



From Green to Smart: Evolution of Sustainable Tourism in the Digital Era

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Abstract:

Sustainable tourism has undergone a significant transformation, shifting from traditional “green” practices toward more advanced “smart” approaches that integrate digital technologies, data-driven management, and interconnected systems. This transition reflects the growing need to balance tourism development with environmental protection, social well-being, and economic sustainability. Smart tourism destinations utilize emerging technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and big data analytics to optimize resource use, enhance tourist experiences, and support long-term environmental conservation. Digitalization plays a crucial role in redefining sustainability by enabling real-time monitoring, predictive analysis, and efficient management of natural and infrastructural resources. Smart systems help reduce environmental impacts by managing energy consumption, waste disposal, and visitor flows more effectively. At the same time, they contribute to improving service quality, operational efficiency, and decision-making processes within tourism management. The digital transition also influences multiple stakeholders, including local communities, government authorities, and private enterprises. While smart technologies promote transparency, innovation, and improved public service delivery, they also raise important ethical concerns related to data privacy, digital equity, and inclusivity. Therefore, the adoption of smart tourism requires thoughtful governance frameworks to ensure that technological advancement supports sustainable development rather than merely accelerating technological growth. Through emerging examples and case studies, such as AI-supported heritage conservation and smart mobility systems, the chapter highlights how digital solutions are transforming tourism destinations. Smart tourism initiatives demonstrate the potential to address global challenges such as overtourism, climate change, and resource depletion. Ultimately, integrating intelligent technologies into tourism management can create resilient, sustainable, and future-ready destinations that benefit both visitors and host communities.

Keywords: Smart Tourism, Sustainable Development, Artificial Intelligence, Internet Of Things, Digital Transformation.

Introduction:

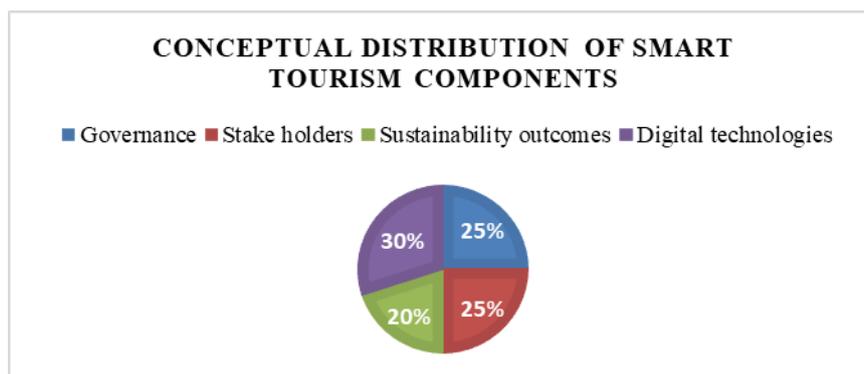
Over the past three decades, tourism has evolved from traditional “green” sustainability practices toward a broader “smart tourism” paradigm that integrates

digital technologies with environmental, social, and economic objectives. While early sustainable tourism initiatives focused mainly on eco-certification and operational efficiencies such as water, energy, and waste

management, these approaches were often limited by fragmented data and outdated information. The emerging smart tourism model addresses these limitations by using **digital connectivity, real-time data, and intelligent systems** to manage tourism destinations more effectively. Technologies such as **Artificial Intelligence (AI), Internet of Things (IoT), sensors, mobile platforms, and big data analytics** enable tourism stakeholders to monitor environmental impacts, manage visitor flows, and improve decision-making. In this ecosystem, public and private actors collaborate through shared data platforms, allowing destinations to function as **integrated systems where value is co-created** among businesses, governments, and communities. Real-time monitoring also enables dynamic demand management, personalized visitor services, and behavioral nudges that encourage sustainable choices such as low-carbon transport, time-shifted visits, and responsible travel practices. Smart

tourism also plays a critical role in addressing **global climate challenges**, particularly the growing carbon footprint of tourism activities such as aviation, cruises, accommodation, and attractions. Advanced data systems allow more precise emissions tracking and support strategies such as decarbonization, energy-efficient infrastructure, and transparent sustainability reporting aligned with the **Sustainable Development Goals (SDGs)** and net-zero targets. However, the transition from green to smart tourism requires **strong governance, ethical data practices, and inclusive participation**. Issues such as data privacy, digital inequality, and power imbalances between large platforms and small enterprises must be addressed. Ultimately, smart sustainability emphasizes using digital innovation not just for growth, but for **creating resilient, equitable, and environmentally responsible tourism destinations**.

