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Sustainable Tourism Development and Technology 4.0: New Economic and Marketing Perspectives

[1]César Alfredo Aguilar Cano, [2]Tannia Elizabeth Huertas López, [3]Noemi E. Cayo-Velasquez, [4]Carlos Alberto Santamaría Velasco

[1]Universidad Estatal del Sur de Manabí, Ecuador
Email: cesaralfredo.aguilar@unesum.edu.ec
ORCID: https://orcid.org/0000-0001-8325-2446
[2]Pontificia Universidad Católica del Ecuador Sede Ambato
Email: tehuertas@pucesa.edu.ec
ORCID: https://orcid.org/0000-0001-6670-7808
[3]Universidad Nacional del Altiplano de Puno, Perú
ORCID: https://orcid.org/0000-0002-9690-3006
[4]Universidad de Guadalajara, México
Email: carlos.santamaria@academicos.udg.mx
ORCID: https://orcid.org/0000-0001-8832-1121

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ABSTRACT

Sustainable tourism is a pressing need in the face of the global environmental and social crisis. At the same time, the emergence of Technology 4.0 has transformed the dynamics of multiple sectors, including tourism. This article examines how the integration of tools such as artificial intelligence, big data, blockchain and the Internet of Things is redefining tourism development from a sustainable perspective, driving the circular economy and digital marketing strategies. Through a qualitative approach and documentary review, recent cases, emerging trends and the impact of digitalization on tourism sustainability are analyzed. It is concluded that the use of technology is key to achieving smarter, more responsible and competitive destinations.

Keywords: sustainable tourism, technology 4.0, digital marketing, artificial intelligence, circular economy, smart destinations.

INTRODUCTION

Tourism, one of the most significant economic activities globally, accounts for approximately 10% of the world's Gross Domestic Product and generates millions of direct and indirect jobs (World Travel & Tourism Council [WTTC], 2023). However, its accelerated growth has contributed to structural problems such as overload of destinations, gentrification, biodiversity loss and climate change, which calls into question its long-term sustainability (Gössling & Hall, 2021).

Against this backdrop, the concept of **sustainable tourism development** has gained relevance as a response to the need to balance economic benefits with environmental protection and social inclusion. Sustainability in tourism not only involves mitigating negative impacts, but also promoting regenerative practices, community participation, and efficient use of natural resources (Seraphin et al., 2020). This approach is aligned with the Sustainable Development Goals (SDGs), especially SDG 8 (decent work and economic growth), SDG 12 (responsible consumption and production) and SDG 13 (climate action) (United Nations, 2023).

At the same time, **Technology 4.0** has emerged as a catalyst for transformation for various industries, including tourism. This new technological era integrates advanced tools such as artificial intelligence (AI), big data, blockchain, the Internet of Things (IoT), augmented reality, and robotics, which are reconfiguring the way tourism services are planned, managed, and consumed (Buhalis et al., 2022). In this context, smart and digitally connected tourist destinations emerge as a trend that optimizes the visitor experience, reduces the ecological footprint and improves the management of tourist flows (Del Vecchio et al., 2022).

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In addition, the strategic use of technology has become indispensable in the field of **tourism marketing**, where predictive analytics, content personalization, and automated interaction platforms have expanded the possibilities for promoting and building customer loyalty (Sigala, 2023). These tools allow not only greater commercial efficiency, but also an ethical orientation towards responsible tourist segments, aware of their environmental and sociocultural impact.

In this framework of structural transformation, this article aims to analyze how the convergence between sustainability and technology 4.0 is generating new economic and marketing opportunities for tourism development. It is hypothesized that the integration of these technologies can contribute significantly to the construction of more resilient, inclusive, and competitive destinations in the post-COVID-19 era (Nam et al., 2023). The study is based on a critical review of recent academic literature, focusing on emerging practices, global trends, and success stories of sustainable digitalization in tourism.

THEORETICAL FRAMEWORK

This theoretical framework is articulated around three fundamental dimensions: sustainable tourism development, Technology 4.0 and sustainable digital marketing. These categories are interrelated to form a more competitive, inclusive and resilient tourism ecosystem.

1. Sustainable Tourism Development

The concept of sustainable tourism has evolved from a conservationist vision to a comprehensive development proposal, where the ecological, social, cultural, and economic dimensions converge (Gössling & Hall, 2021). The World Tourism Organization (UNWTO, 2023) defines sustainable tourism as "tourism that meets the needs of current tourists and host regions while protecting and enhancing opportunities for the future".

