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Technology Factors in the Sustainability of the Hotel Industry. A Bibliometric Study

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Abstract: *Sustainable hotels protect the environment by reducing emissions. Sustainable methods attract environmentally conscious guests. Sustainable practices help hotels differentiate themselves. Despite research in this sector, few have explored the technological aspects of hotel sustainability. This study will reveal the views of professionals on the main technological forces affecting green hotel operations to address this gap. A quantitative methodology was used, employing bibliometric analysis. Data were obtained from articles in the Scopus database. In total, 48 articles were selected for bibliometric analysis. The novelty of the study lies in the evidence of the use of hotel sustainability technologies. This article explains the technological determinants of hotel sustainability and the most common enablers. It shows how technological aspects help hoteliers make sustainable decisions and the perspectives they should consider. This study recommends further research on the impact of Industry 4.0, corporate social responsibility, dynamic process reengineering, and environmental intelligence as sustainable technological factors in the hospitality sector.*

Keywords: *Technological enablers, sustainability, hotels, bibliometric analysis, internet of things.*

1. INTRODUCTION

Studies on technology, sustainability, and tourism indicate that technology is essential for promoting sustainability in the tourism sector, particularly in the hotel industry (Sigala, 2018). Information and communication technologies (ICTs) form the basis of the concept of smart innovations, which encompasses smart tourism.

López de Ávila (2015) states that the application of smart principles in a hotel or tourist destination guarantees sustainable development by improving mobility, increasing resource availability, optimizing resource allocation, and raising the quality of life for both residents and visitors. Höjer and Wangel (2015) define the concept of intelligence as the set of technologies that use sensors, big data, open data, information sharing, and increased connectivity to drive technological, sustainable, social, and economic progress.

Hospitality companies are increasingly adopting digital transformation as a strategic method to achieve their sustainability goals and gain a competitive advantage. Digital transformation can significantly improve the sustainability of corporate operations, thus contributing to the achievement of the Sustainable Development Goals (Bekele et al., 2024). Integrating digital transformation and sustainable practices offers numerous advantages: cost savings through increased efficiency, regulatory compliance, greater market access, improved brand image, enhanced reputation, and reduced staff turnover (Bashir et al., 2023). Digital technologies enable hotel companies to optimize procedures, automate operations, and reduce reliance on physical resources, thereby decreasing energy consumption, carbon emissions, and waste generation. Hotels can use digital platforms to communicate information about their sustainability activities and inform guests about environmentally friendly consumption practices, resulting in a sustainable hotel business ecosystem (Rasoolimanesh et al., 2020).

Over the past decade, a growing number of hotel and resort managers have become aware of sustainability technology and principles, particularly with a desire to acquire expertise in these areas. While larger hotels and chains have the resources to address technological and environmental challenges, small and medium-sized hotels and resorts require assistance. These latter businesses represent the largest segment of the global hotel industry.

Therefore, decision-makers in hotels and resorts must understand sustainable tourism and the actions these establishments can take to implement sustainable practices with technological support (Prakasha, 2018).

This becomes crucial as pressure on these institutions increases. Hotels and resorts must understand sustainability concepts and criteria. The notion of a fully sustainable resort is novel and demands a comprehensive understanding. However, this will only be feasible if decision-makers understand the concept of a 100% eco-friendly resort. They must also understand the technical drivers of sustainability. This will enable them to adopt reasonable expectations, set achievable goals, and understand the technological and sustainability challenges in the context of hotels and resorts (Prakasha, 2018).

As travelers become increasingly aware of environmental concerns, the hotel industry has begun adopting sustainable practices to meet guest expectations and demonstrate its commitment to the environment, thereby gaining a competitive advantage (Gössling, 2018).