Conceptual Framework: From Green to Smart:



The concept of sustainability in tourism initially emerged through the “**green tourism**” movement, which focused on reducing environmental impacts through eco-efficiency, certification systems, environmental standards, and community

participation. These approaches were grounded in the broader principles of **sustainable and responsible tourism**, aiming to balance economic competitiveness with environmental and social accountability. However, as tourism

destinations became more complex—with increasing visitor flows, interconnected supply chains, and diverse stakeholder needs—traditional green management approaches proved insufficient. Static indicators, delayed feedback mechanisms, and slow policy responses often failed to address emerging challenges such as **overtourism, climate change, and infrastructure pressures**. To overcome these limitations, tourism governance has gradually shifted toward a “**smart sustainability**” paradigm, which integrates digital technologies, data networks, and intelligent systems into sustainability management. In this model, technologies such as **IoT sensors, mobile platforms, artificial intelligence, and big data analytics** enable destinations to continuously monitor environmental and social indicators, predict future challenges, and implement adaptive management strategies. Smart tourism systems allow destinations to function as interconnected ecosystems where governments, businesses, communities, and tourists collaboratively create value through shared data and coordinated decision-making. The transition involves three major shifts: from static sustainability indicators to **real-time monitoring systems**, from organization-level eco-efficiency to **ecosystem-level coordination**, and from reactive reporting to **predictive and proactive governance** supported by digital tools such as analytics and digital twins. These systems also support progress toward the **Sustainable Development Goals (SDGs)** by improving energy management, promoting responsible consumption, ensuring inclusivity, and strengthening partnerships. However, smart tourism also raises challenges related to **data**

governance, privacy, algorithmic bias, and digital inequalities. Therefore, effective implementation requires ethical governance frameworks, transparent data management, and inclusive stakeholder participation to ensure that technological innovation genuinely contributes to sustainable and equitable tourism development.

Role of Digital Technologies in Smart Sustainable Tourism:

The evolution of tourism sustainability has recently shifted toward a **smart sustainable model**, where digital technologies integrate environmental objectives with real-time data, public participation, and system-wide efficiency. Traditional “**green tourism**” focused mainly on compliance, conservation, and operational practices such as energy efficiency, waste reduction, and eco-certification. In contrast, smart sustainability treats sustainability as an **operational capability**, where tourism systems continuously sense, analyze, and adapt to maintain environmental balance and positive visitor experiences. Digital technologies play a central role in enabling this transformation. Tools such as **Internet of Things (IoT) sensors, smart meters, and connected building management systems** allow tourism facilities to monitor and optimize water and energy consumption in real time. Similarly, **sensor-based waste management and predictive infrastructure maintenance** reduce emissions and resource wastage at the destination level. When these data streams are integrated through destination-scale platforms, they allow coordinated optimization of **transportation,**

accommodation, and tourism activities across the entire system rather than isolated sectors. Big data and analytics further enhance sustainability management by providing insights into **tourist behavior, visitor flows, and destination pressures**. Data from social media, mobile devices, and booking platforms help managers identify congestion points and environmental stress, enabling interventions such as timed entry, dynamic pricing, and alternative routing to reduce overcrowding while maintaining visitor satisfaction. Emerging technologies like **augmented reality (AR), virtual reality (VR), and personalized recommendation systems** also support sustainability by distributing tourist demand and promoting less-visited attractions. However, digital transformation also introduces challenges related to **data privacy, governance, algorithmic bias, and unequal access**. Therefore, effective smart tourism requires transparent data governance, inclusive participation, and impact-based indicators such as carbon intensity, resident satisfaction, and local economic participation. When supported by ethical governance and collaborative partnerships, digital technologies can transform sustainability goals into **practical, measurable outcomes for tourism destinations**

