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Navigating overtourism destinations: Leveraging smart tourism solutions for sustainable travel experience

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Abstract: This paper explores the integration of artificial intelligence (AI) and smart tourism technologies to address the multifaceted challenges of overtourism in tourist destinations. Overtourism leads to significant environmental degradation, strains local resources, and diminishes visitor satisfaction, ultimately threatening the sustainability of these destinations. Destinations can enhance sustainability and tailor travel experiences by utilizing cutting-edge technologies like the Internet of Things (IoT), augmented reality (AR), virtual reality (VR), and big data analytics. These technologies offer innovative solutions to optimize resource use, enhance visitor engagement, and promote responsible tourism practices. The study underscores the potential of smart tourism technologies to manage tourist flows, reduce environmental impacts, and improve the overall quality of life for local communities. Strategic planning, substantial investment, and collaboration among various stakeholders, including government agencies, local communities, and the private sector, are essential for the successful implementation of these solutions. The findings highlight the critical role of technological innovation in fostering a balanced and sustainable future for tourism, ensuring that destinations can thrive economically while preserving their cultural and natural heritage. This research provides valuable insights for policymakers and tourism managers aiming to mitigate the adverse effects of overtourism through the adoption of AI and smart tourism technologies.

Keywords: smart tourism; artificial intelligence; internet of things; augmented reality; virtual reality; big data analytics; overtourism; sustainable tourism

1. Introduction

Tourism, one of the world's largest and fastest-growing industries, has seen unprecedented growth over the past few decades [1]. With advancements in technology, the ease of global travel, and the increasing affordability of airfare, more people are exploring the world than ever before [2]. This surge in tourism has significantly benefited many economies by providing jobs, fostering cultural exchange, and contributing to infrastructure development [3]. However, this growth has also led to a phenomenon known as overtourism [4], which poses significant challenges to popular tourist destinations. Overtourism results in overcrowding, environmental damage, strained local resources, and a decline in the overall quality of the tourist experience [5]. Addressing this issue requires innovative solutions to ensure the long-term viability of tourism and the preservation of treasured destinations. Overtourism not only affects the immediate environment of destinations but also threatens their long-term sustainability, jeopardizing the natural and cultural heritage that attracts visitors in the first place. As a result, finding effective strategies to combat overtourism has become a crucial issue for tourism stakeholders worldwide.

Overtourism describes the overwhelming number of visitors to a specific location [6], resulting in crowding, pressure on local facilities, environmental harm, and a

reduced quality of life for local residents [7–9]. Additionally, overcrowding compromises cultural heritage sites and diminishes the authenticity of local experiences for both visitors and residents [10]. This issue is particularly pronounced in iconic destinations such as Venice, Barcelona, and Bali, where the number of visitors often exceeds the capacity of the local environment and infrastructure [11]. The negative impacts of overtourism are multifaceted, affecting the physical and social environment and leading to a decline in visitor satisfaction and a tarnished reputation for the destination [12,13]. With tourism being a key economic driver for many regions, these challenges highlight the pressing need for solutions that balance tourism growth with sustainable destination management.

In response to these challenges, the concept of smart tourism has emerged as a promising solution. Smart tourism leverages advanced technologies such as artificial intelligence (AI), the Internet of Things (IoT), augmented reality (AR), virtual reality (VR), and big data [14] to create more efficient, sustainable, and personalized travel experiences. By harnessing these technologies, destinations can better manage tourist flows, optimize resources, enhance visitor engagement, and ultimately create more sustainable tourism practices. Smart tourism technologies have played a pivotal role in mitigating the adverse effects of overtourism in various destinations. For instance, the city of Amsterdam has successfully implemented a real-time visitor management system that uses data analytics to monitor and manage tourist flows, thereby reducing overcrowding in popular areas like the Red Light District and the Anne Frank House [15]. By redirecting tourists to less crowded locations and offering personalized recommendations, the city has not only improved the visitor experience but also alleviated pressure on overburdened sites. Similarly, Barcelona has employed big data and Internet of Things (IoT) technologies to manage visitor numbers at iconic landmarks such as the Sagrada Familia. This has helped balance the distribution of tourists across the city, preserving the quality of life for residents and protecting the local environment [16]. These examples illustrate how smart technologies can be leveraged to address overtourism effectively, providing empirical evidence that supports the integration of these tools into sustainable tourism strategies. On a socio-economic level, destinations like Dubrovnik have witnessed a sharp rise in property prices and living costs, driven by the influx of short-term rentals catering to tourists [17]. To counteract these effects, the city has introduced regulatory frameworks supported by data-driven insights to balance tourism growth with residents' quality of life [9]. This demonstrates that smart tourism technologies not only mitigate environmental impacts but also contribute to protecting local communities from the socio-economic consequences of overtourism.

