourism attainment is the control over the use of resources to reduce wastes and the involvement of the local communities into the conservation (Mishra, 2025). It has not achieved this solely by preaching conservation practices, but also by becoming an integral part of the contemporary environmental management agenda, incorporating both indigenous and cultural environmental knowledge to provide comprehensive, culturally sensitive solutions for sustainability.

Environmental Risk Assessment

ERA is a process of identifying, evaluating, and addressing the potential environmental hazards associated with human and economic undertakings, particularly in the context of ecotourism development. ERA is a good management and planning tool in the ecotourism industry, as it aims to strike an appropriate balance between environmental protection and tourism development, thereby reducing habitat degradation, biodiversity loss, waste generation, and greenhouse gas emissions (Lu, 2025). Previously, the application of ERA methodologies was primarily supported by qualitative measures and subjective evaluation processes, which required minimal data and time. New methodological advances have introduced more quantitative, technologically enhanced procedures that combine Geographic Information Systems (GIS), remote sensing, and predictive modelling to enable more precise, fine-grained spatial analyses at reduced cost (Shekhar, 2024).

Digital technologies, including AI, the IoT, and Blockchain, have radically changed the ERA framework by enabling continuous environmental tracking, providing data transparency, and enabling predictive analytics through dashboards (Herrero et al., 2025). These inventions make management dynamic and adaptive, allowing it to identify and act on risks before they exceed the set environmental limits. Additionally, LCA, when applied in conjunction with ERA, has broadened the assessment scope to encompass both upstream and downstream effects of tourism supply chains and has led to the informed consideration of cumulative and indirect environmental impacts (Herrero et al., 2025). Despite these developments, specific challenges remain, including the degradation of information quality, limited access to the latest technologies, and the inability of countries to fully adopt digitalization (Talukder, 2025b). The lack of standardized indicators and the collapse of governance are also restricting the applicability of ERA in the example of ecotourism. Nevertheless, the literature captures the growing recognition of the need to incorporate a hybrid, data-centric model of ERA, which implies implementing new analytics and participatory governance to deliver environmental integrity and socio-economic inclusivity (Hezam et al., 2024). Thus, the study aligns with the literature on ERA by examining how ecotourism activities can be enhanced to incorporate technological innovation and lifecycle thinking, while accounting for environmental risk assessment and sustainability.

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Life Cycle Analysis

LCA is a holistic model that assesses the environmental impact of products, services, or systems throughout their life cycles, encompassing the extraction and production of raw materials, use, maintenance, and disposal. The other beneficial opportunity LCA provides to the ecotourism industry is that it offers a broad perspective of the industry, not only in direct ecotourism metrics such as environmental performance of a particular site but also indirectly and cumulatively through tourism supply chains (i.e., transportation emissions, accommodation energy use, water use, and waste production) (Candia & Pirlone, 2021). The holistic approach helps identify environmental hotspots where resource waste and environmental pressure are prevalent, and sustainable interventions become the dominant approach in these cases. Even the LCA models have been adapted to fit the tourism industry, including process-based and hybrid models. This enables researchers to measure the energy flows, carbon footprints, and material cycles of different tourism activities (Candia & Pirlone, 2021). LCA has become more accurate and relevant due to the implementation of digital technologies, including AI and IoT in ecotourism activities (Pena et al., 2021). The technologies enable performance improvements in sustainability by allowing continuous monitoring, processing information, and making model predictions.

However, there are also methodological concerns, with the most severe ones being the availability of data, the consistency of tourism indicators, and trade-offs between the forms of impacts, i.e., energy efficiency and water use (Pena et al., 2021). However, it has also been used to influence sustainability policymaking, where LCA provides evidence to balance the management of the ecotourism industry with international standards, including ISO 14040/44 and the United Nations Sustainable Development Goals (SDGs).

Relation of Ecotourism, Sustainability, Environmental Risk Assessment, and Life Cycle Analysis

Integration has been a concern for the ERA and LCA regarding ecotourism sustainability, which can provide a more systematic and data-driven understanding of its environmental effects. In the past, ERA played a significant role in characterizing, evaluating, and reducing environmental risks, including habitat destruction, biodiversity loss, and pollution in tourism destinations. Recent empirical evidence indicates that ERA has shifted to a dynamics-based, predictive modelling paradigm that embraces AI, Geographic Information Systems (GIS), remote sensing, and IoT technologies, and that this transformation has led ERA to adopt a responsive, adaptive model (Hezam et al., 2024). Using computational tools, real-time environmental management, spatial risk mapping, and decision-support systems, these practices are implemented, enabling managers to forecast potential threats before they occur and combat the disastrous consequences (Talukder, 2025c). Consequently, ERA can be regarded as a robust managerial framework that promotes active interventions and enhances the environmental sustainability of tourism ecosystems under environmental threats. One of the most important tools for calculating the total environmental cost of ecotourism activities, including construction and operation, waste disposal, and post-use disposal, has been the LCA (Wang et al., 2024). The other LCAs used in ecotourism are the hybrid approach of process-based analysis and input-output analysis, which AI and IoT assist. Such processes may impede the accurate establishment of carbon footprints, energy pathways, and material consumption across different tourism processes. By combining blockchain with artificial intelligence, data analytics improve sustainability ratings by enhancing accuracy, transparency, and accountability, providing novel opportunities to audit eco-certifications and resource performance. However, standardizing tourism-related LCA indicators and local environmental data is also necessary to ensure comparability and relevance across the two ecotourism contexts (Wang et al., 2024).
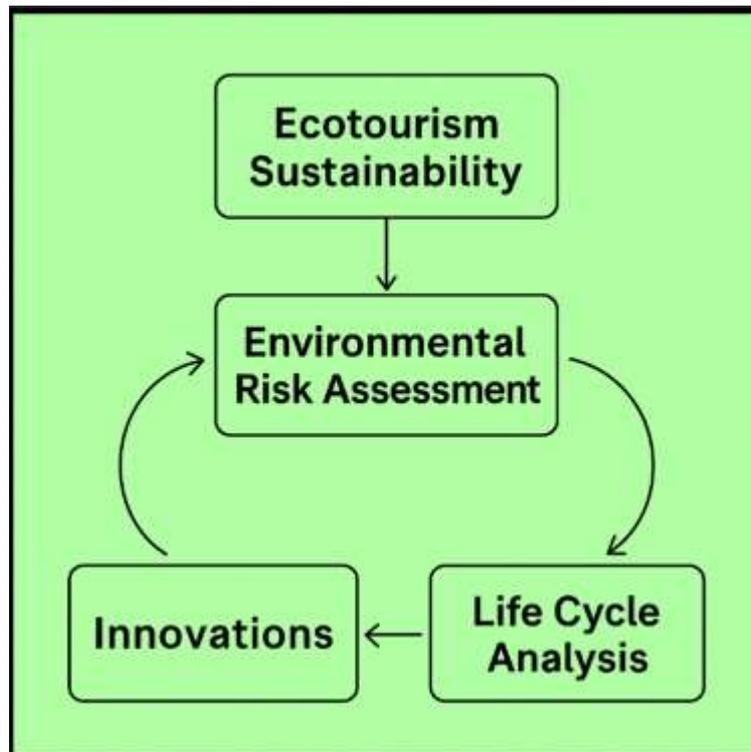
Figure 02: Linking ERA and LCA for Innovative Ecotourism Sustainability Framework. Source: Author Compilations