To determine the current state of technological drivers of sustainability in hotel research, this study aims to identify and understand the technologies that promote sustainability in hotels and propose future lines of research in this field. The literature review established the foundation for defining an appropriate methodology to answer the research question: What are the main technological drivers of sustainability in hotels? To answer this question, this study aims to evaluate the scientific literature on technological drivers of sustainability and identify the state of the art in this area. To achieve this general objective, the following specific objectives are adopted:

(1) Identify the state of the art of technologies used to promote sustainability in the hotel industry.

(2) Determine the technologies that promote sustainability in hotels.

2. METHODOLOGY

A quantitative methodology was employed using bibliometric analysis, which identified various aspects, such as the output of sources, the countries and authors that most extensively cover the topic, as well as the central themes. Bibliometric analysis, widely applied in the hospitality sector, provides statistics on research output and dissemination (Campos et al., 2022) and identifies the most popular topics and research gaps. Bibliometric analysis is a descriptive statistical method that allows for the study of the contributions of countries, authors, and journals to a topic (Mensah et al., 2024). Bibliometric studies analyze the productivity and relevance of a topic through citations (Mensah et al., 2024). In other words, a bibliometric approach maps the anatomy of knowledge within a body of research (Mensah et al., 2024). In addition, content analysis was applied to the scientific articles that were among the 10 most cited. A qualitative analysis was also applied to this research, in which a detailed analysis of the scientific articles revealed patterns and concepts (White & Marsh, 2006; Campos et al., 2022). This analysis began with a word cloud constructed from the authors' keywords in all the research documents. Consequently, using a hybrid methodology, the authors will compile various studies on the main technological drivers of sustainability in hotels into a single scientific article to understand the evolution of this line of research and define future lines of inquiry.

The bibliometric analysis was performed on February 9, 2024, based on a literature review of scientific articles in the Scopus database, which offers high-quality information (Baas et al., 2020). Several keyword searches were conducted, based on titles, abstracts, and keywords, using the following combinations: (“internet of things” or “artificial intelligence” or “big data”) and (“sustainable”) and (“hotel” or “hospitality” or “resort”). Regarding technologies directly and widely applied to promote sustainability in the hospitality sector, IoT, AI, and Big Data were selected as keywords. A total of 48 scientific articles were obtained and exported from the SCOPUS database in CSV format for analysis using Bibliometrix and R Studio. For content analysis, a word cloud was created using the 48 scientific articles and the 10 most cited (see Table I).

Table I. *List of the 10 most cited articles*

Authors	Total citations	Title	Methodology
Pencarelli (2020)	215	The digital revolution in the travel and tourism industry	Conceptual approach.
Nilashi *et al*., (2019b)	96	Preference learning for eco-friendly hotels recommendation:	Self-Organizing Map (SOM); Higher Order Singular Value

		A multi-criteria collaborative filtering approach	Decomposition (HOSVD); Adaptive Neuro-Fuzzy Inference System (ANFIS); Classification and Regression Trees (CART).
Marine-Roig (2019)	88	Destination Image Analytics Through Traveller-Generated Content	Content analysis techniques
Buhalis (2023)	53	Smart hospitality: from smart cities and smart tourism towards agile business ecosystems in networked destinations	In-depth analysis of the extracted publications
Ban *et al.,* (2019)	52	Investigating Key Attributes in Experience and Satisfaction of Hotel Customer Using Online Review Data	Collecting online hotel reviews, text mining and linear regression analysis
Nilashi *et al.,* (2019a)	48	A Hybrid Method with TOPSIS and Machine Learning Techniques for Sustainable Development of Green Hotels Considering Online Reviews	SOM clustering, LDA for extracting satisfaction dimensions, TOPSIS for ranking hotel features, ANFIS for predicting
Serrano *et al.,* (2021)	35	Exploring preferences and sustainable attitudes of Airbnb green users in the review comments and ratings: a text mining approach	Data preprocessing, filtering "green" Airbnb users, sentiment analysis, Latent Dirichlet Allocation (LDA), and Latent Rating Aspect Analysis (LARA).
Kim & Kim (2022)	35	The Impact of Hotel Customer Experience on Customer Satisfaction through Online Reviews	Text mining, semantic network analysis, CONCOR analysis, factor analysis and regression analysis
Mariani & Borghi (2021)	33	Are environmental-related online reviews more helpful?	Used Negative Binomial regression model
Horng *et al.*, (2023)	29	Modelling competitive advantage using the concepts of BD and social media to develop a sustainability strategy	Online survey methodology and tests for nonresponse bias