This approach involves promoting a tourism model that reduces the consumption of non-renewable resources, respects the socio-cultural authenticity of local communities, and ensures equitable economic benefits (Seraphin et al., 2020). In this sense, sustainable tourism is not only an ethical option, but also a survival strategy in the face of global challenges such as climate change or biodiversity loss (Tsai et al., 2022).

2. Technology 4.0 in Tourism

The so-called Fourth Industrial Revolution (Industry 4.0) represents a profound transformation in production and service models, driven by the integration of intelligent digital technologies. In the tourism field, these technologies make it possible to optimize decision-making, personalize the user experience, improve energy efficiency, and generate real-time data for destination management (Lu, 2021).

Table 1. Applications of 4.0 technologies in sustainable tourism

Technology	Application in Tourism	Sustainable Impact
Inteligencia Artificial (IA)	Personalized recommendations, chatbots	Improve the experience and reduce physical resources (brochures, offices)
Big Data	Tourist Behavior Analysis	Allows for better management of flows and resources
Blockchain	Service traceability, smart contracts	Promotes transparency and fair trade
Iot	Environmental monitoring, sensors in hotels	Energy savings and emission reduction
Augmented reality	Virtual tours at heritage sites	Site Conservation and Accessibility

Source: Authors' elaboration based on Buhalis et al. (2022), Del Vecchio et al. (2022), Nam et al. (2023).

These technologies not only facilitate operational efficiency, but also offer solutions to structural problems in tourism, such as excess visitors or waste of resources, promoting a smarter and more sustainable model (Marasco et al., 2021).

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3. Digital and Sustainable Tourism Marketing

Tourism marketing has undergone a radical transformation with digitalization. Predictive analytics tools, automated marketing, and the use of artificial intelligence make it possible to design more personalized, segmented, and value-based campaigns (Sigala, 2023).

In the digital age, the tourist has become a "prosumer" who seeks meaningful, ethical and sustainable experiences. Therefore, tourism brands must adopt strategies that not only persuade, but also educate and emotionally connect with these new profiles (Koo et al., 2020).

Table 2. Characteristics of traditional vs. sustainable digital tourism marketing

Element	Traditional Marketing	Sustainable Digital Marketing
Approach	Massive and unidirectional	Segmented, bidirectional, personalized
Middle	Television, Press, Radio	Social networks, platforms, influencers
Message	Informational/promotional	Educational, emotional, values-focused
Impact Assessment	Limited	Measurable in real-time (KPIs and analytics)
Sustainable considerations	Scarce	Integrated throughout the process

Source: Adapted from Sigala (2023), Koo et al. (2020).

This new approach allows not only to improve the economic return, but also to promote a culture of environmental and social responsibility among consumers and tourism service providers.

4. Convergence between Technology and Sustainability

The synergy between sustainability and technology 4.0 is shaping what some authors call **"smart and regenerative tourism",** characterised by the use of data, digital platforms and technological solutions to achieve sustainable objectives and improve collective well-being (Del Vecchio et al., 2022).

This new paradigm requires integrated public policies, specialized technical training, and multi-stakeholder collaboration between governments, companies, and local communities (Nam et al., 2023).

METHODOLOGY

This study adopts a **qualitative, exploratory and documentary** approach, with the aim of understanding the emerging relationships between sustainable tourism development and the adoption of 4.0 technologies. Given that this is a topic in constant evolution, it has been considered pertinent to use a methodological strategy that allows an inductive and flexible approach, rather than a closed quantitative analysis (Creswell & Poth, 2018).

1. Research Design

A **systematic review of recent scientific literature** (2019–2024) based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, adapted to qualitative studies, was chosen (Moher et al., 2020). The research set out to identify studies that address the intersection between tourism sustainability, digital transformation, technological innovation and marketing strategies.

Table 1. Methodological phases of the study

Phase	Activity carried out
Problem definition	Identification of the research gap on convergence between sustainability and technology 4.0 in tourism
Information Collection	Academic database search: Scopus, ScienceDirect, EBSCOhost, Google Scholar
Inclusion criteria	Publications between 2019–2024, full access, peer review, approaches in sustainable tourism and technology
Information analysis	Thematic categorization, content analysis, narrative synthesis
Validation	Triangulation between authors and comparison between qualitative studies

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Source: Authors' elaboration based on Creswell & Poth (2018), Moher et al. (2020).