This paper explores the role of smart tourism technologies in crafting sustainable experiences for overtouristed destinations. As the future of travel unfolds, it is crucial to harness technological advancements to manage visitor flow, personalize experiences, and promote responsible tourism practices. Thus, this paper aims to provide an overview of how advanced technologies can be utilized to address the challenges posed by overtourism and promote sustainable tourism practices.

2. The future of travel

The future of travel is poised to be shaped by a confluence of technological advancements, changing consumer preferences, a growing emphasis on sustainability, and evolving socio-economic conditions. The environmental and socio-economic impacts of overtourism are well documented in the literature [18], highlighting the urgency of implementing smart tourism solutions. Several key trends are shaping the travel landscape.

2.1. Digital transformation in tourism

One of the most significant trends shaping the future of travel is the digital transformation of the tourism industry. Technologies such as artificial intelligence (AI), the Internet of Things (IoT), augmented reality (AR), virtual reality (VR), and big data analytics are revolutionizing how travel experiences are created, marketed, and consumed [14]. These technologies enable personalized travel experiences, real-time information dissemination, and enhanced engagement with destinations [19–21].

2.2. Information and communication technologies

Smart tourism involves integrating Information and Communication Technologies (ICTs) with tourism experiences to enhance resource efficiency, improve visitor experiences, and ensure sustainable development [22,23]. This concept includes smart destinations using IoT to monitor and manage tourist flows and mobile apps providing real-time information and personalized recommendations [24]. Smart destinations utilize data from sensors, social media, and mobile devices to gain insights into tourist behavior and preferences. This data-driven approach allows destinations to optimize offerings, manage crowding, and enhance visitor satisfaction.

2.3. Sustainable tourism practices

Environmental and social responsibility are becoming core values for travelers [25,26]. As awareness of environmental issues grows, sustainable tourism is becoming a priority for both travelers and industry stakeholders [27]. The future of travel will increasingly focus on minimizing the negative impacts of tourism on the environment and local communities. Sustainable practices include promoting eco-friendly accommodations, reducing carbon footprints through responsible travel choices, and supporting local economies [28]. Travelers are becoming more conscious of their environmental impact and are seeking destinations and services that align with their values.

2.4. Experiential and authentic travel

Contemporary travelers are increasingly looking for genuine and immersive experiences that extend beyond typical sightseeing. The future of travel is expected to feature a growth in experiential tourism, where individuals interact more profoundly with local cultures, traditions, and ways of life [29]. Experiential travel includes activities such as culinary tours, cultural workshops, adventure travel, and volunteer tourism [30]. These experiences allow travelers to interact with local communities, learn new skills, and contribute to preserving cultural heritage. Destinations offering

unique and authentic experiences are likely to attract more visitors and create stronger emotional bonds with them.

2.5. Travel safety, wellness, and health

In the wake of global events such as the COVID-19 pandemic, ensuring traveler safety has become a paramount concern. The future of travel will see increased use of technology to enhance safety and security measures. Contactless technologies, such as digital check-ins, mobile payments, and biometric identification, are being adopted to reduce physical interactions and minimize contagion risks [31]. Health monitoring technologies, such as wearable devices and health apps, can track travelers' health status and provide real-time alerts in emergencies. Moreover, the demand for wellness and health tourism is expected to grow significantly. Travelers increasingly seek destinations and experiences that promote physical, mental, and emotional well-being [32]. Wellness tourism includes activities such as spa treatments, yoga retreats, meditation sessions, and holistic health practices. Health tourism, involving travel for medical treatments and procedures, is also on the rise.