3. Results and Discussion

3.1. Overall performance

Considering the years identified in the sample, the study of the main technological drivers of sustainability in hotels began in 2016 with the publication on the use of "Big Data" to improve energy efficiency in the hotel sector. Publications have increased over the years, reaching their peak in 2023, with 15 articles (see Figure 1):

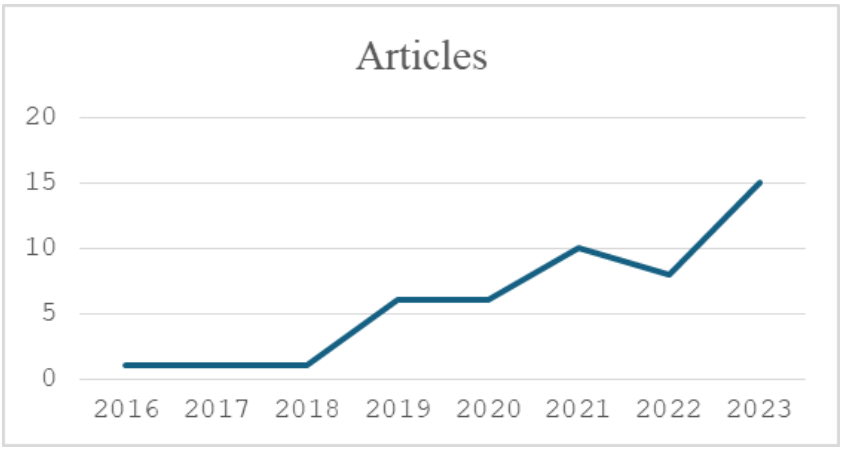

Figure I. *Annual Scientific Production*

Regarding the most relevant authors, there are five authors with four publications: Chou, S.; Horng, J.; Kim, H.; Lieu, Z. and Yu, T., some of which were co-authored works.

Table 2. *The most relevant sources*

Sources	Number of Publications
Sustainability	9
International journal of contemporary hospitality management	3
Journal of hospitality and tourism insights	2
African journal of hospitality, tourism and leisure	1
Buildings	1
Buildings and cities	1
Computers and industrial engineering	1
Cornell hospitality quarterly	1
Cornell law review	1
Current issues in tourism	1

Key Applications of Technology and Their Relationship to Sustainability

The evolution of smart hospitality is closely linked to technological advancements and the growing emphasis on customer-centric approaches. Smart hospitality is based on various factors that improve guest experience, operational efficiency, and stakeholder engagement. These factors, taken together, aim to generate value for all participants, ensuring a sustainable and innovative hospitality ecosystem (Buhalis, 2023).

The main drivers are related to understanding consumer needs and the ability of technologies such as AI and machine learning to create services and experiences based on each guest's profile and preferences.