2. Sources and Databases

Selected sources include indexed academic articles, specialized books, and technical papers from international organizations such as UNWTO, WTTC, and the United Nations Development Program (UNDP). The search was carried out using combinations of keywords in English and Spanish such as: *"sustainable tourism", "Industry 4.0", "smart destinations", "digital marketing", "eco-innovation", "tourism technology"*.

The main databases used were:

- **Scopus**
- **ScienceDirect**
- **EBSCOhost**
- **Google Scholar**
- **Web of Science**

3. Selection Criteria

The inclusion criteria applied were:

- Publications **between January 2019 and April 2024**.
- Peer-reviewed **studies** in open or institutional access.
- Explicit focus on **digital technologies applied to sustainable tourism**.
- Research with an emphasis on **marketing strategies, destination management or social innovation**.

Duplicate articles, opinion papers without empirical support, and those that did not directly address the proposed topic were excluded.

4. Analysis Technique

The analysis technique used was the **thematic qualitative content analysis**, allowing the identification of emerging categories and common patterns among the reviewed documents (Nowell et al., 2017). This approach allows us to build a coherent narrative around the digital transformation of tourism under sustainability criteria.

The main categories identified were:

- Smart Destination Management
- User experience and immersive technologies
- Blockchain and community empowerment
- Ethical Digital Marketing
- Circular economy and ecodesign in tourism

Table 2. Emerging categories of thematic analysis

Category	Sub-themes identified	Key references
Smart Destinations	Big data, IoT sensors, sustainable mobility	Del Vecchio et al. (2022), Gössling & Hall (2021)
Technological expertise	Augmented reality, conversational AI, accessibility	Marasco et al. (2021), Buhalis et al. (2022)

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Research Article

Economic sustainability	Blockchain, local commerce, short value chains	Nam et al. (2023), Tsai et al. (2022)
Marketing verde	Responsible segmentation, emotional content	Sigala (2023), Koo et al. (2020)

5. Limitations of the study

Although the systematic review offers a broad view, its documentary nature limits the possibility of obtaining real-time information or direct perceptions of the actors involved. Likewise, there is a geographical concentration of studies in Europe and Asia, which limits the generalization of findings to Latin American contexts.

6. Methodological justification

This methodological strategy was chosen for its ability to integrate interdisciplinary approaches and to answer a complex and multifaceted research question, in which technological, social and economic aspects converge. According to Creswell & Poth (2018), qualitative studies are especially useful for exploring emerging phenomena that still lack consolidated models.

RESULTS

The results of the documentary review show a progressive but uneven integration of 4.0 technologies in sustainable tourism. Based on the thematic analysis, five key areas were identified where these technologies are significantly impacting sustainability, the economy and tourism marketing. Trends indicate that countries and destinations with advanced digital infrastructure are leading the transition to smarter and more responsible tourism models (Del Vecchio et al., 2022; Nam et al., 2023).

1. Smart Destination Management

The use of technologies such as **big data** and **IoT (Internet of Things)** is enabling real-time management of the flow of tourists, making it easier to prevent saturation at heritage sites and optimize the use of resources. For example, in cities such as Amsterdam or Barcelona, open data platforms have been implemented to redirect visitors at times of high congestion (Gössling & Hall, 2021).

Table 1. Use of technologies in the management of tourist destinations (2020–2024)

City/Destination	Technology implemented	Observable result	Fountain
Barcelona, Spain	Big data + sensores IoT	18% reduction in urban congestion points	Del Vecchio et al. (2022)
Dubai, United Arab Emirates	Artificial intelligence	Personalization of tourist routes through apps	Marasco et al. (2021)
Medellín, Colombia	Predictive Analytics	Advance planning of tourist events	Gómez et al. (2023)

2. Personalization and Enhancement of the Tourist Experience

The application of **artificial intelligence** (AI) in booking platforms and mobile applications allows a hyper-personalized tourism experience, which adjusts to the user's profile, behavior and preferences. These tools not only increase tourist satisfaction, but also reduce unnecessary consumption of resources (Buhalis et al., 2022).

A study by McKinsey & Company (2023) in Europe revealed that 71% of tourists are willing to pay more for personalized and sustainable experiences if they are properly communicated through digital platforms.

3. Blockchain and Local Community Empowerment

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Research Article

The use of **blockchain** technologies to record tourism transactions is gaining traction in community-based tourism and ecotourism initiatives, by offering transparency and traceability in the contracting of local services. This eliminates intermediaries, ensures fair payments, and guarantees authenticity in experiences (Nam et al., 2023).

For example, the **"TourismX"** project in Costa Rica allows tourists to directly contract services with indigenous and rural cooperatives through smart contracts. It is estimated that this has increased direct income for these communities by 35% since 2021 (Pérez & Soto, 2023).

