

The importance of Smart Tourism Innovation in Promoting Sustainable Ecotourism: A Case Study of Singapore

أهمية الابتكار السياحي الذكي في تعزيز السياحة البيئية المستدامة: دراسة حالة سنغافورة

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Abstract

This study aims to examine the role of smart tourism innovation in promoting sustainable ecotourism, using Singapore as a case study. A descriptive-analytical approach was adopted, based on a comprehensive review of the literature and the analysis of data obtained from official tourism reports and statistical databases covering the period from 2008 to 2025.

The findings indicate that the adoption of smart tourism innovations, including artificial intelligence, the Internet of Things (IoT), and data analytics contributes to improving resource management, enhancing sector performance, and supporting environmental sustainability by optimizing tourist flow distribution and reducing negative environmental impacts, while also improving the overall tourist experience.

Keywords: Smart Tourism, Tourism Innovation, Ecotourism, Singapore Experience.

JEL Classification: O31, O33, Q010, Z320.

ملخص

تهدف هذه الدراسة إلى تبين أهمية الابتكار السياحي الذكي في تعزيز السياحة البيئية المستدامة، مع التركيز على سنغافورة كدراسة حالة. وقد تم تطبيق منهج وصفي-تحليلي، يجمع بين مراجعة الأدبيات، وتحليل البيانات المستمدة من تقارير رسمية وإحصائيات صادرة عن هيئات السياحة للفترة من 2008 حتى 2025. وتشير النتائج إلى أن تبني الابتكارات السياحية الذكية بما في ذلك الذكاء الاصطناعي، إنترنت الأشياء وتحليل البيانات يساهم في تحسين إدارة الموارد، وتعزيز أداء القطاع، ودعم الاستدامة البيئية، من خلال تحسين توزيع التدفقات السياحية وتقليل الآثار البيئية السلبية، إلى جانب تحسين تجربة السائح بشكل عام.

كلمات مفتاحية: سياحة ذكية، ابتكار سياحي، سياحة بيئية، تجربة سنغافورة.

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Introduction

The tourism sector constitutes a fundamental pillar of the global economy and is widely recognized as one of the most dynamic and rapidly expanding industries. Beyond its economic significance, it plays a crucial role in fostering cultural exchange and enhancing mutual understanding among nations. This sustained growth has been largely driven by the continuous expansion of middle-income populations and the increasing levels of global consumer expenditure. In 2018, the travel and tourism sector recorded a growth rate of 3.9%, exceeding the overall global economic growth rate of 3.2%. However, this accelerated expansion has intensified concerns regarding the environmental implications of tourism development, underscoring the urgent need to reconcile economic growth with environmental sustainability through the adoption of more sustainable tourism practices.

Within this context, ecotourism has emerged as a modern trend aimed at achieving environmentally responsible tourism development through the rational use of natural resources and the preservation of biodiversity and natural heritage. Despite its significance, this type of tourism still faces several challenges, including limited attractiveness, weak promotion, and insufficient utilization of digital capabilities to enhance the tourist experience.

In this regard, smart tourism innovation has emerged as a key approach to addressing these challenges. It relies on the integration of advanced digital technologies, particularly artificial intelligence, to improve the efficiency of tourism resource management, enhance service delivery, and personalize tourism experiences in line with sustainability requirements. Such innovation contributes to increasing the attractiveness of ecotourism while ensuring a balanced integration of economic, environmental, and social dimensions.

The experience of Singapore stands out as one of the leading global models in integrating smart tourism innovation within sustainable development strategies. The country has successfully developed an integrated tourism system based on the use of advanced technologies to manage tourist destinations, improve service quality, and preserve environmental resources, making it a benchmark in sustainable ecotourism.

From this perspective, the research problem of this study can be formulated as follows:

How does the adoption of smart tourism innovation contribute to the promotion of sustainable ecotourism, and in what ways has Singapore effectively implemented these innovations to advance its ecotourism sector?

In response to the research problem, the present study formulates the following two hypotheses:

H1: Evidence derived from the case study suggests that the adoption of smart tourism innovations contributes to the advancement of sustainable ecotourism through improved resource management and the enhancement of the overall tourist experience

H2: The case study of Singapore indicates that the implementation of smart tourism strategies plays a significant role in promoting sustainable ecotourism and strengthening tourism performance.

This study examines the intersection of smart tourism innovation and sustainable ecotourism within the digital economy. It aims to develop a theoretical framework clarifying the relationship between smart tourism, ecotourism, and sustainable development. The study highlights the role of technological innovation in enhancing environmental sustainability and optimizing tourism resource management. It also emphasizes improving service quality and enriching the overall tourist experience. The research explores the implementation of advanced technologies, particularly artificial intelligence, in advancing ecotourism performance. Ultimately, the study contributes to academic knowledge by offering insights and future research directions for integrating innovation with sustainability in tourism.