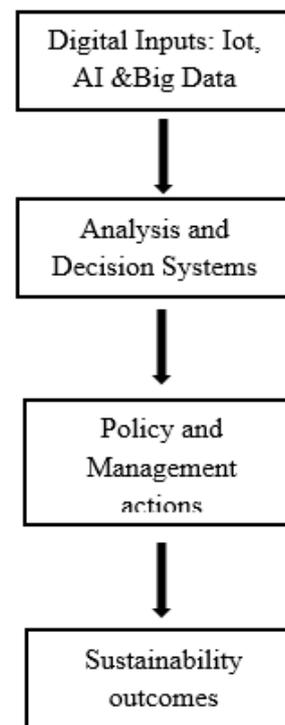


Table 1: Stakeholder ecosystem in smart sustainable tourism destinations.

Smart Tourism Stakeholders and Governance:

The shift away from traditional "green" tourism to an intelligent, data-driven model of tourism has fundamentally reshaped the governance structures that underpin sustainable tourism and rearranged stakeholder relationships at their core. For example, individual organization or attraction-based traditional sustainability frameworks typically foregrounded certification and compliance issues, carrying capacity, and care for the environment. With the revised version of this part, we review a variety of stakeholders and how their roles have evolved over time, and systems of governance that enable collaboration. Besides outlining the institutional solutions that introduce openness, accountability, and co-value creation, it challenges data-driven governance risks, which include digital

exclusion, algorithmic opacity, and imbalance of power. (Mandic, A., & Kennell, J 2021).

1.The Smart Tourism Ecosystem: From Linear Roles to Distributed Value Creation:

The conventional model of tourism administration had well-defined roles: the state regulated, businesses operated and sold, DMOs promoted places, and visitors consumed experiences. It is likely that these established norms are challenged by platform-based engagement, common data infrastructures, and crosssector collaboration heading towards smart tourism. Data, infrastructure, expertise, local knowledge and social legitimacy are all resources that stakeholders today combine with each other in order to create value. (Ribes, J, F, P., & Baidal, J, A, I 2021).

1.1 Public Sector Authorities:

Federal, state, and local governments play a key role in smart tourism governance by ensuring public safety, environmental protection, and spatial planning. They establish data governance frameworks, interoperable digital infrastructure, adaptive regulations, and partnerships. Strong municipal leadership, as seen in Barcelona and Amsterdam, promotes equitable digital transformation and prevents corporate dominance.

1.2 Destination Management Organisations (DMOs):

Destination Management Organizations (DMOs) are shifting from promotion-focused roles to managing tourism data ecosystems. Their responsibilities now include monitoring visitor flows, coordinating with platforms and SMEs, fostering innovation labs, and aligning digital actions with sustainability

KPIs. To support this transition, many DMOs are investing in training, data literacy, and public-private collaborations.

1.3 Private Sector Actors:

Destination-level analytics integrate operational data from hotels, transport providers, attractions, and retailers to track occupancy, mobility, and transactions. Businesses support sustainability by sharing anonymized data, adopting sensor-based efficient processes, coordinating demand and mobility, and promoting circular economy initiatives. However, large platform datasets require regulation and cooperation to ensure fair competition and responsible data use.

1.4 Technology Providers and Platforms:

Companies included in this category function on IoT, analytics, mobility applications, mapping, and cloud infrastructure, to mention a few. To begin with, they bring technical acumen to the table along with an innovative spirit.

1.5 Residents and Civil Society:

Local residents are key stakeholders in smart tourism governance, contributing local knowledge, cultural insights, and environmental awareness to decision-making. Through participatory tools like citizen observatories and sentiment dashboards, they help monitor tourism impacts. Ignoring communities may increase inequality and resistance; therefore, active community engagement is essential for inclusive and sustainable tourism development.

