



Title: Smart Tourism Spaces – Integrating Technology and Sustainability in Urban Destinations

Student Name: Deepak Chand Ramola

Student ID: DE240295

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Abstract

The matter of urban tourism destinations has never explored such challenges in the quest to balance visitor satisfaction, the environment, and well-being of the community. This paper discusses the ways in which the smart city technologies, such as Internet of things (IoT), Artificial intelligence (AI), and digital twins, can be used to establish sustainable tourism spaces within the city. Based on the case studies of Barcelona, Singapore, and Amsterdam, the study indicates that data-based solutions to managing visitor flows, resources, and waste reduction can contribute greatly to the sustainability of destinations. The results indicate that effective implementation of smart tourism needs integrated technological infrastructure, cross-stakeholder cooperation and dynamic governance systems. The recommendations are offered as to how the resource-constrained cities can consider adopting the scalable, cost-effective solutions that make use of open-source platforms and implementation plans that are gradual in nature. This study will help in planning sustainable tourism because it will show that technology can be used as a facilitator of environmental conservation, economic effectiveness and social justice in urban destinations.

1. Introduction

1.1 Background and Context

The growth of urban tourism has been exponential over the last 20 years, and it has increased to 1.5 billion international tourists before the COVID-19 pandemic, which occurred in 2019. This expansion has brought huge economic gains but has also brought on great environmental and social strains to city destinations. Such problems include overtourism, resource exhaustion, creation of waste, and commodification of cultures that pose a threat to the sustainability of the popular cities in the long-term.

Smart tourism became a solution to these issues in an attempt to use digital technologies to improve the experience of visitors, as well as sustainable destination management. Smart tourism spaces combine both physical and digital layers of infrastructure to build an environment in which data-driven environments allow adaptive management of visitor numbers, resource use, and to assess the impact on the environment.

1.2 Research Problem

City destinations have conflicting goals: increasing tourism rates, conserving the quality of the environment, sustaining the quality of life of the residents, and guaranteeing cultural genuineness. The conventional management methods are usually not sufficient to handle the complexities and dynamism of urban tourism systems. The question that is critical to this research is as follows:

How can smart city technologies be strategically implemented to develop sustainable tourism spaces in urban destinations?

1.3 Research Objectives

This study aims to:

- Review the theoretical basis of smart tourism and sustainable spatial planning.
- Examine the ways IoT, AI, and digital twins can be used to achieve sustainable visitor management.
- Evaluating the waste, transport, and energy systems optimization using data analytics.
- Consider the implementation strategies by analysing the example cities of smart tourism.
- Design viable solutions to what is affordable in the developing cities.

1.4 Significance of the Study

This study is relevant in the context of planning sustainable tourism by filling the gap between the technological ability and the actual practice. It offers practical information to destination managers, urban planners, and policymakers interested in using technology to attain sustainability performance and dealing with the distinctive limitations of developing cities with limited financial resources.

2. Literature Review

2.1 The Smart Tourism Theoretical Foundations

Smart tourism is the intersection of tourism research, urban informatics and sustainability science. According to Gretzel et al. (2015), smart tourism can be defined as tourism with the support of combined actions of a destination aimed at the collection and assembly of the data based on physical infrastructure, social networks, and organizational sources and the subsequent use of the high-technology facilities to convert them into real-time experiences and business value propositions. This definition highlights three important dimensions, including technological infrastructure, data ecosystems, as well as value creation.

Smart tourism theoretical framework is based on a number of concepts. To begin with, there is the triple bottom line approach (Elkington, 1997) which focuses on the sustainability of the economy, environment, and society. Second, the systems thinking viewpoints view tourism destinations as complex adaptive systems where technological interventions form feedback loops and emergent behaviors (Baggio, 2008). Third, there is the notion of carrying capacity, physical, environmental, and social, which offer standards in management of the volume of visitors (O'Reilly, 1986).

2.2 Smart City Technology in Tourism management.

2.2.1 Internet of Things (IoT)

The IoT technologies establish networked spaces wherein physical objects gather and transfer information by means of embedded sensors and connectivity. Some of the applications of IoT in tourism are smart waste bins with indication of the fill level, air quality and noise pollution sensors, and beacons that track visitor presence (Gretzel et al., 2015). Such systems allow real-time monitoring and predictive analytics which changes the reactive management to proactive optimization.