Figure 02 shows the dynamic and cyclical nature of the relationship between Ecotourism Sustainability, ERA, and LCA, in which the main factor and mediating and transformative element is the Innovations in ecotourism. The first framework, Ecotourism Sustainability, establishes the strategic objective of ensuring ecological balance and promoting social and economic well-being.

The final sustainability systems of ecotourism have been changed to include holistic environmental management incorporating ERA and LCA innovations. The tools help present a more detailed picture of the gaps already in the environment and the trade-offs that will have to be made in the future. Every one of these innovations needs to be incorporated into policy frameworks, community participation, and adaptive governance to be implemented sustainably and efficiently, as demonstrated in the new literature (Hezam et al., 2024). The fact that global indicators of sustainability are only correlated with local environmental and socio-economic conditions is also a drawback of future technology application; however, it is more focused on analysis. The new ERA and LCA paradigm provide a platform for achieving environmental integrity, enhancing the visitor experience, and creating socio-economic value, thereby facilitating a sustainable transition to data-driven, resilient tourism ecosystems as the global ecotourism industry grows (Reynolds, 2024).

Methodology of the Study

The research design in this study employs a secondary data-driven approach to identify current trends in the ERA and LCA as environmental tools to promote the sustainability of the ecotourism industry. Through this study, a structure of interdependence for implementing technological and methodological breakthroughs in the ecotourism sector can be developed by analyzing the existing academic literature, institutional publications, and open-source databases. The secondary data method enables extensive, evidence-based research on how new digital technologies, including AI, Blockchain, and IoT, affect the conduct of environmental management and sustainability monitoring. Table 1 below was used to derive the ERA tools and LCA tools. Summary

of qualitative themes, core descriptions, and representative secondary Data Sources. According to Table 01, the researcher uses descriptive analysis based on the merging theme.

Theme	Core Description	Representative Secondary Sources
1. Digitalization of ERA	Research on the impact of AI, IoT, drones, and GIS technologies on ecotourism, environmental monitoring, and evaluation. These instruments are more precise and enable automated data collection and predictive management of environmental hazards.	(Abbas et al., 2023)
2. Integration of LCA	Discusses the application of lifecycle methods in ecotourism operations to measure the environmental burdens in terms of energy, waste, and transport.	(Mishra, 2025)
3. Data-driven Decision Support and Predictive Analytics	Concentrates on AI-based forecasting, real-time data analytics, and decision-support systems relying on LCA and ERA results to be used in adaptive tourism management and policy planning.	(Zhang and Bin, 2024)
4. Governance, Collaboration, and Policy Alignment	Highlights the role of multi-stakeholder collaboration, public–private partnerships, and policy frameworks in promoting ecotourism innovations. Identifies barriers, including technical limitations and fragmented data governance.	(Duarte et al., 2024)
5. Socio-environmental and Economic Co-benefits	Illustrates how technological innovations in ERA and LCA generate broader benefits—community empowerment, cost efficiency, conservation outcomes, and improved visitor experiences—beyond environmental protection.	(Shekhar, 2024)

Source: Author Compilations

Merging Themes

Theme 1: Digitalization of ERA

One theme identified during the analysis is the increased digitalization of the Era in ecotourism. According to the literature, the timeliness and accuracy of environmental assessments can be enhanced through the implementation of AI algorithms, remote sensing, and monitoring systems, which utilize IoT (Rane et al., 2023). These technologies are used to identify environmental stressors (pollution, biodiversity disturbance, and habitat degradation) so that managers can respond in advance.

The cases of Southeast Asia and Scandinavia demonstrate the applicability of drones and GIS mapping in tracing the state of environmental systems, optimizing spatial performance, and reducing the cost of manual surveys (Popowicz et al., 2024). Similarly, AI recognition in photos has been applied to track wildlife and

estimate visitor numbers in conservation. Computerization has made ERA more dynamic and predictive, unlike the old reporting system; therefore, ecotourism operators can have an early-warning capability.

Theme 2: The Integration of Life Cycle Analysis

The second theme is the application of lifecycle assessment principles to ecotourism design, management, or certification systems. The literature also notes an increasing need to measure environmental burdens at every stage of tourism activities, including transport, accommodation, and waste management (Maslesa, 2019).

The secondary point is that international eco-lodge certifications (e.g., Green Globe, ISO 14001) support the fact that the introduction of LCA has enabled operators to calculate resource intensity and identify emission hotspots. Going through the list of technological tools that offer a methodological way of analyzing the environmental trade-offs and making decisions on mitigation (Ciampa et al., 2024).

