Towards Smart Ecotourism: Artificial Intelligence Applications as a Pillar for Sustainability

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Summary:

This study aims to demonstrate the role of artificial intelligence technologies in enhancing sustainable ecotourism. The research reflects an in-depth study of the theoretical framework and fundamental concepts of sustainability and ecotourism, in addition to analyzing the various applications of artificial intelligence in managing ecotourism destinations. It also highlights the economic, social, and environmental benefits of these technologies, alongside the challenges they face in light of technological gaps between different tourist destinations. It becomes clear that artificial intelligence represents a fundamental tool for improving the efficiency of natural resource use and environmental conservation.

Data indicate a varied distribution in the use of artificial intelligence technologies in sustainable tourism, where some technologies occupy a high status while others face difficulties in adoption and application. Artificial intelligence technologies contribute fundamentally and measurably to achieving the goals of sustainable tourism across three main dimensions : economic, environmental, and social.

Keywords : ecotourism, artificial intelligence, sustainability.

Jel Classification Codes: Q32; Q2; Q5; Z32

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I- Introduction :

The tourism industry is witnessing a radical transformation amid the rapid advancement of artificial intelligence technologies, which emerge as innovative and effective solutions to address environmental challenges and sustainability in the ecotourism sector. According to recent data, the tourism industry contributes about 8% of total global carbon emissions, placing it under increasing pressure to adopt sustainable practices. In this context, artificial intelligence appears as a transformative force capable of balancing economic growth and environmental preservation, with market growth projections from $2.95 billion in 2024 to $13.38 billion by 2030. Practical evidence confirms that artificial intelligence technologies achieve an average return on investment of up to 246.3% across various sustainable ecotourism fields, with increases of up to 50% in some applications.

I-1 Research Problem: Ecotourism faces the challenge of balancing demand attraction with ecosystem protection, necessitating digital solutions capable of real-time monitoring, resource allocation, and driving behavioral change responsibly. Artificial intelligence represents a lever to achieve efficiency, reduce environmental impact, and enhance inclusivity, provided privacy and ethics are upheld. The research problem is as follows: To what extent do artificial intelligence technologies contribute to achieving sustainable ecotourism? To answer this question,
the following sub-questions

• What are the most important AI tools and technologies that help ecotourism achieve sustainability?
• What are the contribution rates of AI technologies in embodying sustainable ecotourism?
• What are the most prominent international pioneering experiences applying AI in ecotourism?
• Do AI technologies face obstacles and difficulties in implementation to achieve sustainable ecotourism?

I-2 Research Importance:

• The research contributes to enriching knowledge about how smart technologies can be used to achieve environmental conservation goals.

• The research provides valuable insights for tourism planners and governments on how to design supportive policies to accelerate AI adoption.

• AI can help address environmental pressures, reduce their impacts, and manage energy and resources.

I-3 Research Objectives:

• To build a theoretical framework linking AI applications in environmental conservation within ecotourism destinations.

• To measure the environmental impact of AI technology interventions in real cases through standardized indicators for sustainable environmental tourism monitoring.

• To provide practical recommendations for adoption when using AI in environmental destinations.

II-Concepts of Ecotourism

II-1Ecotourism

The origin of the term “ecotourism” dates back to 1965 when it was used by Klaus-Dieter Hetzer, but the term did not become widespread until the 1980s and 1990s, when the environmental movement and growing concern about mass tourism began to drive demand for alternative nature-based experiences. **(tourismnotes, 2025)**

The International Ecotourism Society (TIES) defines ecotourism as “responsible travel to natural areas that conserves the environment and improves the well-being of local people and involves interpretation and education.” This philosophy goes beyond merely enjoying nature to a deep commitment to preserving ecosystems and local cultures.

The Global Environment Facility defines ecotourism as "travel to natural areas that have not been polluted and whose natural balance has not been disturbed, in order to enjoy their landscapes, flora and wildlife, and manifestations of their civilizations past and present." This type of tourism is considered very important for developing countries, as it represents a source of income in addition to its role in environmental preservation and in entrenching a culture and practices of sustainable development. **(Madi, 2012)**

It is worth noting the need to differentiate between nature-based tourism and ecotourism. Nature-based tourism is a type of tourism that relies primarily on visiting natural areas, similar in this respect to ecotourism, but it may affect the resources available in these areas, whether plant or animal, and thus does not take into account environmental conservation, which can significantly impact the area. Because it negatively affects the environment, ecotourism emerged to reduce these impacts to their minimum level; that is, ecotourism came as a result of the negative effects produced by nature-based tourism. **(Khan, 2010, p. 288)**