Furthermore, smart hospitality leverages advanced technologies and interconnected systems to create agile business ecosystems within connected destinations. Key elements of these ecosystems relate to various aspects: "Interconnectivity and interoperability," where smart hospitality integrates diverse systems, enabling a seamless exchange of data among stakeholders (Buhalis, 2020). This interoperability facilitates collaboration and real-time decision-making across the entire hospitality ecosystem; “Utilization of business data” (BD), since by leveraging business data, stakeholders can gain insights into customer behavior, preferences, and market trends. This information supports strategic planning and dynamic adjustments to services and offerings (Buhalis, 2023); “Ambient intelligence (AmI),” where the implementation of AmI creates an interactive environment that enables real-time interactions and enhances the guest experience. It facilitates the delivery of personalized services through interconnected devices (Buhalis, 2020); “Dynamic process reengineering,” as smart hospitality encourages the reengineering of operational processes to improve flexibility and responsiveness. This enables the co-creation of personalized experiences tailored to the needs of each guest (Buhalis, 2020). “Sustainability and CSR,” where a focus on sustainable practices and corporate social responsibility fosters customer loyalty and enhances the reputation of hotel organizations. Participating in green initiatives is increasingly important for attracting guests (Buhalis, 2023; Han et al., 2018; Han et al., 2019); “Smart Connectivity,” as the establishment of smart networks allows hotels to connect with local communities and share relevant information, such as cultural events and dining options, enriching the guest experience (Buhalis, 2023); “IoT Integration,” where IoT plays a crucial role in smart hospitality by connecting diverse assets and processes, enabling efficient management and real-time, data-driven operational decision-making; and “Operational Agility,” as agility is vital for responding to market changes and customer expectations. It allows hotel organizations to innovate rapidly and adapt to emerging trends and technologies. “Collaboration among stakeholders,” because smart hospitality fosters collaboration among the various participants in the ecosystem, improving the overall value chain and ensuring that each stakeholder benefits from shared resources and information; “Enhanced guest experiences,” by integrating technology into service delivery, smart hospitality improves the overall guest experience, making it more memorable and personalized (Buhalis, 2023).

In their research, Horng et al. (2023) highlighted the role of technology in hotels' commitment to sustainable practices. The authors noted that technology helps hotels identify sustainability commitments that align with customer preferences, such as eco-friendly practices and products. By leveraging business data analytics (BD), hotels can enhance their service offerings and marketing strategies, giving them a competitive edge. They also utilize social media platforms to engage with customers and gather feedback on sustainability initiatives. This interaction not only helps hotels understand consumer preferences but also allows them to effectively communicate their sustainability

efforts. Integrating social media with business data analytics improves the ability to predict customer behavior and preferences regarding sustainable practices. Recognizing the importance of integrating sustainable practices into their hotels led the Marketing department to adopt strategies that promote their sustainability efforts and commitments to attract environmentally conscious consumers. This approach not only enhances brand image but also fosters customer loyalty and repeat visits. Database data analysis is also used to optimize food services by analyzing customer preferences and minimizing food waste. This includes offering dishes that appeal to customers and integrating sustainable practices into food sourcing and preparation. These initiatives not only improve customer satisfaction but also contribute to sustainability goals.

Online review analysis has been the subject of numerous studies (Kim & Kim, 2022; Mariani & Borghi, 2020; Marine-Roig, 2019; Nilashi, 2019; Serrano et al., 2020) because it allows for understanding user opinions and, consequently, improving service quality and customer satisfaction. By analyzing recurring themes in online reviews, hotels can identify which attributes (such as service quality, dining experience, and cleanliness) are most important to guests. Reviews often include specific mentions of service experiences, both positive and negative. Hotels can use this feedback to train staff, improve service protocols, and address specific complaints, resulting in a more satisfying guest experience that can be marketed as a differentiator from the competition. By effectively leveraging the information gleaned from online reviews, hotels can enhance their service offerings, develop effective marketing messages, and foster stronger relationships with both prospective and returning guests (Mariani & Borghi, 2020; Pencarelli, 2020; Serrano et al., 2020).

3.2. Benefits of Integrating Technologies for More Sustainable Practices

Smart hospitality has a significant impact on various stakeholders in the sector, including hotels, consumers, suppliers, and destination management organizations (DMOs).