2.6. Customization and personalization

Personalization will continue to be a key driver of the travel industry. Travelers increasingly seek bespoke experiences tailored to their interests, preferences, and travel styles. Advances in data analytics enable travel companies to offer highly personalized services, from tailored itineraries to bespoke recommendations [33]. Machine learning algorithms analyze vast amounts of data, including past travel behavior, social media activity, and real-time feedback, to understand travelers' preferences and predict their future needs [34]. This allows travel companies to provide targeted offers, personalized content, and customized experiences that enhance customer satisfaction and loyalty.

2.7. The sharing economy

The sharing economy, characterized by peer-to-peer services such as Airbnb and Uber, has already disrupted the traditional travel industry and will continue to play a significant role in its future [35]. The sharing economy provides travelers with more diverse and flexible options for accommodation, transportation, and experiences. Platforms that facilitate the sharing of resources allow travelers to access unique and often more affordable options while enabling local residents to benefit economically from tourism [36]. The rise of the sharing economy contributes to the decentralization of tourism as travelers explore less-visited areas and engage with local communities more meaningfully.

2.8. Social media and influencers

Social media continues to play a pivotal role in shaping travel trends and influencing traveler behavior. Platforms like Instagram, Facebook, and TikTok allow travelers to share their experiences, discover new destinations, and connect with like-minded individuals [37]. Influencers with large followings and the ability to sway public opinion are increasingly important in the travel industry. Destinations and

tourism providers leverage social media and influencer partnerships to reach a broader audience and create engaging content [38]. By showcasing unique experiences and hidden gems, influencers can drive interest in lesser-known destinations and contribute to more balanced tourism distribution.

2.9. Bleisure travel

The lines between business and leisure travel continue to blur, with travelers seeking destinations that offer opportunities for work and well-being, with co-working spaces and wellness amenities becoming standard features. This emerging trend, known as "bleisure" travel, combines business and leisure activities, allowing professionals to seamlessly integrate work commitments with leisure experiences [39]. Destinations that cater to bleisure travelers are enhancing their offerings to meet the demands of this growing market. Bleisure travel presents significant opportunities for destinations to boost their tourism economies by extending the duration of stays and increasing spending.

3. Smart tourism strategies for combating overtourism

The potential of AI and smart tourism technologies lies not just in enhancing travel experiences but also in mitigating the negative impacts of overtourism. Smart tourism strategies leverage advanced technologies to address the challenges of overtourism, enhance visitor experiences, and promote sustainable practices [40]. Concrete examples of how smart tourism technologies are being implemented can significantly illustrate their potential to manage overtourism effectively. For instance, in Florence, Italy, IoT technology has been utilized to monitor and control tourist flows in real time. The city has installed sensors throughout popular areas like the Uffizi Gallery and the historic city center [41], which gather data on visitor numbers and movement patterns. This information is then used to manage crowd density, offering tourists alternative routes or suggesting visits to less crowded attractions via mobile apps. Such applications not only improve the overall visitor experience but also help protect Florence's fragile historical sites from the wear and tear caused by excessive foot traffic. Another notable example is the use of augmented reality (AR) and virtual reality (VR) to enhance visitor engagement while reducing physical impacts on sensitive locations. The UNESCO World Heritage site of Petra, Jordan, has introduced AR/VR experiences that allow tourists to explore the ancient city virtually, offering immersive historical narratives without necessitating physical access to its most vulnerable areas [42]. By integrating these advanced technologies, destinations can mitigate the detrimental effects of overtourism while providing enriching, sustainable visitor experiences. This section explores how smart tourism can mitigate overtourism through innovative solutions.