The study adopts a descriptive—analytical approach, combining a structured review of recent literature on smart tourism and tourism innovation with an in-depth qualitative case study of Singapore. The research aims at analytical generalization, focusing on understanding the mechanisms through which digital innovation supports sustainable ecotourism. The selection of Singapore is justified by its global leadership in smart tourism, its resource-constrained context, and its strong relevance as a model of integrated digital and sustainability strategies.

The analysis is based on multiple secondary data sources to ensure triangulation and methodological rigor, including peer-reviewed academic publications, official statistics, and

institutional reports. A thematic analytical approach is employed to identify patterns and relationships between smart tourism technologies and sustainable ecotourism outcomes.

1. Literature Review

1.1 Theoretical Foundations of Smart Tourism and Digital Transformation

From a theoretical perspective, smart tourism is considered a natural extension of advancements in information and communication technologies, relying on the integration of big data and the Internet of Things (IoT) to enhance the value delivered to tourists. In this regard, Gretzel et al. (2015) proposed a conceptual framework for smart tourism, arguing that its true value lies not in technology itself, but in its ability to integrate and transform data into operational and strategic decisions that foster innovation and competitiveness (Gretzel, Sigala, Xiang, & Koo, 2015). Furthermore, Gretzel et al. (2020) highlighted the role of digital transformation in supporting sustainable tourism, noting that global crises such as the COVID-19 pandemic have reshaped the role of technology, making it a fundamental tool for enhancing sector resilience and rebuilding tourism systems based on more sustainable and innovative models, with a focus on digital governance, transparency, and ethics (Gretzel, et al., 2020). At the intersection of technology and environmental sustainability, Djennai (2021) emphasized that smart cities provide a conducive environment for the development of sustainable ecotourism, by leveraging digital technologies, such cities enhance resource management, reduce environmental impacts, and increase the attractiveness of tourism destinations, reflecting the strong interconnection between digital transformation and sustainable development (Djennai, 2022). At the applied level, Bouchnafa and Boukrif (2024) analyzed the impact of tourism innovation on achieving competitive advantage through a field study of tourism agencies in Djelfa (Algeria). Their findings indicated a statistically significant relationship between tourism innovation and enhanced competitiveness, confirming that innovation serves as a key mechanism for improving the performance of tourism enterprises in local contexts (Bouchnafa & Boukhrif, 2024).

1.2 Technological Innovation and Smart Tourism Systems

Loureiro and Nascimento (2021) proposed an integrated framework linking technological innovation with sustainability practices in the tourism sector. Their study employed a bibliometric analytical approach based on a comprehensive literature review. The findings revealed that technology contributes significantly to sustainable tourism by enhancing the tourist experience, improving resource management efficiency, reducing environmental impact, and supporting local communities. The study further emphasized that integrating technology within a strategic sustainability framework serves as a key driver of positive transformation (Loureiro & Nascimento, 2021).

Similarly, Semwal et al. (2024) developed an advanced model combining artificial intelligence and the Internet of Things (IoT) to analyze tourist behavior in real time. Using an applied methodological approach, the authors integrated machine learning algorithms with smart sensor technologies. The results demonstrated the model's effectiveness in providing personalized tourism recommendations and optimizing destination management with high precision, while also highlighting the importance of ethical considerations and data protection (Semwal, Bairwa, Tripathi, Mathur, Rana, & Kumari, 2024).

Likewise, Gupta et al. (2024) emphasize the convergence between smart tourism and sustainable tourism in the digital era. They demonstrate that technologies such as IoT, big data, and immersive media enable real-time environmental monitoring, personalized tourist experiences, and efficient resource allocation, while also highlighting challenges such as data privacy and digital inequality (Gupta, Sharma, Gautam, & Kumar, 2025).

1.3 Artificial Intelligence and Sustainable Tourism Development

Extending this perspective, Song and Chen (2025) examined the role of artificial intelligence in promoting sustainable tourism through a case study in China, adopting a descriptive-analytical approach. Their findings indicated that AI contributes to reducing carbon emissions, improving the allocation of tourism resources, and directing tourist flows toward less environmentally vulnerable areas, thereby enhancing environmental sustainability (Song & Chen, 2025).

In the same context, Bobirovna (2026), conducted in Uzbekistan, highlights that smart tourism technologies—such as artificial intelligence, mobile applications, augmented reality, and smart transport systems—play a crucial role in enhancing service efficiency and facilitating travel processes. The study also shows that these technologies contribute to better management of tourist flows and optimization of tourism infrastructure, while supporting environmental sustainability. However, it points out challenges related to insufficient digital infrastructure and lack of qualified specialists in certain regions (Bobirovna, 2026).