II-2Fundamental principles of ecotourism

According to Kay Blamey, these principles are used to guide the evaluation and implementation of ecotourism activities to ensure their sustainability and their benefit to both the environment and communities: **(Blamey, 2001, p. 5)**

- **Conservation**: This includes the preservation of natural resources, biodiversity, and ecosystems.
- **Participation**: This principle focuses on engaging local communities in planning and managing ecotourism activities to ensure they have a voice and benefit from the sector.
- **Recreation and education**: Ecotourism should provide rich and educational experiences for visitors, enhancing greater appreciation of nature and culture.
- **Economy**: This principle requires that ecotourism generate economic benefits for the local community, with revenues often used to support conservation efforts and improve local livelihoods.
- **Control**: This principle emphasizes the need for local communities and stakeholders to have control over ecotourism development to prevent negative impacts and ensure long-term sustainability.

II-3The importance of ecotourism: **economic, social, and environmental**

Ecotourism provides multi-dimensional benefits that contribute to sustainable development. **(Houria, 2017, p. 35)**

- **Environmentally**, ecotourism preserves biodiversity and protects natural resources by providing financial incentives to conserve natural ecosystems. By generating revenues from nature-oriented tourism activities, ecotourism encourages communities to adopt sustainable land-use practices and protect natural habitats.
- **Economically**, ecotourism generates significant growth in rural and local communities. It provides new job opportunities in accommodation, restaurants, and guided tours, reducing rural–urban migration. Ecotourism supports small and medium-sized local enterprises through demand for tourism products and services, diversifying rural economies and strengthening local businesses.
- **Socially and culturally**, ecotourism promotes cultural exchange and mutual understanding between tourists and local communities. When tourists interact with local residents in authentic settings, their appreciation and respect for local traditions, crafts, and customs increases. This cultural respect not only enriches the visitor's experience but also encourages tourists to become ambassadors for protecting the destinations they visit.

III - Sustainable Ecotourism

Sustainable ecotourism represents an advanced model that goes beyond the basic concepts of ecotourism to focus on the **practical application of sustainable principles** in all aspects of tourism operations. This approach combines the conservation of natural resources, the enhancement of local community well-being, and the preservation of indigenous cultures.

III - 1 Definition of sustainable ecotourism

It is defined as "responsible travel to natural areas that balances environmental protection with economic benefits for the local community." It differs from traditional ecotourism in that it focuses on **continuous evaluation and periodic improvement** of tourism practices rather than merely adhering to fixed standards. This model focuses on three integrated dimensions:

- **Environmental sustainability**: Preserving natural resources and reducing negative impacts on ecosystems.
- **Economic sustainability**: Generating real employment opportunities and a fair distribution of financial benefits.
- **Social and cultural sustainability**: Protecting local identities and cultural heritage and enhancing effective community participation.

III - 2 Practices of sustainable ecotourism

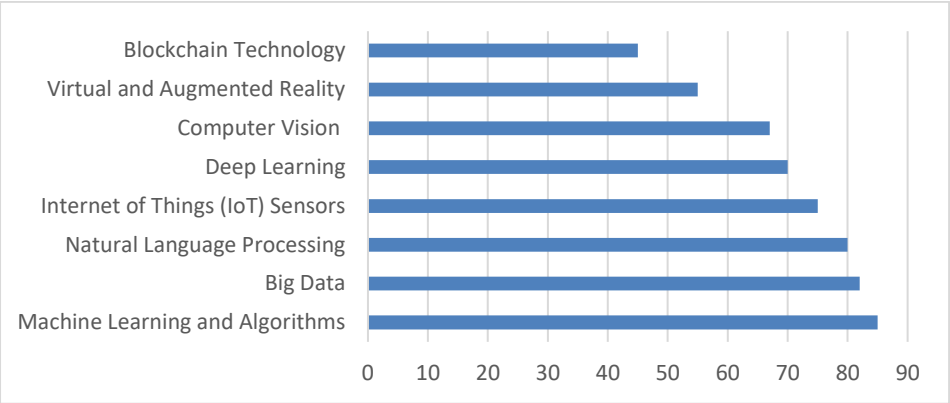
Sustainable ecotourism relies on several specific practical practices. **(School, 2025)**