3.1. AI Solutions for overtourism

Artificial intelligence (AI) offers numerous solutions to manage and mitigate the impacts of overtourism. AI-powered predictive analytics can help manage tourist flows by analyzing historical data, weather patterns, and event schedules to predict visitor numbers, allowing destinations to prepare for peak times and manage resources

efficiently [43]. AI can also predict crowd movements and suggest alternative routes or times for visiting popular attractions, helping to distribute visitors more evenly and reduce congestion [44]. AI enhances visitor experiences through personalized recommendations, creating customized itineraries based on visitors' preferences, interests, and past behavior [45,46]. This ensures unique and fulfilling experiences without overwhelming popular sites. AI-driven dynamic pricing strategies can encourage off-peak travel by modifying prices according to demand, thereby effectively controlling visitor traffic and alleviating congestion during peak times [47]. AI also helps optimize resource management in tourism destinations by monitoring and managing energy and water usage in hotels, attractions, and public facilities, reducing waste, and ensuring resources are used efficiently [48]. AI-powered waste management systems optimize waste collection and recycling processes, reducing environmental impact and maintaining cleanliness. These AI-driven solutions support the creation of smart, sustainable tourism strategies that balance economic growth with environmental preservation.

3.2. IoT solutions for overtourism

The Internet of Things (IoT) offers numerous solutions to manage and mitigate the impacts of overtourism by enhancing operational efficiency and visitor experience [49]. Real-time data collection from IoT devices allows for effective visitor tracking and environmental monitoring, enabling destinations to adjust in real-time to manage crowds and maintain a healthy environment. IoT sensors monitor air quality, noise levels, and water quality, addressing pollution issues promptly. IoT enhances tourism infrastructure through smart transportation systems that optimize traffic flow, reduce congestion, and provide real-time updates on public transport schedules [50]. Smart lighting and energy systems adjust usage based on occupancy and natural light, reducing energy consumption and operational costs. Visitor engagement is improved through IoT-enabled smart guides and interactive displays that provide real-time information about attractions, directions, and points of interest. These tools enhance the visitor experience by offering engaging and informative content [51]. IoT significantly boosts safety and security in tourism destinations with emergency response systems and surveillance monitoring. IoT devices can detect emergencies and trigger immediate alerts, ensuring prompt response and enhancing safety. IoT-enabled surveillance systems monitor crowded areas and tourist hotspots, preventing crime [52].

3.3. Augmented adventures

Augmented reality (AR) technology overlays digital information onto the real world, offering immersive and interactive experiences for tourists and addressing overtourism by distributing visitor engagement more evenly across destinations [53]. AR apps use smartphone cameras to integrate text, 3D models, videos, and animations, creating a layered experience where physical and virtual elements coexist. AR enhances the experiences of tourists by offering real-time details about landmarks, historical locations, and attractions. This technology aids in evenly distributing visitors and alleviating crowding at popular destinations. AR also creates virtual tours that

guide tourists through museums, parks, and cities, offering engaging and educational 3D models, animations, and audio commentary, which can direct tourists to less-visited areas. AR-based scavenger hunts and games make sightseeing interactive and fun, encouraging exploration of lesser-known areas and alleviating pressure on crowded spots [33]. AR improves accessibility for all tourists, including those with disabilities. AR apps provide real-time translation of signs, menus, and informational plaques, breaking down language barriers and guiding tourists efficiently, which helps in better managing tourist movement and reducing overcrowding.