Theme 3: Database Decision Support and Predictive Analytics

The advanced design of data analytics and artificial intelligence as a means of achieving sustainable decision-making is one of the most intriguing subjects of contemporary research, and it can be traced in the literature that has survived to the present. The fact that predictive analytics is supported by the constant flow of data generated by the Internet of Things, in turn, enables tracking key environmental indicators, such as energy use, CO_2 emissions, and water consumption, in real time (Abbas et al., 2023). In a case in point, eco-lodges have applied AI-driven forecasting models to identify high-impact visitation days and, therefore, streamline operational processes to reduce environmental footprints. Governmental agencies and tourism authorities have also adopted decision-support dashboards that combine LCA and ERA results, providing evidence-based information for informed policy and investment decisions. This reflects a theme of environmental management change that is responsive to anticipatory and adaptive administrative styles, aligning with the sustainability goals of the ecotourism industry.

Theme 4: Alignment, Governance, and Collaboration of Policies

The qualitative review also had well-grounded arguments in favor of multi-stakeholder cooperation as the key to the successful implementation of innovative ERA and LCA systems. According to reports from UNWTO and UNEP, governments, private operators, and local communities should align their efforts at the institutional level to adopt the principles of sustainable tourism frameworks (Hezam et al., 2024). Other secondary sources suggest that the formation of partnerships between the state and companies (public-private partnerships, or PPPs) has been facilitated by common data platforms and environmental indicators. The use of lifecycle thinking and risk assessment in policy instruments is becoming increasingly popular in national tourism policies in Europe and Asia, to support eco-certifications, carbon offsetting, and procurement sustainability.

However, according to other literature, numerous obstacles remain, including technical capacity, high costs associated with advanced technology, and fragmented data governance models (Wondirad et al., 2019). Such findings suggest that it is necessary to create policy spaces that facilitate knowledge sharing and inclusiveness in technology.

Theme 5: Co-benefits of Socio-environmental and Economic

Finally, another theme revealed in the analysis is the interdependence between technological innovation and overall sustainability outcomes. Not only are environmental risks minimized through ERA and LCA innovations, but the community is also empowered, economic development in the area is achieved, and the visitor experience is enhanced. This has been demonstrated in the cases of Kenya, Costa Rica, and Finland, which show that ecotourism operators with new environmental monitoring systems are more efficient and accountable environmental stewards. Other inventions culminated in the development of community-based data collection and creation, which raised awareness among the local population and inspired them to join conversations.
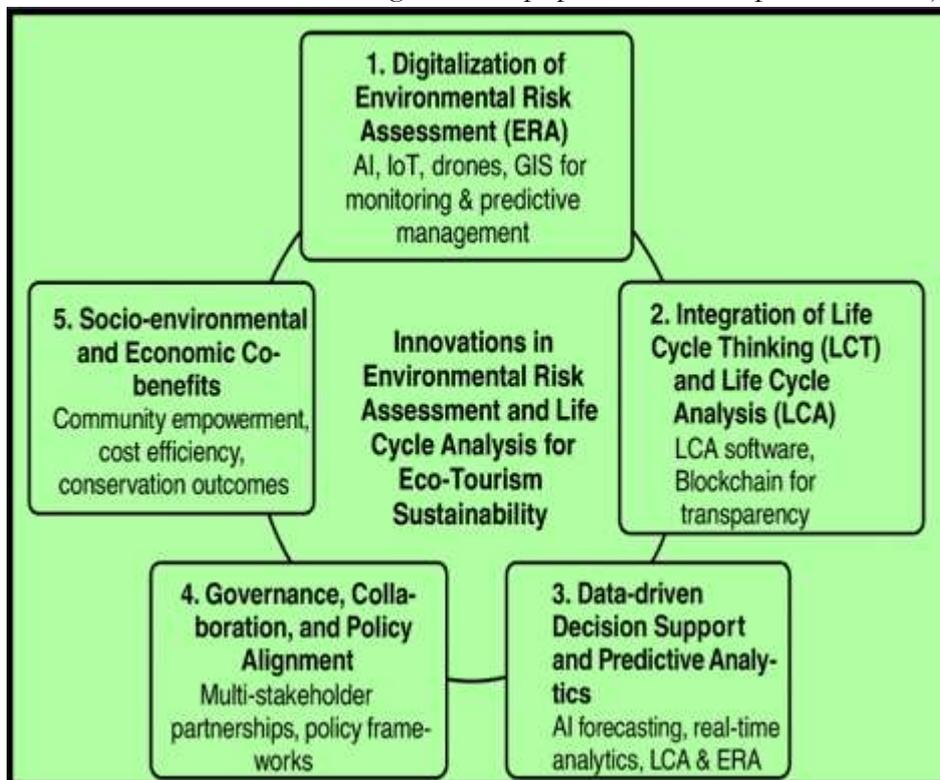

Figure 03. Integration of ERA and LCA within a unified analytical framework. Source: Author Compilations

Figure 03 presents a conceptualization of the five thematic areas derived from the qualitative synthesis. Every theme is essential to innovation in ERA and to the lifecycle analysis of ecotourism. The technological base includes the digitalization of ERA (Theme 1) and the inclusion of LCA (Theme 2). On the contrary, data-driven decision systems are used to operationalize insights for sustainability management (Theme 3). The governance and collaboration (Theme 4) give rise to institutional enablers, and the co-benefits of these innovations are socio-environmental (Theme 5). These mutually dependent spheres form a system model for achieving ecotourism sustainability through technological and systematic innovation.

Results and Discussion

The results, within the framework of the given paper, suggest a five-overlapping concept, with specific interest in ecotourism sustainability development, drawing on contributions to ERA and LCA innovations. The convergent themes encompass ecotourism digitalization, the integration of lifecycle thinking, data-driven decision support, alignment between governance and policy, and social-environmental co-benefits, representing convergent trends toward a more systematic, technology-enabled, and participatory approach to sustainability management in ecotourism (Akalibey et al., 2024). Both themes are key phenomena in evaluating the

environmental dynamics of environmentally friendly tourism, providing insight into how the industry is developing and the problems it faces.