2.2.2 Artificial Intelligence and Machine Learning.

The AI systems are used to analyze large volumes of data to draw patterns, forecast behaviors, and compute decisions. The uses of tourism are in demand forecasting, recommendation systems that are personalized, and resource allocation that is automated (Buhalis and Sinarta, 2019). The algorithms of machine learning have the ability to forecast the crowding hotspots, time traffic lights in the most optimal way depending on the visitor flows, and dynamically adjust prices to allocate the demand both in time and space.

2.2.3 Digital Twins

Digital twin technology is one that develops physical space replicas that can be simulated and have operations managed in real time. Urban digital twins are a combination of various streams of data, such as visitor flows, air quality, infrastructure behaviors, which enable planners to simulate intervention cases and forecast their results prior to actual involvement in real-life efforts (Batty, 2018). This is very useful especially in dealing with complex tourism systems that interventions can have unintended effects.

2.3 Urban Tourism Sustainability-Issues.

There are various sustainability pressures brought about by urban tourism. The effects on the environment are high energy consumption, water usage, generation of wastes and carbon emission due to transport (Gossling, 2002). Social effects include displacement of the residents, commodification of culture, and the weakening of community cohesion (Koens et al., 2018). The economic effects include volatility of seasonal employment, loss of tourism earnings, and perfect competition of local prices.

Overtourism has become a burning issue in tourist attraction sites. According to Dodds and Butler (2019), overtourism is manifested in the situation when the number of visitors exceeds the capacity of a particular destination to maintain physical, ecological, social, economic, psychological, and political sustainability. The problem of overtourism needs more complex strategies that would not only reduce visitor numbers but also cover the trends in space and temporal dispersion.

2.4 Resource maximization Data analytics.

The data-driven system facilitates accurate resource systems monitoring and optimization. Occupancy sensors and weather information are used in energy management systems to optimize the HVAC systems within tourism buildings (Buhalis and Amaranggana, 2015). Smart water systems identify the presence of leakages and optimize irrigation in parks in cities. Smart roads can minimize traffic congestion and pollution with the help of real-time navigation and multimodalism (Benevolo et al., 2016).

2.5 Gaps in Current Literature

Although proved potential of technology, gaps in the current research are still evident in the issues of how the technology is to be implemented when resources are limited. The sector researched by most of the case studies is well-invested European or Asian cities with fewer studies concerning replicable mechanisms in the development of emerging destinations. Moreover, studies also tend to focus on technological capacities rather than governance systems, processes of stakeholder engagement and change management that are needed to make implementation successful.

3. Methodology

3.1 Research Design

The qualitative case study approach is used in the study, along with analysis of secondary data. The case study method allows a thorough analysis of the practical aspects of smart tourism deployment in practice and brings out areas of success and challenges (Yin, 2018). Various case studies offer the possibilities of comparative investigation and identification of patterns in various urban settings.

3.2 Case Selection

The three cities were chosen because they have been identified as leaders in the field of smart tourism and sustainability: Barcelona (Spain), Singapore and Amsterdam (Netherlands). The destinations are varied geographical settings, political frameworks and development stages and showcase innovative technological use to manage eco-tourism.

The criteria of selection were:

- Recorded use of smart city technologies in the management of tourism.
- Publication of sustainability outcomes.
- Geographical heterogeneity and form of ruling.

- Achieving the status of smart tourism leaders by international bodies.

3.3 Data Collection

Data sources included:

Peer-reviewed journal articles (2015-2025) of academic literature.

Authoritative reports of the city governments and tourism agencies.

Technological documentation by technology vendors and implementers.

Publications in the industry and proceedings of conferences.

Reports of international organizations (UNWTO, OECD, World Bank).

3.4 Analytical Framework

Thematic coding method has been used in analysis, and patterns were determined in three dimensions:

Technological Infrastructure: The kind of technologies that are implemented, integration architecture and data management systems.

Sustainability Outcomes: The results of the measured impacts in the indicators of environmental, economic, and social sustainability.

Implementation Strategies: Model of governance, finance and stakeholder involvement, and scale.

3.5 Limitations

This study is limited to a number of reasons. The use of published sources restricts the proprietary data and unsuccessful implementations. The case studies are well-equipped cities and this may not be generalized to developing situations. The assessment of long-term outcomes is not possible due to temporal constraints because most implementations are still rather new. Lastly, urban tourism systems are intricate and it is difficult to separate the impacts of technology and other factors.