1.6 Academic and Research Institutions:

Universities and research laboratories play a vital role in the development and governance of smart sustainable tourism. They act as consultants and evaluators of smart tourism initiatives, ensuring that technological solutions align

with sustainability objectives. Academic institutions also contribute to the design of indicator systems that measure environmental, social, and economic impacts effectively. In addition, they serve as data ethicists and advisors on algorithm governance, helping address issues related to privacy, transparency, and fairness in digital systems. Through training, research, and knowledge transfer, universities strengthen evidence-based policymaking and capacity building, fostering innovation and sustainable tourism development grounded in scientific rigor

2. Governance in Smart Tourism: From Hierarchies to Polycentric Networks:

Smart tourism governance emphasizes collaboration, distributed intelligence, and adaptive management, departing from the linearisms of traditional tourism planning.

2.1 Multi-level, Polycentric Governance:

In essence, there are several centres of authority that function semi-autonomously but collaborate through common protocols; this type of smart tourist administration is frequently called polycentric. The governments of federal, state and regional levels are cooperating in managing urban services, and national frameworks control data privacy and market competitiveness.

Interdisciplinary teamwork But polycentric systems risk disintegration, as well as wasted investments and inequitable data practices, without transparent coordinating methods.

2.2 Platform-Based Governance:

The growing use of digital platforms in tourism governance raises concerns about data ownership, algorithm transparency, and fair access to benefits. Destination

authorities must regulate platforms by ensuring open data access, interoperability, bias evaluation, and public-interest data sharing, so that digital systems support sustainability goals and equitable tourism development, rather than only commercial profits.

2.3 Collaborative Governance:

Collaborative governance plays a crucial role in the effective management of smart and sustainable tourism destinations. It brings together diverse stakeholders from academia, government institutions, and the private sector to participate in shared decision-making through platforms such as participatory mapping, innovation laboratories, and steering committees. These collaborative mechanisms help align different interests by harmonizing benefits, building trust and reliability, negotiating compromises, and balancing social, environmental, and economic priorities. Research shows that tourism challenges such as overtourism and environmental limits are managed more effectively through collaborative approaches than through purely technocratic or top-down strategies, as they encourage inclusive participation and more balanced, sustainable decision-making.

3. Data Governance: The Institutional Backbone of Smart Tourism:

Smart destinations depend on the responsible collection, sharing, and use of data. Data governance ensures that stakeholders can collaborate while respecting privacy, equity, and sustainability.

3.1 Principles of Data Governance:

Key principles of smart tourism data governance include interoperability, transparency, accountability, privacy, and equity. Interoperability ensures data sharing

through common standards and APIs. Transparency clarifies how data and algorithms are used. Accountability requires audits and corrective measures, while

privacy protects individuals through anonymisation. Equity guarantees fair access to data for governments, communities, and SMEs-.



Table 2: Framework of Data Governance Principles for Smart Tourism Destination

3.2 Data Trusts and Commons:

New governance models such as data trusts help manage shared datasets among businesses, citizens, and public institutions. They define data access permissions, ensure ethical use, distribute benefits fairly, and prevent platform monopolies. By promoting transparency and accountability, data trusts support balanced and sustainable digital governance in tourism systems.

3.3 Privacy, Security, and Algorithmic Fairness:

The smart tourism raises ethical concerns which is related to:

- The surveillance of digital.
- Facial recognition.
- Biased recommender systems.
- Exclusionary pricing.

Governance structures must therefore incorporate algorithmic audits, privacy impact assessments, ethical AI guidelines, and community oversight.

4. Global Case Illustrations:

It is being illustrated that mostly this global turn towards smart sustainable tourism from these actual destinations that have integrated the use of digital technology into the long term social and ecological goal. The correct examples have depicted about how community involvement, data ecosystems, and governance interface to support the key sustainability outcomes.

4.1 Barcelona, Spain: A Benchmark for Data-Governed Sustainability:

Barcelona is seen by many as one of the early adopters of data-driven governance to better integrate social and environmental concerns into the tourist industry. The issues of overtourism and satisfaction of residents led the city to change its focus from green mobility and heritage protection to a smart paradigm.