The initial theme that drives the growth of AI, IoT, drones, and GIS-based systems is the Digitalization of the ERA, which enhances the precision, responsiveness, and efficiency of environmental monitoring. The Southeast Asian and Scandinavian practices confirm that automated detection systems are both time- and cost-efficient, unlike the old-fashioned field analysis methods, which provide almost real-time data on the health of ecosystems (Chaer et al., 2025). For example, AI image recognition and drone mapping can monitor wild animals 24/7 and predict the pressure that vulnerable ecosystems experience from visitors (Lu, 2025). ERA has also been revolutionized into an active, predictive, and flexible management system, in contrast to the traditional reporting system. This means that the risks in ecotourism are easier for ecotourism operators to anticipate, allowing them to develop appropriate mitigating measures before it is too late to address the massive impact on the environmental integrity of ecotourism, particularly in the face of growing pressures and changing climatic conditions.

The second helpful suggestion is the shift towards a holistic sustainability vision for the sector at every phase of tourism activities, and the successful implementation of this change with the assistance of LCA. The life cycle approaches are already included in the sustainable tourism requirements, as the reports provided by the secondary sources (e.g., the eco-certification schemes such as the Green Globe or the ISO 14001:2008) clarify and allow the operators to estimate the efficiency of their resource extraction and the abilities of waste disposal (Akalibey et al., 2024). LCA tools enable scenario analysis, identify hotspots, and consider options for addressing them, allowing tourism stakeholders to visualize areas with high environmental intensity (Zhang and Bin, 2024). Additionally, the openness of sustainability reporting is complemented by the genuineness of sustainability information, accountability, and other blockchain-based traceability features. The developments can enhance the credibility and efficiency of ecotourism businesses' operations, aligning with global sustainability goals in the tourism industry.

The third theme, Data-Driven Decision Support and Predictive Analytics, states that big data and AI are transforming the evidence-based management of ecotourism. The adoption of predictive analytics can be supported by IoT sensor data, enabling continuous monitoring of sustainability indicators (CO2 emissions, water use, and energy consumption) that are both important and relevant (Zhang and Bin, 2024). Eco-lodges and destination managers can use this information to predict when they be most efficient (i.e., when tourism is in full bloom or during a drought) and to modify their operations to curb environmental pressures. Government agencies and commercial operators are transitioning to decision-support dashboards that consolidate ERA and LCA results, creating a single platform for monitoring, reporting, and evaluating policies (Ikevuje et al., 2024). This reaction to the proposed change in management would make the institutions more flexible and responsive to ecotourism management, aligning with the country's global environmental philosophy and sustainable development policies.

The fourth primary outcome is the governance, collaboration, and alignment of policies, which is significant in the successful introduction of such new systems. According to the UNWTO and UNEP reports, multistakeholder cooperation between governments, private operators, and local communities is necessary to integrate the ERA and LCA into the national tourism framework (Firoozi et al., 2025). The concept of public-private partnerships (PPPs) is also defined as a method for sharing and mobilizing knowledge, thereby creating a common database of information and a set of unified sustainability metrics. However, there are still a few unresolved problems, such as the prohibitive cost of technology, technical incompetence, and incomplete data systems (Suanpang & Pothipassa, 2024). These contradictions are long-term, which underscores the need to implement capacity-building programmes, strengthen policymaking capacity, and reform institutions to

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enhance equitable access to expanding and complex sustainability resources across varied geographical locations and operational levels.

The literature on socio-environmental and economic co-benefits shows that ERA and LCA have evolved beyond environmental protection analysis to include socio-economic sustainability and community development. The case studies on Kenya, Costa Rica, and Finland show that ecosystems are supported by the introduction of new technologies into monitoring processes. Such innovations support collective data gathering and environmental management, backed by a feedback system that aims to combine environmental well-being and socio-economic health. The findings, in their turn, suggest that technological innovation in the ecotourism industry can lead to the triple bottom line, including the environmental, social, and economic realms, and therefore transform ecotourism into a model of sustainable development.

Overall, the argument has shown that the establishment of ERA and LCA models enabled by digital technologies and executed through multi-stakeholder governance is an irrefutable move towards ensuring ecotourism's sustainability. Such a shift towards dynamic, data-driven reviews of fixed parameters would likely lead to greater precision, accountability, and inclusivity. The other point the article presents is that including health provisions would imply the introduction of policies that would go hand in hand with investment in online infrastructure and the creation of stronger community engagement systems. These loopholes can be closed through ecotourism policies that ensure the development of advanced infrastructure to balance environmental conservation and socio-economic development, in line with international sustainability standards.

Practical Implications

The research has several practical implications that can be communicated to policy makers, ecotourism managers, and practitioners concerned about sustainability. Firstly, AI-based monitoring and remote sensing, along with IoT, can be used to digitize ERA. In this regard, the quality, timeliness, and continuity of environmental assessments would be significantly improved. This would imply that tourism operators can now take evidence-based, proactive actions to reduce threats such as biodiversity depletion, pollution, and habitat degradation.

Second, the LCA can be combined with the above technologies to provide a systematic approach that enables operators in the ecotourism industry to measure the environmental impact of their operations at every level, including transport, accommodation, and waste management. This comprehensive analysis helps identify processes that consume significant resources and actions that result in emissions, enabling informed choices about sustainable options, such as switching to renewable energy sources and low-carbon modes of transportation.

Third, predictive analytics and data-driven decision systems can help tourism planners anticipate environmental strains when tourists flock to their areas or when the weather is extreme. Planners can prepare preventive measures to curb negative environmental impacts by using the principles of adaptive management. It can also be achieved through the assistance of tools to streamline resource allocation processes, making waste management more effective, and ensuring that visitors can spend happier moments without interfering with the environmental balance.

In the governance context, the results indicate a need for a multi-stakeholder approach involving government agencies, local community stakeholders, and the private sector. Policy coherence can be achieved by establishing common data platforms, implementing eco-certification, utilizing common environmental indicators, and enhancing transparency in environmental management.

The socio-environmental and economic co-benefits can be generated, as analyzed, by introducing new ERA and LCA strategies. This implies that when ecotourism businesses adopt these tools, the community

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involved in the activities most likely benefits, jobs are generated within the community, conservation awareness increases, and, at the same time, operational costs are reduced. In one way or another, such innovations render sustainability not only a control tool during ecotourism design but also a strategic tool.