- **Carrying capacity and visitor management**: Determining the number of visitors that an environmental site can host without affecting the ecosystem. This includes implementing electronic ticketing systems, scheduling visits, and setting a daily cap on tourists.
- **Eco-friendly accommodation**: Designing and constructing tourism facilities that use renewable energy sources, water-saving systems, and modern waste management. Such facilities include eco-lodges in tropical forests and resorts that rely on solar energy.
- **Sustainable transport**: Encouraging the use of low-emission transport modes such as buses, trains, bicycles, and electric boats.
- **Waste and water management**: Implementing advanced waste treatment and recycling systems and reducing water consumption in tourism facilities.
- **Environmental and cultural education**: Providing educational programs for tourists about the value of ecosystems and local culture, thereby enhancing environmental awareness and responsibility.
- **Effective community participation**: This is a critical element of sustainable ecotourism. It involves engaging local communities in tourism planning and policy-making, ensuring fair distribution of financial benefits and revenues, and training local residents in tourism, hospitality, and environmental management skills.

IV The most important Artificial Intelligence Technologies Used in Sustainable Ecotourism

AI technologies play central and multi-dimensional roles in achieving the goals of sustainable ecotourism. Their roles go beyond mere technical applications to include reshaping the relationship between humans and nature within the tourism industry. Through their integration with natural ecosystems and interaction with local communities, AI technologies enable the creation of a comprehensive sustainable tourism system that combines environmental protection, economic development, and environmental education, placing them in a unique position as a transformative tool for the future of global tourism.

Figure 1 : Percentages of AI technology use in sustainable ecotourism



Source : Prepared by the researchers based on previous references.

IV-1 Machine Learning and Algorithms (ML & Algorithms)

The chart shows that machine learning and algorithms rank first with 85% as the most widely used technologies in sustainable tourism. These technologies form the backbone of almost all smart applications in this field and are reflected in :

- **Wildlife monitoring and ecotourism** through automating species identification, tracking behavior, and analyzing habitats. These systems use deep learning algorithms such as neural networks to analyze images and videos from camera traps and drones. **(Pandiselvi R, 2024)**
- **Tourism demand forecasting**, where advanced algorithms are used to predict tourist flows and optimize resource allocation. These systems enable destinations to anticipate peak periods and take proactive measures to manage crowds, helping to prevent overtourism**. (Bajić, 2024)**
- **Tracking and reducing travel carbon footprints**, where AI platforms help companies and individuals monitor and reduce the carbon footprint of travel by analyzing real-time travel data. These systems provide actionable recommendations to reduce emissions, such as choosing direct flights instead of connecting flights or selecting environmentally certified hotels. **(predictx, 2024)**
- **AI-powered recommendation systems**, which play a critical role in directing tourists toward more sustainable choices. These systems can recommend lesser-known but equally attractive destinations, reducing pressure on popular sites and distributing tourism's economic benefits more fairly. **(Wise, 2025)**

IV-2 Big Data

Big data comes second with 82%. It has become a transformative tool in the tourism sector, providing unprecedented insights that help enhance sustainable practices and improve traveler experiences while reducing environmental impact. By analyzing large volumes of data from multiple sources, destinations and tourism businesses can make effective decisions that balance economic growth with environmental protection. Big data is also essential for training and improving machine learning models, and its role includes:

- Tour operators use data from booking platforms, surveys, and visitor tracking systems to distribute tourists more evenly, thereby reducing environmental pressure on fragile ecosystems. **(Gregory, 2023)**
- Data analytics plays a crucial role in understanding and reducing tourism's carbon footprint. Studies indicate that global tourism accounts for about 8.8% of total greenhouse gas emissions, amounting to 5.2 gigatons of CO_2 equivalent in 2019. By analyzing data on

destinations, transport modes, and consumption patterns, impacts can be better understood and mitigated. **(Sun, 2024)**

- These data also support visitor counting using ultrasonic sensors, which reinforces sustainable tourism practices through better visitor flow management. Heat maps can be used to display interaction levels across different areas at different times, helping destination managers understand tourist behavior and make strategic decisions. **(Pawar, 2025)**

IV-3 Natural Language Processing (NLP)

Natural language processing achieves an 80% utilization rate in sustainable tourism. It is one of the most prominent AI applications reshaping sustainable ecotourism. Through its ability to understand, analyze, and generate human language, NLP opens new horizons for improving visitor experiences, enhancing conservation, and developing more sustainable tourism practices, through:

- **Smart chatbots**: NLP-powered chatbots are among the most common applications in ecotourism. They provide 24/7 instant support to tourists, answering questions about environmental destinations, suggesting eco-friendly activities, and providing information about sustainable tourism practices. **(Vianna, 2023)**
- **Content creation and marketing**: NLP is used to create marketing content promoting sustainable ecotourism. Generative AI models such as ChatGPT can produce customized travel guides, destination descriptions, and educational content about the importance of environmental conservation. **(Fareed, 2023)**
- **Recommendation systems**: NLP-based recommendation systems use advanced techniques to analyze travelers' preferences and past behavior to deliver personalized suggestions. By combining textual data from travel reviews, blogs, and social media, these systems can build knowledge graphs representing relationships between various tourism entities. **(Chanrueang, 2024)**
- **Real-time translation**: AI-based machine translation plays a vital role in breaking language barriers in ecotourism. It allows tourists to communicate with local communities, understand menus and signs, and access information in their native language. Apps such as Google Translate and DeepL use neural machine translation to provide more natural and context-appropriate translations. **(Rancati, 2025)**

IV-4 Internet of Things (IoT) Sensors

IoT sensors reach a 75% utilization rate in sustainable tourism. They have become a pivotal tool in transforming tourism management from a reactive to a proactive model, enabling early detection of environmental threats and rapid intervention before irreversible damage occurs. Their uses include:

- **Wildlife monitoring**: Endangered animals are equipped with advanced tracking collars that provide real-time location data, movement patterns, and health indicators. These devices send instant alerts when abnormal behavioral changes occur, allowing rapid responses to potential threats. **(Wingrave, 2020)**
- **Energy and water management**: Sensors monitor electricity consumption in real time and automatically adjust heating, ventilation, air conditioning, and lighting systems based on room occupancy and environmental conditions. This can reduce energy consumption by 10–25% and maintenance costs by 20–40%. These systems can also significantly reduce waste by automatically adjusting water flow based on actual need. **(Botta, 2)**
- **Visitor flow tracking**: By analyzing sensor data, managers can identify the most crowded areas and redirect visitors to alternative routes, reducing pressure on sensitive sites.
- **Air and water quality monitoring** : Sensors continuously measure pollution levels, pH, turbidity, and dissolved oxygen in water bodies. In tourist areas, these data can reveal the

impact of human activity on aquatic ecosystems, allowing immediate intervention when acceptable standards are exceeded. **(Admin, 2025)**

IV-5 Deep Learning

Deep learning has a 70% utilization rate. It is revolutionizing sustainable ecotourism by enabling complex data analysis, improving resource management, and enhancing visitor experiences while reducing environmental impact. Its main applications include several critical areas that contribute to environmental and economic sustainability, such as:

- **LSTM time-series models for visitor forecasting**: Deep learning provides advanced predictive capabilities for sustainably managing visitor flows. A hybrid model combining fuzzy clustering algorithms, grey theory, and the Markov chain method was developed to forecast visitor numbers, achieving a very low error rate of only 1.25%. **(Shao, 2022)**
- **Convolutional Neural Networks (CNNs) for classification and detection**: Deep learning plays a pivotal role in protecting ecosystems through smart monitoring systems. CNNs are used to analyze images from camera traps and drones to identify individual animal species and track their movements with high accuracy reaching 90%. **(Bioengineer, 2025)**
- **Reducing the carbon footprint of tourism facilities**: Deep learning achieves tangible results in reducing the carbon footprint of tourism establishments. Reports indicate that AI systems can reduce energy consumption by up to 30%, thereby improving sustainability and operational efficiency. In an office building in Poland, the Exergio system achieved a 20% reduction in energy waste over nine months, resulting in savings of around 80,000 euros. **(asia, 2024)**

IV-6 Computer Vision

Computer vision has a 67% utilization rate and is one of the most impactful AI applications in transforming ecotourism toward a more sustainable model. By enabling digital systems to "see" and analyze visual data, this technology contributes to environmental protection, improving visitor experiences, and supporting biodiversity conservation in ways that were previously impossible. It is a practical application of deep learning and is used in:

- **Revolutionizing wildlife monitoring and protection**: In ecological tourism areas, surveillance cameras equipped with deep learning algorithms such as YOLO (You Only Look Once) automatically identify animals in their natural habitats. Models such as YOLO-WildASM achieve accuracy of up to 94.1% in recognizing protected wild animals in complex environments. **(pushpak, 2025)**
- **Protecting cultural heritage**: Image recognition techniques help preserve and protect cultural heritage at tourism destinations. AI-powered systems can analyze images to detect damage at heritage sites, create three-dimensional models for documentation, and digitally restore artifacts. **(Ju, 2024)**
- **Monitoring environmental conditions**: Computer vision plays a crucial role in monitoring environmental conditions and protecting fragile ecosystems in tourist areas. By analyzing aerial and satellite imagery, systems can track changes in vegetation cover, monitor deforestation, and assess water quality. **(Lynn, 2023)**
- **Litter detection and classification**: Computer vision systems help detect and classify litter in natural areas and on beaches. Studies have used YOLOv5 models to identify and classify various types of marine litter (plastic, metal, glass, textiles) with an F1 score of 0.797. These systems can be integrated with automated cleaning systems or drones to pinpoint litter hotspots and facilitate collection. **(Akkoyun, 2024)**

IV-7 Virtual and Augmented Reality

Virtual reality (VR) and augmented reality (AR) technologies have a 55% utilization rate. They are revolutionizing sustainable ecotourism by providing immersive and interactive experiences

that enhance environmental awareness and reduce the negative impact of traditional tourism on fragile ecosystems. These technologies combine technological innovation with a commitment to sustainability, redefining how travelers interact with natural and cultural destinations.

- VR technologies are used to transport learners to distant and fragile ecosystems such as coral reefs and rainforests without the need for physical travel, thereby reducing the carbon footprint associated with field trips. Conservation International created a VR experience titled "Under the Canopy" that takes users into the Amazon rainforest to explore its biodiversity and the threats it faces. Studies have shown that immersive VR experiences significantly enhance environmental knowledge and positive attitudes toward conservation. (**GEDEON, 2024)**
- Research shows that immersive VR experiences lead to positive behavioral changes toward the environment. One study found that 360-degree VR with a negative message increased donations to an environmental charity by more than 50% compared to traditional video treatments among tourists. Another study of 336 students showed that VR significantly enhances environmental knowledge, attitudes, and pro-environmental behaviors such as waste reduction and energy saving. **(Nelson, 2020)**
- AR can highlight local businesses, products, and services through digital guides and apps, thereby driving economic growth within communities and ensuring that tourism benefits are reinvested locally. Ecotourism contributes significantly to supporting local economies; for example, South Africa generates 8.4 billion USD and 5,000 jobs from ecotourism alone. **(stqry, 2024)**

IV-8 Blockchain Technology

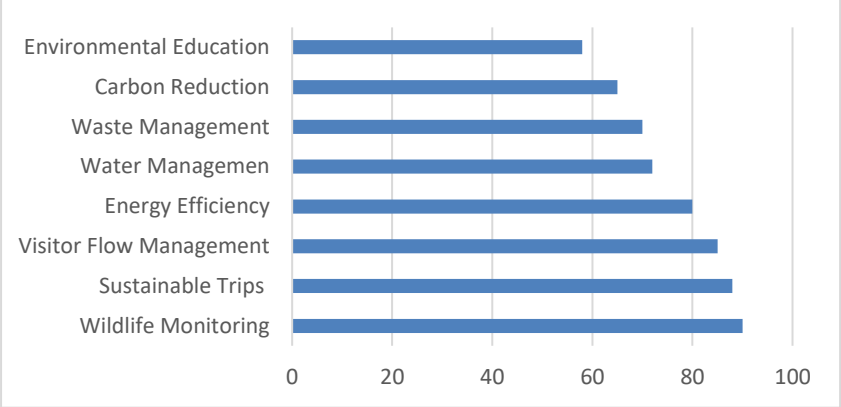
Blockchain has the lowest utilization rate at 45%, yet it represents a transformative opportunity to develop sustainable ecotourism, addressing fundamental challenges related to transparency, trust, accountability, and fair revenue distribution. Through its unique features of decentralization, transparency, and security, blockchain offers innovative solutions that strengthen sustainable practices in the ecotourism industry, notably in:

- Measuring and managing carbon emissions: Blockchain plays a pivotal role in measuring and managing carbon emissions in ecotourism. By tracking activity data, travelers can understand their carbon footprints and offset emissions through certified projects. **(BAYDENİZ, 2024)**
- Value chain management and revenue distribution : Blockchain can streamline tourism value chain management and revenue distribution to local communities. Decentralized platforms can be created for booking travel services that prioritize local providers and businesses, enhancing tourism revenue retention in the local economy and encouraging sustainable growth. **(Peng, 2022)**
- Certification and combating greenwashing : Decentralized platforms can record sustainability certificates issued by recognized bodies on the blockchain, enabling travelers to instantly verify the authenticity of any certificate and eliminate fraudulent claims. Smart contracts further enhance this process by automatically verifying compliance with sustainability standards. **(Beachum, 2023)**

V-Analysis of AI's Contribution to Sustainable Ecotourism

The chart presents the main contributions of AI to achieving sustainable tourism, measured as percentages. The data shows eight specific areas in which AI plays a major role in enhancing sustainable tourism practices.

Figure 2 : Percentages of AI technologies' contributions to sustainable ecotourism



Source: Prepared by the researchers based on previous references.

V-1 Wildlife Monitoring

Wildlife monitoring ranks first with the highest contribution rate of 90%, reflecting the critical role of AI in protecting species and natural habitats. Technologies such as smart camera traps and species recognition algorithms are used to monitor biodiversity with very high efficiency, making this the field that benefits most from smart applications. **(Vietze, 2024)**

V-2 Sustainable Trips

Sustainable trips come second with 88%, where AI helps plan and optimize travel routes to reduce emissions and environmental impacts. Smart applications use route optimization algorithms and recommend low-emission transport modes. **(Hasija, 2025)**

V-3 Visitor Flow Management

Visitor flow management achieves 85%, as AI systems enable intelligent distribution of visitors across various routes and areas to reduce congestion and pressure on sensitive ecosystems. **(almawave, 2025)**

V-4 Energy Efficiency

Energy efficiency records 80%, where tourism facilities use smart building management systems to optimize electricity, heating, and cooling consumption based on occupancy forecasts and weather conditions. **(Feller, 2024)**

V-5 Water Management

Water management reaches 72%, as smart systems provide monitoring and optimization of water consumption in tourism facilities, detecting leaks and improving usage. (Arnaud, 2024)

V-6Waste Management

Waste management stands at 70%, where AI helps automatically classify waste and improve recycling processes and waste reduction. **(Azarm, 2018)**

V-7 Carbon Reduction

Carbon reduction reaches 65%, with AI systems tracking and reducing carbon emissions from various tourism operations. **(Hillsdon, 2025)**

V-8 Environmental Education

Environmental education comes last at 58%, yet it is a fundamental tool for educating visitors and local communities about the value of the environment and respect for nature through chatbots and smart educational applications. **(seagoinggreen, 2025)**

VI-Practical Applications and Leading Global City Models

Several cities around the world are at the forefront of integrating AI technologies into the development and enhancement of sustainable ecotourism. They stand out due to their smart strategies, digital infrastructure, and commitment to the highest environmental sustainability standards. Among the most prominent cities are:

- **Venice** provides a leading example through its smart control room, which integrates computer vision and IoT sensors to monitor tourist flows and environmental conditions in real time. These systems have achieved a 30% reduction in tourist congestion and an annual return on investment of 69.7%. The project, which took 18 months to implement at a cost of 15.2 million USD, generates annual savings of 25.8 million USD. **(LEPSCHY, 2025)**
- In Asia, **Singapore** stands out as a comprehensive smart city model, where integrated AI systems achieve 35% improvements in resource-use efficiency. Although the project requires a large investment of 45 million USD and a 24-month implementation period, it yields annual savings of 89.3 million USD with a return on investment of 98.4%. **(Sipahi, 2024, p. 41)**
- **Kerala** in India, with its MAYA chatbot experience, presents another success story, achieving a 25% increase in sustainable accommodation bookings and a return on investment of 123.7%. The system, based on NLP and machine learning, was developed over 12 months at a cost of 3.8 million USD and generates annual savings of 8.5 million USD. **(Kulkarni, 2025)**
- **Vienna** and **Copenhagen** in Northern Europe are considered models of sustainable smart cities, employing AI solutions in transport systems, energy conservation, and smart control of tourism infrastructure to promote green tourism. **(Commission, 2025) Madrid** is also among the world's leading cities in deploying AI and smart technologies to develop a sustainable and balanced tourism model that respects the environment and local residents. The Spanish capital ranked first as the best sustainable tourism destination in Europe for 2024. **(DESTINO, 2024)**
- **Dubai** and **Abu Dhabi** are among the prominent cities in the Arab region using AI for sustainable ecotourism. They have established robust digital infrastructures, with applications for analyzing tourist data, managing energy efficiency in hotels, and improving smart transport to reduce emissions. Dubai has also launched "smart city" and "Desert Flower City" projects that integrate AI solutions to boost environmental efficiency, reduce energy consumption, and manage waste autonomously in tourist areas. **(BETA, 2024)**
- **NEOM in Saudi Arabia** is one of the most ambitious and innovative projects in the world, embodying Vision 2030 by applying AI and smart technologies to create a unique sustainable and environmental tourism destination. Launched in 2017 on the northwestern Red Sea coast, the project deploys smart technologies to manage water and energy, conduct environmental monitoring, and comprehensively measure and reduce the tourism carbon footprint. **(Muhandis, 2014)**