The data on mobility, hotel occupancy, expenditure records, and crowd indicators based on sensors may be accessed through a real-time dashboard for the Barcelona tourism board and the city administration. Some examples of the dynamic decision-making this system may support are frequency adjustments in public transportation, flow dispersion by means of real-time route suggestions, and application of event-specific crowd laws. (Lamarca, M, G., et al 2019).

4.2 Singapore: Integrating Smart City Infrastructure with Sustainable Visitor Experience:

Some of the leading examples of using city-wide smart infrastructure in tourism are to be found in Singapore. STAN, or the Singapore Tourism Analytics Network, consolidates insights from various databases-immigration records, cell roaming data, hotel statistics, and attraction footfall indicators-to come up with demand

prediction models in tourism. (Pillai, K, R 2017).

Low-carbon urban transportation manifests itself in the form of driverless shuttles, unified ticketing, and AI-controlled traffic systems. In fact, IoT-enabled environmental monitoring ensures that water usage is minimized, micro-climate is controlled, and energy consumption is optimized at Sentosa Island and the Gardens by the Bay greenhouses and attractions.

These include a carbon tax at the national level, plans pertaining to the circular economy, and environmentally friendly construction standards that are in wide usage in the tourist attractions of Singapore.

4.3 Amsterdam, Netherlands: Managing Visitor Pressure through Digital Nudging:

Amsterdam offers a very unique case study when it comes to safeguarding cultural integrity and improving liveability in conditions of chronic overtourism. Multimodal sensor networks are part of the "Amsterdam Intelligence" platform, helping monitor pedestrian density, canal traffic, and noise levels. The "City Card" software and digital kiosks then disseminate these findings into the resident, tourist, and company populations. (Huang, C, E., & Liu, C, H 2018). One of the notable innovations in Amsterdam is the use of the digital nudging technique. In place of strict restrictions, Amsterdam uses real-time communications to guide the visitors to less crowded areas and hours.

4.4 Dubai, UAE: Technology-Driven Luxury with Environmental Intelligence:

The highly developed digital and urban networks form the baseline of Dubai's

tourist ecosystem. Complementing the visitor experience, it has built smart mobility networks, systems powering artificial intelligence for service customization, and immersive augmented and virtual reality heritage experiences as part of its sustainability goals. (Yang, Y., et al 2021). The Dubai paradigm combines sustainability with luxury tourism through data intelligence, digital twin city planning, and integrated smart grid systems. Dubai shows that digitalization works to favor efficiency in resource-intensive tourist locations, although their size and resources are not replicable anywhere else.

4.5 Copenhagen, Denmark: Community-Centric Smart Sustainability:

Instead, the city of Copenhagen has come up with a strategy based on community values during digital transition. Guided by its mission for supporting "human-centred smart tourism," it places much emphasis on open government and citizen participation.

4.6 Queenstown, New Zealand: Digital Stewardship in a Nature-Based Destination:

Instead, the city of Copenhagen has created a plan that puts community values first in digital transition. In an effort to further "human-centred smart tourism," the city has placed open government and citizen participation near the forefront. With neighbourhood-level data, real-time sentiment analysis, and community feedback in a feedback loop, the tourism board of Copenhagen partnered with citizens on a roadmap for sustainability. Internet of Things devices installed in neighbourhoods allow the city to monitor air pollution, excess trash, and noise, among other environmental metrics, and to trigger