3.4. Virtual realities in tourism

Virtual reality (VR) is a transformative technology in tourism, offering immersive experiences that transport users to different places and times. By immersing users in a computer-generated environment, VR allows them to experience destinations virtually before visiting, creating a 360-degree view that makes users feel physically present in the virtual world [54]. This technology plays a significant role in managing overtourism by providing alternatives to physical travel and distributing tourist interest more evenly across various locations [55]. VR offers engaging virtual tours and experiences, enabling users to discover destinations, hotels, and attractions from the comfort of their homes. Users can move through these tours at their own speed, obtaining a realistic feel for the surroundings and making well-informed choices about accommodations, sights to visit, and itinerary planning. This can help reduce the pressure on popular tourist spots by encouraging visits to less crowded areas [56]. VR makes tourism experiences more accessible and inclusive, providing travel experiences for those who cannot travel physically due to disabilities, financial constraints, or other limitations. Users can visit distant places and experience different cultures from the comfort of their homes. VR can offer language translation and sensory assistance, making travel experiences more accessible to a diverse audience. VR is also a powerful marketing tool for the tourism industry. Tourism boards and companies use VR in marketing campaigns to showcase destinations and attractions, sharing VR experiences online, at travel expos, and in promotional events to attract potential visitors. Hotels, resorts, and tour operators use VR to enhance their online presence, engaging users with immersive glimpses of what they can expect, which can help promote lesser-known destinations and alleviate the burden on overcrowded tourist spots [57].

3.5. Big data in tourism

Big data is pivotal in addressing overtourism by providing insights that help manage tourist behavior and optimize experiences [58]. Analyzing vast datasets from online bookings, social media, and mobile apps reveals tourist preferences and travel patterns, enabling destinations to develop targeted marketing campaigns that promote off-season travel and less crowded areas. Big Data supports sustainable tourism by tracking environmental impacts and informing policies for waste management, energy efficiency, and resource conservation [59]. Real-time data on visitor numbers and patterns helps prevent overcrowding, preserving the visitor experience, and protecting local communities and environments. Predictive analytics derived from big data can

forecast demand and identify potential overtourism risks, allowing destinations to implement dynamic pricing models, capacity controls, and other preventative measures [60]. This data-driven approach ensures that tourism growth is managed sustainably, benefiting both travelers and local communities.

4. Conclusion

Overtourism presents challenges such as environmental degradation, infrastructure overload, and negative social impacts. High volumes of tourists strain resources, contribute to pollution, and disrupt ecosystems. Tackling these challenges necessitates the adoption of sustainable tourism practices, effective capacity management, community involvement, regulatory measures, and technological innovations. This paper has extensively explored how smart tourism technologies can be utilized to combat the urgent problem of overtourism. The advent of technologies such as artificial intelligence (AI), the Internet of Things (IoT), augmented reality (AR), virtual reality (VR), and big data analytics presents innovative solutions for creating more sustainable and personalized travel experiences. The literature has shown that these technologies have significant potential in managing tourist flows, optimizing resource use, enhancing visitor engagement, and promoting responsible tourism practices. However, it is crucial to recognize that while these technologies offer potential solutions, they must be implemented with careful consideration of local contexts, governance structures, and stakeholder engagement. The integration of AI, IoT, AR, VR, and Big Data requires strategic planning, investment, and collaboration among stakeholders, including local governments, tourism operators, and communities, to ensure their effectiveness in mitigating overtourism and fostering sustainable tourism practices. By adopting these technologies, tourism destinations can address overtourism challenges, ensuring a balanced and sustainable future for both residents and visitors. **Table 1** provides a visual summary of the technologies discussed in this paper and their application in managing overtourism.

Table 1. Smart tourism technologies and their role in mitigating overtourism.

Technology	Application	Impact on Overtourism	Case Study/Example
Artificial Intelligence (AI)	Predictive analytics, visitor flow management, personalized recommendations	Distributes tourist flow, reduces congestion in popular areas	Barcelona uses AI-driven data to manage visitor flows at landmarks like the Sagrada Familia.
Internet of Things (IoT)	Real-time monitoring of visitor numbers, environmental sensors	Reduces overcrowding, maintains environmental quality	Florence employs IoT sensors to monitor and manage tourist density in historical areas.
Augmented Reality (AR)	Interactive guides, virtual tours for historical sites	Provides immersive experiences without physical impact on sites	Petra, Jordan uses AR to allow virtual exploration, minimizing foot traffic.
Virtual Reality (VR)	Virtual travel experiences, educational tours	Alleviates pressure on fragile destinations by offering virtual alternatives	UNESCO sites offer VR tours to reduce physical strain on historical landmarks.
Big Data	Data analytics on visitor behavior, resource usage management	Helps in forecasting tourist numbers and optimizing resource allocation	Amsterdam utilizes Big Data to monitor tourist behaviors and improve resource management.