Regarding the benefits for hotels, these include increased efficiency, as technologies simplify operations, resulting in reduced costs and improved service delivery; greater customer satisfaction, since by leveraging technology for personalized experiences (Pencarelli, 2020), hotels can better meet guest expectations; access to real-time data allows for optimized marketing strategies and improved customer profiles, which in turn enhances segmentation and revenue management; improved operational management, as technologies enable comprehensive control, from inventory to customer service; the implementation of sustainable practices; and more effective collaboration with local businesses and communities, fostering partnerships that enhance the guest experience. Technologies also benefit guests, allowing them to create personalized experiences by recording their individual preferences, thus improving their overall experience. Access to real-time information means guests can receive up-to-date information on local events, traffic conditions, and booking availability, enabling them to make informed decisions about their travel and accommodations. Another benefit lies in technologies such as mobile apps and IoT devices, which offer seamless interactions and services, facilitating travel. At the supplier level, these technologies promote greater interconnection, enabling real-time updates and efficient supply chain management, as well as the exchange of data on demand forecasts and inventory levels, allowing them to optimize their operations. Furthermore, intelligent systems enable suppliers to respond quickly to changes in market conditions and customer needs.

For Destination Management Organizations (DMOs), technology can be a great help, as by optimizing resources and integrating data from diverse sources, DMOs can better manage tourism resources and balance supply and demand. Furthermore, technology plays a crucial role in crisis management, since smart systems can assist DMOs in risk analysis and dynamic response to potential crises, thus increasing the destination's resilience. On the other hand, smart technologies are fundamental in the current context of intense debate surrounding data privacy and security. Smart hospitality creates a transformative environment for industry stakeholders, promoting efficiency, sustainability, and an improved guest experience. However, challenges such as data privacy and the need for coherent technological integration must be addressed to fully realize these benefits (Buhalis, 2023; Pencarelli, 2020).

Similarly, Horng et al. (2023) highlighted the role of technology in tourism and hospitality. According to these authors, data analytics is essential for analyzing large volumes of data and generating information that improves decision-making, optimizes service offerings, and identifies market opportunities. Data analytics (DA) is especially valuable for developing analytical capabilities that help organizations adapt to consumer needs and the changing dynamics of the market (Del Vecchio et al.,

2020). Furthermore, social media platforms are used for communication and collaboration with customers, playing a crucial role in marketing strategies and allowing hotels to interact with guests, obtain feedback, and promote sustainability initiatives (Fidel et al., 2016). Integrating social media with data analytics enhances the ability to analyze customer preferences and behaviors.

Data analytics (DA) also enables hotel managers to make informed decisions based on customer insights and market trends, ultimately leading to a greater competitive advantage (Nilashi et al., 2019). The increasing focus on sustainability issues compels hotel managers to concentrate on these trends, which, through data analytics, allows businesses to identify sustainability commitments that align with customer needs (Liu and Dong, 2021). Nilashi et al. (2019) reinforced the idea that using machine learning techniques to analyze large volumes of social data in eco-friendly hotels to gain insights into and segment customers is crucial. In their findings, they demonstrated that green initiatives lead to increased customer satisfaction. Similarly, Nilashi et al. (2019b), in another study, highlighted that online reviews and word of mouth significantly influence travelers' decisions when choosing eco-friendly hotels, as they constitute an important source of information. The implications of online reviews for promoting eco-friendly hotels include influencing travelers' booking decisions and increasing the visibility of environmentally friendly practices. Hoteliers can use social media to identify important eco-friendly features that attract visitors by analyzing user-generated content and online reviews. This data can help personalize hotel offerings and improve the accuracy of recommendation systems, aligning them with travelers' sustainability preferences. Furthermore, social media platforms can be leveraged to effectively communicate eco-friendly practices, increasing customer engagement and attracting environmentally conscious guests.