Theoretical Contribution

The proposed research is necessary because it contributes to the theory of ecotourism sustainability by integrating the components of the ERA and LCA into a single analytical framework. Theoretically, it bridges the divides between environmental administration, sustainability science, and technological innovation by showing how digitalization and lifecycle reflection can simultaneously advance ecotourism and the future of adaptive, evidence-based environmental administration.

The conceptual extension that presents the new digital technologies, namely AI, Blockchain, and the IoT, within the classical sustainability assessment model contributes to the theoretical framework of the sustainability assessment models in this research paper. This improvement aligns with the new environmental assessment paradigms, which are shifting towards a dynamic, predictive, and data-driven approach, making it easier to conceptualize the Smart Sustainability Theory within the ecotourism fraternity.

Secondly, the study adds to the theoretical literature on interdisciplinary environmental management, namely, the correlation between technological innovation and socio-environmental impact. The system theory is consistent with the systems thinking of life cycles and stakeholder collaboration models, which are anchored on the principle of interconnectedness. Therefore, the environmental, social, and economic systems are interdependent. In theory, the sustainability concept in ecotourism can be understood as a desire to minimize environmental impact and to advance the structural coherence across the interactions and dimensions at different levels.

Thirdly, the research applies to institutional and governance theory, which shows that digital transparency (i.e., certification issued on a blockchain) is likely to lead to greater accountability and trust in ecotourism activities. It delves into the multi-level governance approach and illustrates how interoperable information can align national regulations with international sustainability frameworks.

The research paper suggests a conceptual model of the concept (Technological Eco-sustainability Integration) of Technological Eco-sustainability Integration (TESI) through the synthesis of secondary data. The idea unveils digital innovation, environmental evaluation, and socio-economic development as a changing, interconnected concept within the systems of sustainable tourism. This paradigm promotes the abstract innovation of future harmonization between technological development and environmental responsibility, which are spheres of practice for sustainable innovation theory.
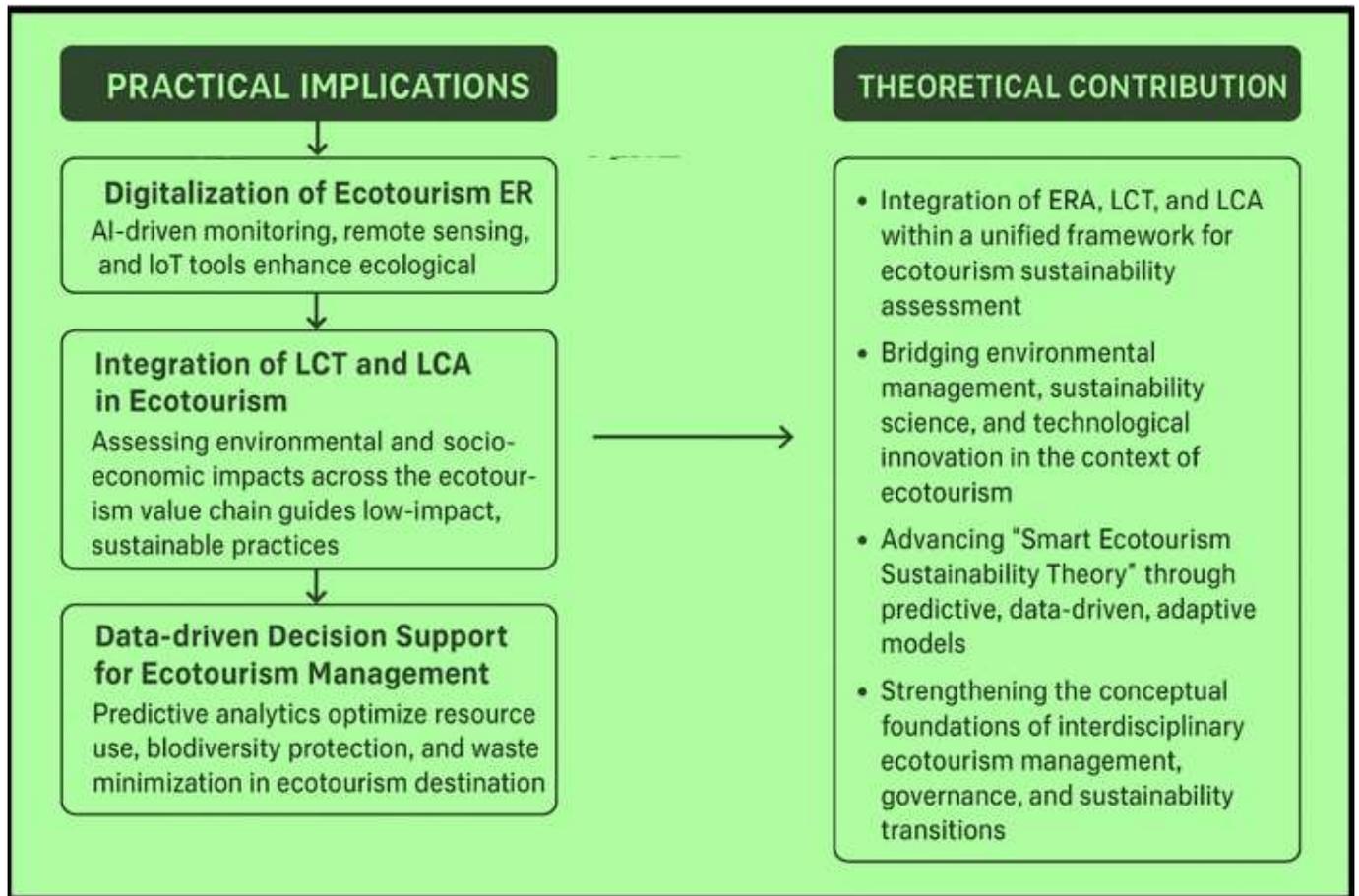
Figure 04. Innovative Ecotourism Sustainability framework by implementing ERA and LCA. Source: Author compilations

The practical and theoretical outcomes of implementing the ERA and LCA in ecotourism sustainability are illustrated in Figure 05. The framework illustrates how computer technologies, data analytics, and collaboration governance can be applied to enhance operational practices and theoretical knowledge related to sustainable ecotourism systems. The fact is that the digitalization of ecotourism, regardless of the aid of AI, remote sensing, or IoT, might enhance the accuracy of environmental monitoring and the management of tourist impacts. A condensed LCA can provide an overall picture of the socio-economic and ecological effects of each activity in the ecotourism value chain, enabling the promotion of ecotourism activities with low carbon emissions and biodiversity-friendly actions. Data-driven decision support systems are based on predictive analytics that can be utilized to optimize resource allocation, manage waste effectively, and protect the ecosystem. The other element that introduces sustainability into ecotourism destinations is governance and policy alignment, which assumes multi-stakeholder collaboration and is beneficial for the operations and maintenance of sustainability objectives.