1.4 Destination Performance, Governance, and Tourist Experience

In a systematic review, Alsaad (2025), focusing on Jordan as a case study, examines the global contribution of smart technologies to sustainable tourism. The findings confirm that digital tools enhance sustainability through improved governance, stakeholder collaboration, and real-time data analytics, while identifying barriers such as infrastructural limitations and policy fragmentation (Alsaad, 2025).

Moreover, the empirical study conducted by Czyz and Javed (2025), applied in Istanbul, demonstrates that smart tourism technologies significantly influence tourist satisfaction and the sustainable image of destinations. Factors such as accessibility, personalization, and information quality enhance tourist experience, which in turn positively affects destination sustainability (CZYŻ & JAVED, 2025).

Djebil and Lakhdari (2023) investigated the role of artificial intelligence applications in developing smart tourism through a case study of Dubai. Their study showed that AI adoption improves service quality, destination attractiveness, and tourism demand (Djebil & Lakhdari, 2023). Similarly, Šakytė-Statnickė and Budrytė-Ausiejienė (2025), in a multi-country study "Lithuania, Latvia, Sweden", found that AI enhances personalization and efficiency, while also highlighting challenges such as data security risks and high implementation costs (Šakytė-Statnickė & Budrytė-Ausiejienė, 2025).

In the Algerian context, Shaki and Boukhari (2021) emphasized that AI is essential for the transition toward a sustainable digital tourism environment, requiring stronger policy support (Shaki & Boukhari, 2021).

Despite the growing body of literature on smart tourism, artificial intelligence, and sustainable tourism across diverse geographical contexts, including China, India, Jordan, Turkey, Uzbekistan, and Algeria, several critical research gaps remain unresolved. These gaps can be summarized as follows:

- First, existing studies tend to examine technological innovation (e.g., AI, IoT, and big data) and sustainability outcomes in isolation, without developing an integrated analytical framework that explicitly links smart tourism innovations to sustainable ecotourism performance. For instance, Semwal et al. (2024), Song and Chen (2025), Bobirovna (2026) primarily emphasize technological efficiency and operational optimization, whereas Loureiro and Nascimento (2021) adopt a broader sustainability perspective without a specific focus on ecotourism systems and their digital transformation mechanisms.
- Second, although studies such as Alsaad (2025), Czyz and Javed (2025) provide valuable insights into governance, tourist satisfaction, and destination image, they remain fragmented in scope. They fail to offer a comprehensive and unified model that integrates environmental, managerial, and experiential dimensions of smart tourism within a single explanatory framework.
- Third, the empirical literature is predominantly concentrated on emerging and developing tourism contexts, with limited attention given to advanced smart tourism ecosystems that have successfully achieved a high level of integration between digital innovation and sustainability. Consequently, there is a lack of in-depth case-based evidence from leading global destinations that can provide transferable and context-independent best practices.

To address this gap, the present study examines Singapore as a leading global case of smart tourism implementation, aiming to understand how digital innovation strategies contribute to enhancing sustainable ecotourism performance, improving resource management efficiency, and enriching the overall tourist experience. Building on existing literature that has highlighted the role of artificial intelligence, the Internet of Things, and smart systems in advancing tourism sustainability, resource efficiency, and visitor experience, this study moves beyond fragmented approaches by integrating these dimensions within a unified analytical framework. It applies this framework to Singapore as an advanced smart tourism ecosystem, thereby providing a more

comprehensive understanding of how digital innovation interacts with and drives sustainable ecotourism development within a mature and highly developed tourism context.

2. Tourism Innovation and Its areas of Application

The term “innovation” originates from the Arabic verb *ibtakar*, derived from the root *bakr*, which refers to “the first of anything” and conveys the meaning of initiating or accomplishing something new for the first time. From a conceptual standpoint, innovation is defined as the process of developing novel solutions that respond to individual needs or facilitate tasks in ways that were previously unknown (Al-Omari & Al-Rifai, 2021). Tourism innovation, in contrast, is a relatively recent concept that has gained academic attention particularly since the early 2000s, coinciding with the increasing integration of emerging technologies within the tourism sector. In this context, Information and Communication Technologies (ICTs) constitute a core driver of innovation, enabling enhanced interaction between tourists and service providers and improving service delivery processes. Moreover, technological advancements in key sectors such as transportation have significantly contributed to the expansion, efficiency, and competitiveness of the tourism industry.