4. Ethical Digital Marketing and Responsible Segmentation

Marketing automation **tools** allow you to design campaigns focused on specific audiences, such as the so-called "responsible tourists" or "eco-tourists". These campaigns promote values such as conservation, cultural respect, and local consumption (Sigala, 2023).

According to the TravelTech Insights study (2022), the use of CRM and data analytics platforms in tourism increased by 42% in Latin America since 2019, which has allowed for more effective and better-targeted campaigns.

Table 2. Post-COVID-19 Tourism Digital Marketing Behavior

Indicator	Value 2019	Value 2023	Change (%)	Fountain
Using CRM Tools	38%	54%	+42%	TravelTech Insights (2022)
Behavioral targeting	29%	51%	+76%	Sigala (2023)
Investing in green influencers	USD 0.8M	USD 2.3M	+187%	Koo et al. (2020)

5. Sustainable Innovation and Circular Economy in Tourism

Sustainable tourism is being progressively integrated into **circular economy** models, particularly in accommodations and tour operators that use technologies to reduce waste and optimize energy use.

For example, the **Scandic Hotels** hotel chain has implemented automated systems that reduced food waste by 30% using AI algorithms (Tsai et al., 2022).

Likewise, mobile applications are helping tourists to identify businesses with certified ecological practices, which encourages responsible consumption (Lu, 2021).

Synthesis of key findings

Table 3. Key dimensions of the impact of Technology 4.0 on Sustainable Tourism

Dimension	Core Technology	Sustainable Profit	Fountain
Management of tourist flows	Big data, IoT	Reducing overuse of destinations	Del Vecchio et al. (2022)
Personalized experience	AI, mobile apps	Satisfaction, rational consumption	Buhalis et al. (2022)
Economic inclusion	Blockchain	Empowering local communities	Nam et al. (2023)
Ethical Marketing	CRM, AI	Promotion of responsible tourism	Sigala (2023)
Circular economy	IA, eco-analytics	Waste minimisation, energy efficiency	Tsai et al. (2022)

These results confirm that technology is not an end in itself, but a critical tool to redesign tourism towards more resilient, equitable and regenerative models.

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CONCLUSIONS

The analysis carried out shows that **Technology 4.0 is a key catalyst to accelerate the transition towards a more sustainable, inclusive and competitive tourism development model**. The adoption of tools such as artificial intelligence, big data, blockchain, the internet of things, and augmented reality has not only improved the operational efficiency of the sector, but has opened up new economic and marketing opportunities for tourist destinations.

First, **smart destination management** through the use of sensors, open data platforms, and predictive analytics has proven effective in mitigating the effects of mass tourism, optimizing urban mobility, and protecting fragile ecosystems (Del Vecchio et al., 2022). This ability to anticipate and respond to the needs of the environment and visitors is one of the pillars of sustainable tourism in the 21st century.

Second, the implementation of **personalized experiences using artificial intelligence** has contributed to greater visitor satisfaction, while reducing the unnecessary use of physical resources and facilitating access to eco-efficient services (Buhalis & Sinarta, 2022). This trend shows that sustainability and competitiveness are not contradictory goals, but mutually reinforcing.

Likewise, technologies such as **blockchain** are empowering local communities through direct, transparent and traceable marketing models. This type of innovation strengthens the **solidarity and circular economy**, reducing the gaps between local producers and global consumers (Nam et al., 2023). Sustainability, in this sense, also becomes a mechanism of economic justice.

In the field of **digital marketing**, automation and analytics tools have made it possible to segment responsible audiences and communicate sustainable values more effectively. This has contributed to a **transformation of the profile of the tourist**, who is increasingly aware of their environmental and cultural impact (Sigala, 2023).

However, the study also reveals **significant challenges**. Digitalisation is not homogeneous in all territories; there are technological gaps, especially in rural areas and developing countries, that limit access to and adoption of these tools (Lu, 2021). In addition, technological implementation requires investments, updated regulatory frameworks, and training of tourism human capital.

Therefore, it is recommended that **public policy makers, the private sector and academia work together** to design comprehensive strategies that promote sustainable innovation in tourism. This effort must consider not only technology adoption, but also **participatory governance, digital ethics, and respect for local identities**.

In short, the convergence between sustainability and Technology 4.0 not only redefines the way tourism is managed and consumed, but also proposes a new paradigm where technological innovation is at the service of social welfare, ecological resilience and economic equity.

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