The combination of all these strategies theoretically constitutes a system of analysis that can be applied in the evaluation and management of ecotourism sustainability. It brings science and technology development in ecotourism and environmental management closer to the overall systems of ecotourism development. It is also stipulated that the Smart Ecotourism Sustainability Theory takes a step further in the framework, as adaptive management is implemented with the incorporation of dynamic and predictive database models. It is also seen to eventually contribute to the theoretical foundation of the interdisciplinary theory of ecotourism governance and the theory of sustainability by providing the basis for evidence-based, valid, and inclusive development of ecotourism.

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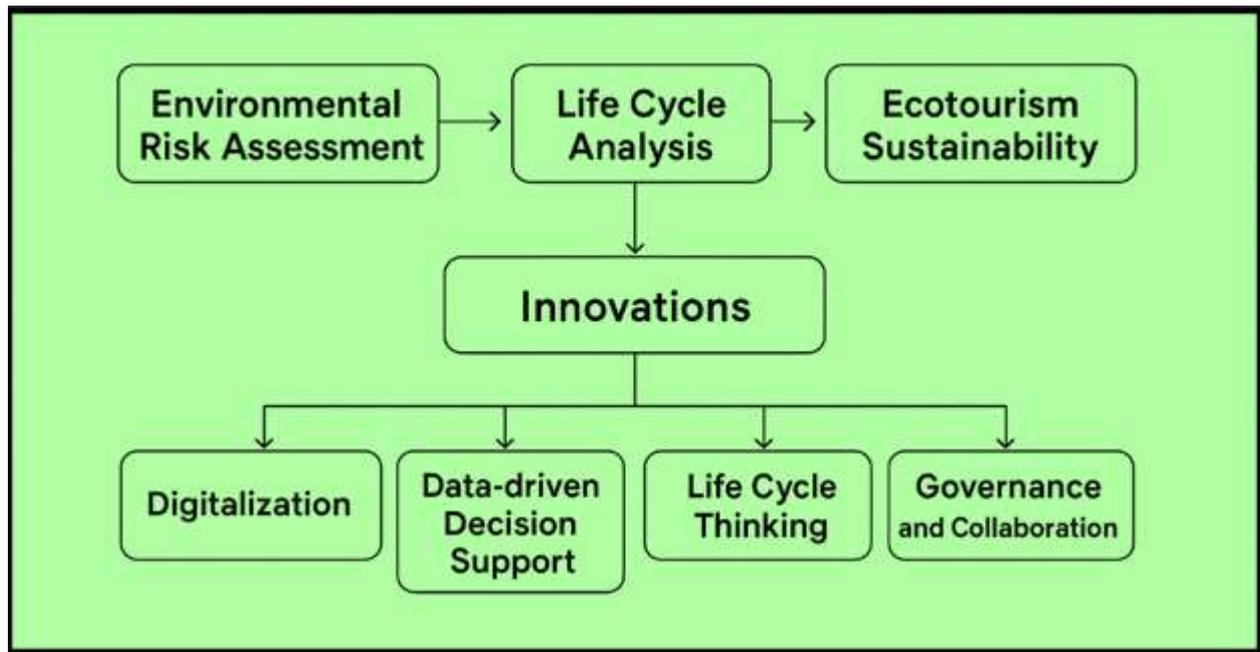Mohammad Badruddoza Talukder

Figure 05: Proposed conceptual framework ERA, LCA, and Ecotourism Sustainability. Source: Author compilation

In Figure 05, the relationship among ERA, LCA, and Ecotourism Sustainability is illustrated, with innovation as the most crucial factor. As the conceptual figure shows, ERA is the place through which the ecological risks associated with tourism development are identified, evaluated, and contained, as LCA is used to ascertain the environmental effects of the entire search of the tourism process- the extraction and transportation of resources, the accommodation and management of waste. ERA, combined with LCA, provides new approaches to make ecotourism more sustainable. The integration technologies of ERA and LCA introduce not only technological and managerial innovations but also generate socio-economic and governance advances in environmental management. The world ecology-tourism practice is a participatory, innovation-driven approach that integrates the economic and social values of the world with its ecological integrity to achieve sustainability goals.

Conclusion

This paper bridges the conceptual and methodological gaps in sustainable ecotourism practices by critically synthesizing the theoretical and empirical literature. The research has identified gaps in current ecotourism systems in capturing the following dimensions: environmental, technological, and governance, using secondary sources and a thematic merging methodology. The synthesis to meet objective A is that, despite the rampant debates over the sustainability of ecotourism, there has always been a gap in theory linking environmental assessment with innovation-based management tools. This knowledge gap explains why a new, stimulative, and multifaceted model is required to address the complex sustainability challenges of dynamic tourism ecosystems.

According to objective B, the research proceeds by adding a Smart Ecotourism Sustainability Framework that integrates technological advances, such as digital monitoring, analytics, and AI-based decision systems, to control the ERA and LCA. The structure enhances the accuracy, openness, and accountability of sustainability evaluation by transforming conventional assessment methods into smart, data-driven systems that can forecast and prevent environmental hazards in real time.