In general, tourism innovation policies focus on introducing new products, improving existing services to meet tourists needs and preferences, and enhancing the efficiency and quality of service delivery (Djedidi & Rezazi, 2024). The importance of tourism innovation lies in increasing the value of tourism products or experiences through quality improvement or cost reduction, ensuring organizational profitability and long-term sustainability in the market. In this regard, innovation goes beyond being a mere business strategy to become an effective tool for economic development, improving living standards, and enhancing quality of life (Bouchnafa & Boukhrif, 2024).

Table (No. 01) presents a comprehensive taxonomy of innovation types within the tourism sector, developed through a synthesis of key scholarly contributions in the field of tourism innovation. The classification is primarily grounded in the seminal work of Hjalager (2010), who established the foundational categories of tourism innovation, namely product/service, process, organizational/managerial, marketing, and institutional innovations (Hjalager, 2010). This framework is further reinforced by the OECD (2005, 2013), which provides a broader innovation

classification system emphasizing product, process, and green innovation dimensions. The technological dimension is additionally supported by the work of Elzek et al. (2020), who highlight the critical role of information and communication technologies (ICT) and digital transformation in reshaping and advancing tourism systems (Elzek, Gafaar, & Abdesemi, 2020). Moreover, the social innovation dimension is informed by the contributions of Brandão (2014), who emphasizes innovation aimed at enhancing social inclusion, community participation, and sustainable socio-economic development within tourism contexts (Brandão, 2014).

Table 1. Areas of Tourism Innovation.

Type of Innovation	Examples
1. Product / Service Innovation: Introduction or improvement of tourism products or services that enhance tourist experience and influence decisions	Religious and medical tourism packages, sharing economy accommodation (e.g., Airbnb), low-cost hotels, new attractions,...
2. Process Innovation: Improvements in operational and internal processes to increase efficiency and service quality.	Online booking systems, automation, predictive analytics, smart airport systems, automated check-in, digital restaurant operations.
3. Organizational / Managerial Innovation: New ways of managing staff, structures, and work organization.	Staff training programs, teamwork strategies, empowerment systems, standardized management models, customer involvement in services.
4. Marketing Innovation: New methods of promoting, branding, and communicating with customers.	Digital marketing, influencer campaigns, loyalty programs, destination branding, CRM systems, online reputation management.
5. Institutional Innovation: Development of new governance structures, policies, and networks supporting tourism.	public–private partnerships, certification systems, tourism alliances and networks.
6. Technological Innovation: Use of modern technologies to enhance tourism services and experiences.	Artificial intelligence, mobile apps, VR/AR experiences, IoT systems, smart city tourism platforms, biometric systems.
7. Green / Sustainable Innovation: Innovations that reduce environmental impact and promote sustainability.	Eco-friendly hotels, renewable energy use, electric transport, recycling systems, green-certified tourism facilities.
8. Social Innovation: Solutions that improve social inclusion and community participation in tourism	Community-based tourism, local employment initiatives, heritage preservation, ...

Source: Author's own elaboration based on (Hjalager, 2010); (Elzek, Gafaar, & Abdesemi, 2020);

(Djedidi & Rezazi, 2024); (Brandão, 2014).

The table shows that innovation in tourism extends beyond product development to include processes, organizational structures, marketing strategies, and institutional frameworks. It highlights the increasing importance of technological, green, and social innovations in improving efficiency, sustainability, and inclusiveness in tourism services. It demonstrates that tourism innovation is highly interconnected, with different types of innovation often occurring simultaneously to create competitive advantage.

3. The Importance of Smart Tourism Innovation in Sustainable Ecotourism

Tourism, broadly defined, constitutes a social, cultural, economic, and environmental phenomenon characterized by the movement of individuals to destinations beyond their usual surroundings for diverse purposes. According to the UN Tourism, these individuals, commonly referred to as visitors, can be categorized as tourists or travelers, encompassing the full range of activities and experiences in which they engage during their visit.

Ecotourism, as defined by the Global Environment Facility, refers to “travel to natural areas that remain relatively undisturbed, with the aim of enjoying their landscapes, wildlife, and both past and present cultural features”. In this context, the tourist is not entirely free to act without constraints but rather operates within a framework that balances “tourism freedom” with “environmental responsibility,” meaning that freedom is conditioned by adherence to environmentally responsible behavior. Furthermore, the World Ecotourism Summit (2002) defined Ecotourism as “a form of sustainable tourism that actively contributes to the conservation of natural and cultural heritage, involves local communities in planning and utilization processes, and contributes to their well-being” (Boukrif & Bouhabila, 2016).