VII- Challenges and Barriers to Applying AI Technologies

The sustainable ecotourism sector is experiencing a new transformation with the adoption of AI technologies, yet this application faces a set of fundamental challenges and barriers that hinder the full realization of its potential benefits. These obstacles range across technical, regulatory, economic, and social dimensions.

VII-1 Technical and Financial Barriers (GroMatica, 2025)

Technical barriers such as data scarcity and poor data quality are among the biggest challenges to applying AI in ecotourism. Many sensitive ecological areas, especially in developing countries, lack comprehensive, long-term datasets needed to train AI models effectively. Limited digital infrastructure is another barrier : many ecological areas, particularly in developing regions, suffer from insufficient internet connectivity and digital infrastructure to support AI applications.

High implementation costs also pose a major obstacle to adopting AI in ecotourism. Developing and deploying advanced AI systems requires substantial investments, including cutting-edge technologies such as drones and machine learning–based algorithms. Additionally, insufficient data storage capacity and high server costs limit AI effectiveness in remote areas. These costs are particularly burdensome for small community projects, NGOs, and developing countries that rely economically on ecotourism.

VII-2 Security and Privacy Barriers (Kumar, 2025, p. 837)

Data protection and cybersecurity represent complex challenges in applying AI to ecotourism. AI systems require massive amounts of personal data about tourists and local communities, raising concerns about privacy and security.

AI-powered monitoring and tracking tools can be intrusive to privacy rights, especially when using biometric prediction in tracking tourists and local communities without explicit consent. This gives rise to concerns about discrimination and misuse of personal data.

VII-3 Ethical and Social Barriers (Gabriel, 2024, p. 14)

Applying AI raises profound ethical concerns related to job loss and economic displacement. Automation of processes carried out by AI may lead to job losses, especially in local communities that depend on tourism income and may be replaced by AI systems.

AI models trained on biased data can reflect and exacerbate these biases, leading to unfair treatment based on characteristics such as race, gender, or economic background. Excessive reliance on AI may also reduce the personal and cultural interactions that form the core of ecotourism.

VIII-Conclusion

This comprehensive study reveals that AI technologies play diverse and integrated roles in achieving sustainable ecotourism—from monitoring and protection to education and awareness, and from optimization and analysis to verification and accountability. With a high impact score of 8.7/10 and success rates reaching 88.1% in environmental conservation functions, these technologies demonstrate their ability to drive a radical transformation of the tourism industry toward genuine sustainability.

Future success depends on the intelligent integration of different technologies to create a holistic system that combines environmental protection, authentic tourism experiences, and sustainable economic development. Through thoughtful investment in high-impact technologies such as blockchain and smart sensors, alongside the expansion of easily deployable technologies such as NLP, it is possible to achieve an ideal ecotourism model that preserves the environment, enhances environmental education, and supports local communities, thereby ensuring the sustainability of this vital sector for future generations.

The aforementioned challenges and barriers form a complex web of technical, financial, ethical, and regulatory obstacles. Overcoming them requires an integrated approach that brings together technological innovation, effective governance, community participation, and human capacity-building. Strategies should focus on developing high-quality data, improving digital infrastructure, implementing clear ethical frameworks, and ensuring social inclusiveness in all aspects of AI application in sustainable ecotourism.

Include data and information not necessary for inclusion within the text, which provide important explanatory information to understand the article, and information that can be included in the annexes, for example: raw data; questionnaires; graphs, tables, and diagrams (New Times Roman10; The interlines spacing lines 1).

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