Addressing objective C, the suggested conceptual framework can unify the ERA and LCA systems into a holistic framework that considers the environmental, socio-economic, and governance aspects of ecotourism sustainability. By synthesizing these two approaches to analysis, the model can provide a more in-depth view

of sustainability outcomes, not merely ecological integrity, but also social equity and the consistency of the policy. All in all, this combined solution transforms the concept of sustainable ecotourism into a dynamic, innovation-driven system grounded in continuous learning, feedback, and adaptation. It lays the groundwork for successful governance, responsible management, and sustainable ecotourism practices that could help sustain both environmental protection and community welfare in the age of digital transformation.

Future Research Directions

Based on the integrated framework proposed in this paper, the next step in the research would be to empirically validate and practically apply the Smart Ecotourism Sustainability Framework. Research may utilize both quantitative data on the environment and qualitative data on the stakeholders to evaluate how well the framework is working in practice in ecotourism destinations. Comparisons across different ecological settings would help establish how the model is affected by context-specific factors, such as the capacity to govern or community involvement, thereby making it more adaptable and successful.

The importance of emerging technologies such as artificial intelligence, the Internet of Things (IoT), remote sensing, and blockchain in improving the accuracy and transparency of ERA and LCA should also be further researched. Technology could mechanize data-gathering processes, predictive modeling of environmental effects, and enhance accountability in sustainability reporting. It is essential to consider how these innovations can be scaled to small and community-based ecotourism operations to ensure fair use of technology.

Also, future research should examine the interdisciplinary governance systems that can help policymakers, scientists, and local communities adopt the integrated ERA-LCA system. Socio-economic and cultural indicators enhance understanding of sustainability, including environmental outcomes, by focusing on community resilience and benefit-sharing. Lastly, longitudinal research is required to determine the effects of continuous innovation and adaptive management on the long-term sustainability and competitiveness of ecotourism destinations amid global challenges such as climate change, biodiversity loss, and overtourism.

References

Akalibey, S., Hlaváčková, P., Schneider, J., Fialová, J., Darkwah, S., & Ahenkan, A. (2024). Integrating indigenous knowledge and culture in sustainable forest management via global environmental policies. *Journal of Forest Science*, *70*(6), 265. https://doi.org/10.17221/20/2024-JFS

Bhattarai, U. (2017). Impacts of Climate Change on Biodiversity and Ecosystem Services: Direction for Future Research. *Hydro Nepal Journal of Water Energy and Environment*, *20*, 41. https://doi.org/10.3126/hn.v20i0.16488

Candia, S., & Pirlone, F. (2021). Assessment of Tourism Environmental Impacts to Guide Public Authorities towards Sustainable Choices in the Post-COVID Era. *Sustainability*, *14*(1), 18. https://doi.org/10.3390/su14010018

Chaer, I., Ozarisoy, B., Ismail, M. A., Salari, S., & Ye, Z. (2025). Energy efficiency in educational buildings: A systematic review of smart technology integration and occupant behaviour [Review of *Energy efficiency in educational buildings: A systematic review of smart technology integration and occupant behaviour*]. *Building and Environment*, *280*, 113132. Elsevier BV. https://doi.org/10.1016/j.buildenv.2025.113132

Duarte, C. M., Cousins, R., Ficociello, M. A., iams, I. D., & Khowala, A. (2024). Advancing Global Climate and Biodiversity Goals Through Regenerative Tourism. *Sustainability*, *16*(20), 9133. https://doi.org/10.3390/su16209133

Fatema, K., Punitha, S., Meng, C. S., & Watabe, M. (2024). Technological Advancements and Innovations in the Tourism Industry: Driving Sustainable Tourism. In *Emerald Publishing Limited eBooks* (p. 121). https://doi.org/10.1108/978-1-83608-668-020241019

Firoozi, A. A., Oyejobi, D. O., & Firoozi, A. A. (2025). Innovations in Energy-Efficient Construction: Pioneering Sustainable Building Practices. *Cleaner Engineering and Technology*, 100957. https://doi.org/10.1016/j.clet.2025.100957

Herrero, C. C., Dias, A. C., Gallego, M. T., Gutiérrez, D., Quinteiro, P., Villanueva-Rey, P., Oliveira, S. M., Albertí, J., Bala, A., Fullana-i-Palmer, P., Puig, M., Mélon, L., Sazdovski, I., Rodríguez, E. P., Roca, M., Xifré, R., Laso, J., Blanco, M. M., & Aldaco, R. (2025). Tool for Greener Tourism: Evaluating Environmental Impacts. *Sustainability*, *17*(8), 3476. https://doi.org/10.3390/su17083476

Hezam, I. M., Ali, A. M., Sallam, K. M., Hameed, I. A., & Abdel-Basset, M. (2024). Digital twin and fuzzy framework for supply chain sustainability risk assessment and management in supplier selection. *Scientific Reports*, *14*(1). https://doi.org/10.1038/s41598-024-67226-z

Ikevuje, A. H., Anaba, D. C., & Iheanyichukwu, U. T. (2024). Optimizing supply chain operations using IoT devices and data analytics for improved efficiency. *Magna Scientia Advanced Research and Reviews*, *11*(2), 70. https://doi.org/10.30574/msarr.2024.11.2.0107

Jain, H. (2024). From pollution to progress: Groundbreaking advances in clean technology unveiled. *Innovation and Green Development*, *3*(2), 100143. https://doi.org/10.1016/j.igd.2024.100143

Lawrence, J., Blackett, P., & Cradock-Henry, N. A. (2020). Cascading climate change impacts and implications. *Climate Risk Management*, *29*, 100234. https://doi.org/10.1016/j.crm.2020.100234

Lü, B. (2025). Sustainable Tourism Management: Balancing Economic Growth and Environmental Preservation. *Journal of Lifestyle and SDGs Review*, *5*(5). https://doi.org/10.47172/2965-730x.sdgsreview.v5.n05.pe06587

Miralles, C. C., Barioni, D., Mancini, M. S., Jordà, J. C., Boy-Roura, M., Ponsá, S., Argelaguet, L. L., & Galli, A. (2023). The footprint of tourism: a review of Water, Carbon, and Environmental Footprint applications to the tourism sector [Review of *The Footprint of tourism: a review of Water, Carbon, and Environmental Footprint applications to the tourism sector*]. *Journal of Cleaner Production*, *422*, 138568. Elsevier BV. https://doi.org/10.1016/j.jclepro.2023.138568

Mishra, R. (2025). Sustainable Ecotourism Practices and Destination Choice: Perspectives from Tourists. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.5235678

Neger, M., Rahid, A. O., & Alnour, M. (2025). Moderating effects of energy poverty for sustainable tourism, policy, innovation, and environmental resilience: evidence from SEM-ANN approaches. *Discover Sustainability*, *6*(1). https://doi.org/10.1007/s43621-025-00904-8

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Innovations in Environmental Risk Assessment and Life Cycle Analysis for Ecotourism Sustainability
Mohammad Badruddoza Talukder

Nezianya, M. C., Adebayo, A. O., & Ezeliora, P. (2024). *(IF)Article 15.pdf*.