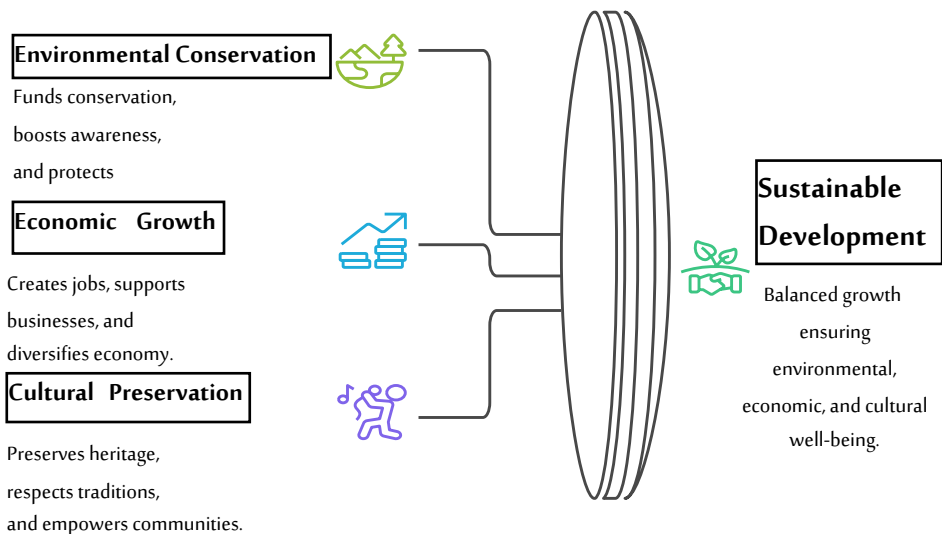
Ecotourism is characterized as a form of human activity guided by principles designed to conserve natural environments, prevent pollution, and protect biodiversity from extinction. It simultaneously constitutes an economically viable sector, integrating the authenticity of natural and cultural heritage with modern tourism practices. Moreover, ecotourism embodies a sustainable model of tourism, as its resources are renewable and its benefits contribute to environmental conservation as well as to local and national socio-economic development over the medium and long term (Bouras, 2025). Conceptually, ecotourism is underpinned by four

fundamental principles: nature orientation, ecological sustainability, environmental awareness, and the enhancement of tourist satisfaction (Djennai, 2022).

Ecotourism has diversified into several types depending on its objectives, including wildlife tourism, climate tourism, ecological nature tourism, stargazing tourism, birdwatching tourism, eco-lodging tourism, camping tourism, marine and river tourism, photography tourism, scientific environmental tourism, desert tourism, agritourism, heritage revival tourism, and diving tourism (Bouki & Gueddouri, 2025).

Ecotourism contributes to sustainable development through three main dimensions: environmental, economic, and cultural. In the following figure, these dimensions are illustrated, highlighting how ecotourism impacts conservation, local economies, and cultural heritage.

Fig. 1: Dimensions of Ecotourism's Contribution to Sustainable Development.



Source: Author's own elaboration based on (Farah & Zaouaoui, 2025)

Globally, several countries represent leading examples of ecotourism. **South Africa** is renowned for its biodiversity and protected areas, including national parks and reserves. **Tanzania** hosts iconic sites such as Serengeti National Park and Mount Kilimanjaro, offering environmentally friendly wildlife experiences. **Iceland** relies heavily on renewable energy and is known for its natural attractions such as hot springs, waterfalls, and glaciers. **Madagascar** is home to unique biodiversity and promotes sustainable tourism programs to protect rainforests and coral reefs. **Costa Rica** is considered a global leader in ecotourism, with over 25% of its

territory covered by protected areas, offering wildlife observation and eco-adventure experiences. Similarly, **New Zealand** is known for its diverse natural landscapes and strict environmental regulations aimed at reducing pollution and managing waste (Chebah , 2025).

In light of recent technological advancements, smart tourism innovation has become a key driver for enhancing sustainability in ecotourism destinations. Recent literature emphasizes that digital transformation, artificial intelligence, and data-driven systems significantly contribute to environmental protection, operational efficiency, and improved tourist experiences (Zhang & Deng, 2024). The role of smart tourism innovation in sustainable ecotourism can be summarized in the following table:

Table 2. smart tourism and Its Role in Enhancing Sustainable Ecotourism

- A Thematic Synthesis of Key Dimensions -.