4.1. Practical implications

Successfully implementing smart tourism solutions demands strategic planning, investment, and robust collaboration among diverse stakeholders, including governments, tourism authorities, private sector entities, and local communities. Governments must take the lead by developing comprehensive policies that support smart tourism initiatives. This involves creating regulatory frameworks that address emerging technologies such as AI, IoT, AR, VR, and big data while offering incentives to encourage widespread adoption. For instance, the collaboration between Amsterdam and Airbnb to manage tourist accommodations through data sharing and strict regulations provides a successful model of how public-private partnerships can address overtourism challenges.

Investing in both technological and sustainable infrastructure is vital for enhancing visitor experiences and minimizing environmental impacts. This includes the development of high-speed internet, IoT networks, energy-efficient buildings, and smart transportation systems. The case of Singapore, which has integrated IoT-enabled smart transportation and energy-efficient systems into its urban planning, serves as an exemplary model for other destinations. Moreover, infrastructure investments should be adaptable to local contexts to ensure long-term success.

Collaboration among stakeholders is essential for driving innovation and ensuring that smart tourism solutions are both practical and beneficial. Public-private partnerships, such as the collaboration between Barcelona's tourism authorities and technology firms to manage visitor flows and enhance tourist experiences through real-time data, showcase the potential of such alliances. International cooperation and the sharing of best practices among global tourism bodies can further facilitate the successful implementation of these strategies. Involving local communities in these collaborations ensures that solutions are inclusive and socially responsible.

Additionally, training and education are critical components of effective smart tourism implementation. Developing targeted training programs for tourism professionals on the use of these technologies and educating visitors on the benefits and responsible use of smart tourism applications can significantly enhance tourist experiences and promote sustainable behavior. Furthermore, adopting smart tourism solutions should be aligned with sustainable practices. Leveraging technology to monitor and mitigate environmental impacts while respecting cultural heritage is crucial for ensuring long-term sustainability. The collaboration between UNESCO and local authorities in Dubrovnik to manage visitor numbers using smart tourism technologies while preserving the cultural integrity of the city provides a practical example of aligning technology with sustainability goals.

4.2. Future avenues

The field of smart tourism is rapidly evolving, with emerging technologies like blockchain, advanced AI applications, and hyper-reality (XR) poised to reshape the industry. Blockchain technology offers promising avenues for enhancing transparency and trust in tourism services through secure data exchange and decentralized booking systems. However, future research could explore the potential of blockchain in mitigating overtourism by enabling more equitable distribution of tourism benefits and

fostering community-based tourism models. Advanced AI applications, such as intelligent chatbots with natural language processing and personalized itinerary creation tools, have the potential to significantly enhance the travel experience [61]. Yet, there is a need for further research on how AI can be leveraged to promote sustainable tourism practices, particularly in managing tourist flows and reducing the environmental footprint of travel.

The integration of VR, AR, and mixed reality (MR) into the tourism sector can create hyper-realistic experiences, opening up new possibilities for tourism education and destination exploration. Future studies could focus on assessing the long-term impacts of these immersive technologies on visitor behavior and their potential to alleviate physical strain on popular tourist sites by offering virtual alternatives. Additionally, there are gaps in understanding the socio-economic impacts of these emerging technologies on local communities, particularly in developing regions. Research could investigate how smart tourism solutions can be adapted to support inclusive and equitable tourism development. Methodologically, longitudinal studies and mixed-method approaches that combine quantitative data with qualitative insights would be valuable in capturing the dynamic and multi-faceted nature of smart tourism and its implications for sustainability. Exploring these areas is essential for developing a sustainable and responsible future for tourism, paving the way for innovative solutions to address overtourism challenges while fostering long-term resilience in the industry.

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