Social media and online reviews play a vital role in promoting eco-friendly practices in the hotel industry, serving as platforms for sharing information about sustainable initiatives and attracting environmentally conscious guests. They facilitate electronic word-of-mouth (e-WOM), which influences travelers' booking decisions and increases the visibility of eco-friendly hotels. These platforms also allow hotels to interact with customers, gather feedback, and adapt their services to meet the growing demand for sustainability. The authors noted that ANFIS plays a crucial role in the hotel recommendation system by generating membership functions and fuzzy rules to predict travelers' preferences for eco-friendly hotels. It is used to build predictive models that evaluate overall ratings based on user preferences, thus improving the accuracy of recommendations.

Kim y Kim (2022) identificaron que las tecnologías también desempeñan un papel esencial en la comodidad y seguridad del cliente. Con la pandemia de COVID-19, la tecnología ha permitido a los hoteles ofrecer a sus clientes un servicio seguro y sin contacto mediante el uso de aplicaciones móviles y robots, por ejemplo. En su investigación, Marine-Roig (2019) señaló que el análisis del contenido generado por los viajeros en diferentes redes sociales también puede ayudar a medir la imagen de los destinos turísticos (IDT), lo que permite realizar comparaciones y obtener información sobre las percepciones de los visitantes. Esta información es valiosa para las organizaciones de gestión de destinos (OGD) para mejorar la sostenibilidad y la gestión de recursos a partir de la retroalimentación de los visitantes. Además, los gerentes de hoteles y restaurantes pueden aprovechar estas métricas para evaluar su desempeño en comparación con establecimientos similares y tomar decisiones estratégicas.

El estudio de Pencarelli (2020) resume los numerosos beneficios del uso de la tecnología en el sector turístico y hotelero. Se destaca su papel en la mejora de la experiencia del cliente mediante la personalización de servicios, basada en las preferencias individuales y el comportamiento del cliente, recomendando actividades, alojamiento, entre otros, y brindando acceso a información en tiempo real a través de aplicaciones móviles e IoT. Asimismo, se mejora la eficiencia operativa mediante la automatización. Tecnologías como chatbots y sistemas robóticos agilizan las operaciones en hoteles, restaurantes y servicios de transporte, reduciendo los tiempos de espera y mejorando la prestación del servicio. Esta automatización permite al personal centrarse en interacciones más complejas con los clientes y en la toma de decisiones basada en el negocio.

El turismo inteligente hace hincapié en el uso de tecnologías para promover la sostenibilidad, como la optimización del consumo de energía y agua, la gestión de residuos y la mejora de las soluciones de movilidad. Esto contribuye a reducir el impacto ambiental del turismo. En cuanto a la seguridad y la protección, las tecnologías son una ventaja ante el creciente uso de plataformas digitales, ya que permiten la implementación de protocolos de seguridad robustos que garantizan la protección de los

datos y las transacciones de los clientes. Pencarelli (2020) también destacó el papel de la realidad aumentada y la realidad virtual, que permiten a los potenciales viajeros experimentar los destinos virtualmente antes de decidirse, lo que mejora las estrategias de marketing e incrementa las tasas de conversión.

4. Conclusions

Regarding the specific objective of using cutting-edge technology to improve sustainability in the hotel sector, 48 academic articles were compiled. The most cited work was by Pencarelli (2020), with 215 citations. Publications on the topic began in 2016, reaching their peak annual number of publications in 2023, with 16. The journal with the highest number of related articles was Sustainability. The main keyword is sustainable development, and the predominant themes include artificial intelligence, eco-friendly hotels, COVID-19, and hospitality and satisfaction.

The identification of technologies that improve sustainability in hotels reveals that the main catalysts are associated with Industry 4.0 technologies, such as artificial intelligence, machine learning, agile business ecosystems, database utilization, ambient intelligence, dynamic process reengineering, corporate social responsibility, smart connectivity, and the integration of the Internet of Things. These technologies streamline operations, foster greater collaboration among stakeholders, enhance the guest experience, and promote sustainable development, with the ultimate goal of improving the conditions that hotels offer their customers, adding value that enriches the consumer experience and raises the quality of life for residents.

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