Dimension	Detail
Technological Innovation, Digital Transformation, and Ecotourism Sustainability	- Enables real-time interaction between stakeholders via digital platforms and smart applications - Supports immersive experiences (AR/VR) that enhance environmental awareness and reduce pressure on fragile ecosystems - Improves accessibility to tourism services and promotes environmentally responsible tourist behavior - Optimizes tourist flows and reduces congestion through digital platforms - Contributes to the protection of natural and cultural resources within the Tourism 4.0 framework (smart mobility and integrated digital services)
Smart Data Systems and Resource Management	- Integrates IoT, GIS, and big data analytics for continuous environmental monitoring - Enables predictive analysis of tourist flows and resource consumption patterns
Artificial Intelligence in Environmental Protection	- Applied in biodiversity monitoring and ecosystem protection - Utilizes drones, smart surveillance systems, and machine learning models - Detects illegal activities and supports wildlife monitoring - Contributes to environmental conservation and reduces human impact on ecosystems

Source: Author’s own elaboration based on (Zhang & Deng, 2024), (Mikhaylov , et al., 2025), (Dias, Fonseca, Vitorino, Martins, Malpique, & Praça, 2023) , (Myrovali, Tzanis, & Morfoulaki, 2025).

4. case study of Singapore

The Singapore case provides a compelling empirical illustration of how smart tourism innovation can be strategically deployed to strengthen sustainable ecotourism performance. Over six decades, Singapore has transformed from a resource-scarce country into a highly advanced economy driven by innovation and technology. Despite structural constraints such as limited land and natural resource scarcity, it has adopted smart governance and advanced technological solutions to ensure efficient resource management. The country has also succeeded in balancing economic growth with environmental preservation by developing a smart tourism model that integrates digital innovation with sustainability principles, positioning Singapore as a global benchmark for sustainable ecotourism development.

4.1 Singapore's Strategy for Integrating Innovation in Tourism and Enhancing Sustainable Ecotourism

Singapore adopts an integrated strategy based on artificial intelligence and smart governance to enhance resource sustainability and develop smart ecotourism. In water resource management, the country has implemented a long-term framework (1965–2060) aimed at achieving water self-sufficiency through advanced recycling technologies, particularly the NEWater system, which treats and reuses wastewater in compliance with World Health Organization (WHO) standards (Lee, 2010). This system is further supported by smart infrastructure, including approximately 130 sensors for real-time monitoring of water pressure and quality, as well as leak detection systems and the WaterWise platform, which integrates data analytics with Geographic Information Systems to enhance operational efficiency (Ahmed, 2020).

In the tourism sector, Singapore has developed a smart tourism model led by the Singapore Tourism Board (STB), which drives digital transformation through artificial intelligence, data analytics, and augmented reality. In 2021, STB launched the Tcube Innovation Space, supporting more than 1,100 tourism companies in adopting digital solutions (Trends, 2025). The country further strengthened its leadership position by signing a memorandum of understanding with OpenAI, becoming the first national tourism authority in Asia to integrate its technologies (Travel and Tour World, 2025).

At the practical level, the **Gardens by the Bay** project represents a leading model of smart ecotourism, combining sustainable architecture with advanced technology. It features two iconic glass domes, Flower Dome and Cloud Forest, which employ advanced cooling systems that reduce energy consumption by approximately 30% compared to conventional building (Gardens by the Bay, 2025). The project also uses data analytics to manage visitor flows, reducing pressure on sensitive ecological areas and protecting biodiversity, while AI-based applications provide personalized and interactive visitor experiences (Singapore Tourism Board, 2025).

Overall, this model reflects Singapore's ability to effectively integrate digital innovation with environmental sustainability, positioning it as a global benchmark in smart ecotourism development.

4.2 Singapore's Smart Tourism Performance Indicators and Their Role in Advancing Sustainable Ecotourism

Singapore demonstrates a strong global position in tourism development, ranking 13th worldwide out of 119 economies in the Travel & Tourism Development Index 2024 by the World Economic Forum, as well as 4th in Asia-Pacific and 1st in Southeast Asia (Nafiri & Omphornuwat, 2025). This achievement is particularly notable given the country's limited natural and historical resources, relying instead on innovative artificial. Its leadership in smart and sustainable tourism is evidenced by a combination of quantitative indicators and innovation-driven practices that highlight the integration of advanced technologies, artificial attractions, and strategic policy frameworks. The country has successfully positioned itself as a global model by leveraging digital transformation, enhancing visitor experiences, and promoting environmental sustainability through data-driven solutions and infrastructure development.

Artificial attractions like Marina Bay Sands, Gardens by the Bay, and Sentosa drive international tourism, with 48% of visitors attending integrated resorts, 46% visiting Gardens by the Bay, and 19% visiting Sentosa in 2023 (Nafiri & Omphornuwat, 2025). Digital adoption, such as biometric airport gates, has enhanced seamless and secure travel, with 79% of travelers in Singapore using them in 2025 compared to the global average of 69% (Singapore Business Review, 2025).