Destination	Smart Technologies Used	Sustainability Focus	Governance Model	Key Lessons
Barcelona	IoT sensors, visitor dashboards, open data, AI alerts	Overtourism control, cultural integrity	Public data rights & digital sovereignty	Smartness works when rooted in ethics and resident protection.
Singapore	Predictive analytics, integrated mobility, IoT ecosystems	Low-carbon mobility, energy efficiency	Whole-of-government smart-city alignment	National digital coherence accelerates sustainable tourism outcomes.
Amsterdam	Crowd sensors, digital nudging apps, data visualisation	Visitor redistribution, liveability	Collaborative governance	Nudging + regulation reduces overtourism impacts.
Dubai	Smart grids, digital twins, AR/VR experiences	Resource efficiency, smart building	Technocentric with strong state leadership	High-tech infrastructure can support sustainability when intelligently managed.
Copenhagen	Environmental sensors, sentiment platforms, smart cycling	Community wellbeing, carbon neutrality	Participatory governance	Resident involvement is vital for legitimacy and equity.
Queenstown	Drones, geospatial analytics, ecological sensors	Nature conservation, cultural stewardship	Co-governance with Indigenous partners	Smart tools can reinforce ecological and cultural values.

Table 3: Case Comparison Table.

Challenges and Ethical Concerns:

1. Data Privacy, Surveillance, and Consent:

Another important ethical problem arises with the smart tourism development related to collecting and processing masses of personal and behavioral information. Analytics, driven by platforms, mobile apps, Wi-Fi tracking, and sensors, continuously monitor everything from visitor flows, dwell periods, spending trends, and mobility options. While these streams of data are beneficial in many cases for crowd control and reducing environmental stresses, they also raise issues of monitoring and invasion of privacy, informed permission.

2. Power Imbalances and Platform Dominance:

The impact of major online marketplaces like Google, Booking, Airbnb, and transportation service providers in smart tourist ecosystems is considerable and increasing. These companies are in command of crucial data streams: those determining physical, financial, and informational access. At the same time, these commercially driven algorithms influence destination flows more directly than government regulations, creating a power imbalance that overshadows local SMEs and public institutions.

3. Algorithmic Bias and Inequitable Outcomes:

From recommending attractions to routing decisions, AI-driven prediction models and recommendation systems that will help in managing visitors are on the rise. Their accuracy remains a function of data used for training them. If preexisting biases or inequities are in the training data of such smart tourism systems, they risk perpetuating unequal spatial development or marginalization of certain communities.

4. Digital Divide and Uneven Access:

Smart sustainable tourism relies heavily on digital literacy, broadband connectivity, and device access. As such, local stakeholders, entrepreneurs, or tourists are not in an equal position regarding access to technologies. SMEs face specific difficulties in the adoption of data-driven solutions due either to resource constraints, lack of skills, or scarcity of financial funds. This can create serious barriers that impede all individuals from benefitting equally from smart tourism.

Conclusion:

The transition from “**green tourism**” to “**smart sustainable tourism**” reflects a significant conceptual and operational shift in how tourism destinations pursue environmental responsibility, social well-being, and economic resilience. Traditional green tourism emphasized eco-efficiency, conservation practices, environmental impact mitigation, and certification systems. While these approaches established the foundation for sustainable tourism, they often relied on static plans and periodic assessments that were unable to respond quickly to rapidly changing tourism dynamics. Smart

sustainable tourism expands these principles by integrating **digital technologies and data-driven systems** into sustainability management. Technologies such as **IoT sensors, predictive analytics, digital twins, mobile applications, and integrated mobility platforms** enable real-time monitoring and analysis of tourism activities. These tools allow destinations to manage visitor flows, optimize resource use, reduce waste, and enhance visitor experiences while safeguarding local communities and ecosystems. As a result, sustainability is no longer based solely on fixed plans but on **continuous, evidence-based management and adaptive governance**. Global case studies demonstrate that there is **no single model** for smart sustainable tourism. Destinations such as **Barcelona and Copenhagen** prioritize ethical digitalization and community empowerment, while **Singapore** emphasizes national-level technological integration. **Amsterdam** focuses on behavioral nudging to address overtourism, **Dubai** leverages high-tech infrastructure for efficiency, and **Queenstown** integrates digital tools with indigenous environmental stewardship. These examples show that each destination interprets “smartness” differently depending on its **cultural values, governance capacity, environmental priorities, and technological readiness**. Ultimately, the shift toward smart sustainable tourism represents not a replacement of green principles but an **integration of sustainability with digital innovation to create more inclusive, resilient, and future-ready tourism systems**

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