Osman, A. I., El-Monaem, E. M. A., Elgarahy, A. M., Aniagor, C. O., Hosny, M., Farghali, M., Rashad, E., Ejimofor, M. I., López-Maldonado, E. A., Ihara, I., Yap, P., Rooney, D. W., & Eltaweil, A. S. (2023). Methods to prepare biosorbents and magnetic sorbents for water treatment: a review [Review of *Methods to prepare biosorbents and magnetic sorbents for water treatment: a review*]. *Environmental Chemistry Letters*, *21*(4), 2337. Springer Science+Business Media. https://doi.org/10.1007/s10311-023-01603-4

Peña, L. V. D. L., Taelman, S. E., Préat, N., Boone, L., Biest, K. V. der, Custódio, M., Lucas, S. H., Everaert, G., & Dewulf, J. (2021). Towards a comprehensive sustainability methodology to assess anthropogenic impacts on ecosystems: Review of the integration of Life cycle analysis, ERA and Ecosystem Services Assessment [Review of *Towards a comprehensive sustainability methodology to assess anthropogenic impacts on ecosystems: Review of the integration of Life cycle analysis, ERA and Ecosystem Services Assessment*]. *The Science of The Total Environment*, *808*, 152125. Elsevier BV. https://doi.org/10.1016/j.scitotenv.2021.152125

Perović, A. B., Karabegović, I., Krstić, M. S., Veličković, A. V., Avramović, J. M., Danilović, B., & Veljković, V. B. (2025). Modern Insights into Traditional Lavender Oil Production: Methods, Optimization, Kinetics, and Perspectives. *Separation and Purification Reviews*, 1. https://doi.org/10.1080/15422119.2025.2480606

Rawat, A., Kumar, D., & Khati, B. S. (2023). A review on climate change impacts, models, and its consequences on different sectors: a systematic approach [Review of *A review on climate change impacts, models, and its consequences on different sectors: a systematic approach*]. *Journal of Water and Climate Change*, *15*(1), 104. IWA Publishing. https://doi.org/10.2166/wcc.2023.536

Reda, R., & M'Bark, M. (2023). Fostering Destination Resilience: A Conceptual Framework Linking Sustainable Tourism and Tourism Threats. *Revue Internationale de Management d Entrepreneuriat et de Communication*. https://doi.org/10.59285/rimec.390

Reynolds, S. (2024). *Unraveling the Complexity of Supply Chain Risk Management: Perspectives from Industry Experts*. https://doi.org/10.20944/preprints202406.0648.v1

Sarfraz, M., Khawaja, K. F., Han, H., Ariza-Montes, A., & Fuentes, J. M. A. (2023). Sustainable supply chain, digital transformation, and blockchain technology adoption in the tourism sector. *Humanities and Social Sciences Communications*, *10*(1). https://doi.org/10.1057/s41599-023-02051-9

Shekhar, C. (2024). Sustainable Tourism Development: Balancing Economic Growth And Environmental Conservation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4901174

Suanpang, P., & Pothipassa, P. (2024). Integrating Generative AI and IoT for Sustainable Smart Tourism Destinations. *Sustainability*, *16*(17), 7435. https://doi.org/10.3390/su16177435

Talukder, M. B. (2024a). Implementing Artificial Intelligence and Virtual Experiences in Hospitality: In S. Manohar, A. Mittal, S. Raju, & A. J. Nair (Eds.), Advances in Hospitality, Tourism, and the Services Industry (pp. 145–160). IGI Global. https://doi.org/10.4018/979-8-3693-2019-8.ch009

Talukder, M. B. (2024b). Implementing Artificial Intelligence and Virtual Experiences in Hospitality. In Innovative Technologies for Increasing Service Productivity (pp. 145-160). IGI Global. https://doi.org/10.4018/979-8-3693-2019-8.ch009

Talukder, M. B. (2025a). Climate change adaptation strategies for a tourism destination: a study of Kuakata beach. Acta Scientiarum Polonorum Administratio Locorum, 24(1), 165–179. https://doi.org/10.31648/aspal.10073

Talukder, M. B. (2025b). Maximizing Impact: The Role of Influencer Marketing in Contemporary Tourism Management. In F. Özsungur (Ed.), Navigating Organizational Behavior in the Digital Age with AI (pp. 277-304). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-8442-8.ch011

Talukder, M. B. (2025c). Revolutionizing Hospitality: Leveraging Mobile Apps and Cutting-Edge Room Technologies in the Hotel Industry. In B. Varghese & S. H. (Eds.), Advancing Smart Tourism Through Analytics (pp. 315-332). IGI Global Scientific Publishing. https://doi.org/10.4018/979-8-3693-3715-8.ch017

Wang, W., Cao, Q., Liu, Y., Zhou, C., Jiao, Q., & Mangla, S. K. (2024). Risk management of green supply chains for agricultural products based on social network evaluation framework. *Business Strategy and the Environment*, *33*(5), 4913. https://doi.org/10.1002/bse.3731

Zhang, Y., & Bin, D. (2024). Exploring the nexus of smart technologies and sustainable ecotourism: A systematic review [Review of *Exploring the nexus of smart technologies and sustainable ecotourism: A systematic review*]. *Heliyon*, *10*(11). Elsevier BV. https://doi.org/10.1016/j.heliyon.2024.e31996