The integration of generative AI in travel planning has improved personalized experiences, rising from 11% in 2024 to 20% in 2025 (Travel and Tour World, 2025). Innovation platforms like STB & Tcube support tourism enterprises, aiding 1,100 companies and 47 startups to develop 58 tourism solutions (The International Media on Arab Affairs, 2025). Smart experiences, including Google AR Tours and Maps integration, are deployed in 30 attractions, while visitor flow management in parks uses AI to prevent overcrowding.

The adoption of robotic systems at Mandai Wildlife Reserve has improved operational efficiency and sustainability by reducing manual labor requirements and saving approximately 1,200 working hours per year, reflecting the broader role of automation in optimizing resource use in smart tourism destinations (Mandai Wildlife groupe, 2025). Sentosa's Sensoryscape integrates nature with technology, offering AR-based night experiences since 2024 (Nafiri & Omphornuwat, 2025). Extended Reality applications, such as the Fort Siloso 5G Experience, provide interactive educational tourism with World War Two simulations launched in June 2023 (Nafiri & Omphornuwat, 2025).

Policy and strategy initiatives like the Tourism Industry Digital Plan, introduced in November 2023, support digital transformation and sustainability with government backing.

These indicators collectively reflect the effectiveness of Singapore's integrated approach in achieving competitiveness and sustainability in the tourism sector.

Singapore's experience in smart tourism is not only reflected in the adoption of advanced technologies and innovative solutions but is also evidenced by significant improvements in tourism performance indicators over time. In particular, key tourism metrics such as international visitor arrivals and tourism receipts demonstrate a positive upward trend, suggesting that smart tourism strategies have contributed to enhancing the sector's overall performance. The following table presents the evolution of these indicators:

Table 3. Visitor Arrivals and Tourism Receipts in Singapore "2008–2025".

Year	Visitor Arrivals	Growth %	Tourism Receipts	Growth %	Year	Visitor Arrivals	Growth %	Tourism Receipts	Growth %
2008	10,116,054	—	15.48	—	2017	17,424,611	6.2	26.81	4.1
2009	9,682,690	-4.3	12.64	-18.3	2018	18,508,302	6.2	26.94	0.5
2010	11,641,701	20.2	18.34	45.1	2019	19,116,016	3.3	27.69	2.8
2011	13,171,303	13.1	22.28	21.5	2020	2,742,443	-85.6	4.84	-82.5
2012	14,496,092	10.1	23.08	3.6	2021	330,059	-88.0	1.89	-60.9
2013	15,567,923	7.4	23.47	1.7	2022	6,305,744	1810	14.18	650
2014	15,095,152	-3.0	23.56	0.4	2023	13,602,215	115.6	27.16	91.6
2015	15,231,469	0.9	21.78	-7.6	2024	16,526,344	21.5	29.78	9.6
2016	16,403,459	7.7	25.75	18.2	2025	16,912,289	2.3	—	—

Source: Author's own elaboration based on Singapore Tourism Board (STB), Tourism Statistics Database, <https://stan.stb.gov.sg/public/sense/app/877a079c-e05f-4871-8d87-8e6cc1963b02/sheet/38bcc4eac597-4fda-8469-c5702ac7104f/state/analysis>; <https://stan.stb.gov.sg/public/sense/app/289a7ba7-52da-45af-bcc7-b8821a76c87f/sheet/199af15e-4321-41e2-8b3c-82cceb9318c2/state/analysis> (accessed on 25 Mars 2026).

The data presented in Table (3) illustrate a significant evolution in both tourist arrivals and tourism receipts in Singapore, characterized by fluctuations that closely correspond to global events and the progressive implementation of smart tourism innovations.

In the pre-2010 period, Singapore experienced a slight decline in tourist arrivals in 2009 (-4.3%) alongside a notable decrease in tourism receipts (-18.3%), mainly due to the global financial crisis. However, the sector recovered rapidly in 2010, recording strong growth in both arrivals (+20.2%) and receipts (+45.1%), reflecting the early strengthening of tourism infrastructure and the initial shift toward digital transformation and innovation-driven development.

Between 2011 and 2019, a stable upward trend is observed in both indicators. Tourist arrivals steadily increased, reaching over 19 million in 2019, while tourism receipts also grew consistently. This sustained growth can be associated with Singapore's continuous investment in smart tourism initiatives, including digital platforms, data-driven destination management, and the integration of smart technologies into tourism services.

The period 2020–2021 reflects a severe decline in performance due to the COVID-19 pandemic, with tourist arrivals dropping by -85.6% and -88.0% respectively, and a sharp fall in tourism receipts. This highlights the vulnerability of the tourism sector to global crises despite technological advancement.

From 2022 onwards, a strong recovery is evident, with an exceptional rebound in tourist arrivals (+1810% in 2022 and +115.6% in 2023), accompanied by a significant increase in tourism receipts. This rapid recovery is closely linked to accelerated smart tourism initiatives, including the adoption of artificial intelligence, digital travel systems, and enhanced data-driven tourism management led by the Singapore Tourism Board.

In 2024 and 2025, growth stabilizes at a more sustainable pace, with arrivals continuing to increase moderately and tourism receipts reaching 29.78 billion S\$ in 2024. This reflects a mature phase of Singapore's smart tourism ecosystem, where technologies such as AI, big data analytics, biometric systems, and smart visitor flow management have become fully integrated into tourism governance and operations.

On the whole, the trend clearly demonstrates that Singapore's tourism performance is not only influenced by economic cycles but is strongly driven by the evolution of its smart tourism ecosystem. Digital innovation has played a central role in enhancing resilience, accelerating post-crisis recovery, and improving the efficiency and sustainability of tourism management.

5. Results and Discussion

The empirical evidence indicates that Singapore's smart tourism model translates technological innovation into measurable outcomes in sustainable ecotourism, reflected in improved tourism performance, resource efficiency, and environmental management. The main results can be summarized as follows :

- Smart tourism strategies (including artificial intelligence, big data analytics, Tcube, and international technological partnerships) are associated with sustained growth in tourist arrivals, alongside efficient destination management and controlled environmental pressure.
- Digital transformation has contributed to improved resource utilization and enhanced economic performance within the tourism sector.

- The post-pandemic period is characterized by a strong recovery in tourism activity, reflecting improved system adaptability.
- AI-based visitor management systems have contributed to regulating tourist flows in environmentally sensitive areas, reducing congestion and improving spatial distribution.
- The integration of advanced technologies (AI, AR/VR, biometric systems, and data-driven platforms) reflects a transition toward a more mature and technology-enabled tourism model.
- Ecotourism destinations demonstrate the role of smart technologies in supporting biodiversity protection through controlled visitor flows.
- Data-driven systems contribute to improved operational efficiency and reduced environmental pressure, supporting a more sustainable tourism performance.

The findings provide strong evidence supporting both hypotheses. For H1, the results demonstrate that artificial intelligence, IoT, and data-driven systems operate as interconnected mechanisms that enhance resource efficiency, improve service quality, and support environmental sustainability within ecotourism contexts. Rather than functioning as isolated technological tools, these innovations contribute collectively to optimizing tourism operations and reducing environmental pressure.

For H2, the Singapore case confirms that smart tourism innovation plays a central role in strengthening the performance and resilience of the tourism sector. The evidence indicates that digital transformation is closely linked to improved destination competitiveness and the ability to adapt to external shocks, particularly through more efficient management of tourism demand and resources.

These findings are consistent with Gretzel et al. (2015;2020), who emphasize the role of smart tourism in transforming data into strategic insights that enhance sustainability and system efficiency. They also align with Semwal et al. (2024) and Song and Chen (2025), particularly regarding the contribution of AI and IoT to improving operational performance and minimizing environmental impacts in tourism systems.

However, this study extends existing literature by showing that Singapore's approach is not fragmented across separate technological applications, but rather integrated within a coherent

digital ecosystem that connects environmental management, operational efficiency, and visitor experience in a mutually reinforcing way.

In contrast to previous studies that often focus on isolated aspects such as technological adoption or service quality, this research highlights the importance of system-wide integration in achieving sustainable ecotourism outcomes.

Conclusion

Beyond the specific empirical findings, the broader implication of this research is that digital transformation in tourism is increasingly evolving into a structural component of sustainability strategies rather than a complementary tool. In this sense, smart tourism represents a paradigm shift in how destinations design, manage, and optimize tourism systems in line with environmental and socio-economic objectives.

More broadly, the study highlights that the effectiveness of smart tourism is closely dependent on the presence of coherent governance frameworks, institutional coordination, and long-term strategic planning. When these elements are aligned, digital technologies can support a more balanced form of tourism development that integrates competitiveness with environmental responsibility.

Despite these contributions, the study has certain limitations. It is primarily based on a single-country case study, which may limit the generalizability of the findings to other tourism contexts with different levels of digital readiness, institutional capacity, or environmental constraints. In addition, the analysis relies on secondary data sources, which may not fully capture the perceptions of all stakeholders involved in the tourism ecosystem.

Future research could address these limitations by adopting comparative multi-country analyses to evaluate the transferability of the Singapore model across different contexts. It would also be valuable to incorporate primary data from tourists, policymakers, and tourism operators to gain deeper insights into behavioral, managerial, and governance dimensions.

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