4. Findings

4.1 Case Study: Barcelona, Spain

4.1.1 Context and Challenges

Barcelo is visited by more than 30 million people each year, which causes extreme overtourism stress in the Gothic Quarter and other historic areas. The resident displacement, straining

infrastructure, environmental pollution, and opposition of the community on the increasing tourism are challenges. Technology-driven sustainable tourism has been one of the key priorities of the city as a part of the overall smart city approach.

4.1.2. Implementations of technology:

Barcelo has implemented a massive sensor network of the IoT in the city. Some important implementations are:

Visitor Management: The city provided a type of visitor management system that installed pedestrian counting sensors in busy tourist spots, which could help in recording real-time statistics on visitor numbers. This information is used in predictive models which predict the amount of crowding, and therefore, flexible visitor dispersal policies can be implemented based on this information by means of digital signage and mobile-based apps (Barcelo City Council, 2022).

Smart Lighting: LED Streetlights Adaptive Control will save 30% of the energy and enhance safety. The motion sensors cause the lights to be on low mode during low-traffic hours and brighter when someone walks into the premises, which results in maximum use of energy without affecting the experience of the visitor.

Waste Management: Smart waste bins with fill level sensors optimize the collection routes, which cuts the number of kilometers travelled by the collection vehicle by 25 and the collection-related emissions. The system reads 150,000 sensor data every day and allows predictive maintenance and effective resource allocation.

4.1.3 Sustainability Outcomes

The smart tourism projects in Barcelona have already delivered sustainable gains in the following ways:

- A quarter of the energy reduction in municipal buildings with smart management systems.
- Twenty percent reduction in traffic jams in tourist full districts.
- Efficiency in waste collection increased by 30% percent.
- Improved distribution of visitors, 15 per cent. more visits to peripheral neighborhoods.

However, challenges remain. There have been tension between community issues related to surveillance and data privacy. Also, technology by itself has not alleviated the issue of overtourism and needs other supporting policy aspects such as accommodation caps and cruise ship bans.

4.2 Case Study: Singapore

4.2.1 Context and Approach

Singapore has established itself as a smart country and has incorporated technology in all its systems in the city, including the tourism sector. Singapore has a small land area and a large number of visitors (19 million international arrivals in 2019), which implies the need to apply advanced management strategies to address the density issue.

4.2.2 Implementations of technology.

Digital Twin Platform: Singapore has created Virtual Singapore which is a complete digital twin of the whole city-state. It is a 3D mapping, real-time sensor, and predictive analytics platform that allows tourism planners to model how various events impact the city, how traffic is affected, and how crowds are managed before the actual implementation (Singapore Land Authority, 2023).

Artificial Intelligence Crowd Control: Marina Bay Sands and other large visitors use AI-based video surveillance to check the number of people at the location in real-time. Automated systems make interventions such as changing the entry rate, staff deployment and visitor communications suggesting alternative times or locations when predetermined thresholds are met.

Smart Energy Management: The tourism facilities are part of a smart kind of energy grid which will optimise the usage according to the occupancy, weather conditions and the load on the grid. Hotels state that 15-25% of energy is saved by automated systems that control the use of HVAC, lighting, and equipment.

Contactless Systems: Contactless payments, authentication systems, and service delivery systems are widely deployed to limit physical touchpoints, enhance hygiene, and create valuable data on transaction data on which forecasts of demand and capacity planning can be made.

4.3 Case Study: Amsterdam, Netherlands

4.3.1 Context and Strategy

The city of Amsterdam is extremely overfaced with overtourism, especially the historic canal area. The city has taken a distinctly sustainability-declared method of smart tourism, which concentrates on the quality of life of the residents and visitor management. The Amsterdam strategy is focused on de-marketing the overcrowded zones and applying technology to make the places more sustainable.

4.3.2 Implementations Technology.

Crowd Monitoring and Dispersal: Amsterdam installed a network of WiFi and Bluetooth sensors that were tracking the anonymized movement of mobile devices. This information shows live crowding and movement of tourists. The city redistributes visitors with the help of information to encourage taking alternative routes and neighborhoods on its official visitor app and webpage, reaching 12% redistribution of visitors to peripheral areas (City of Amsterdam, 2023).

Smart Parking Management: Dynamic Parking Pricing: Occupancy and location-based dynamic parking pricing will deter the use of cars in crowded places. Vehicles moving into and out of inner cities are reduced by 30% as tourist coaches are redirected to outer park-and-ride with nice public transport links.

Collaborative Data Platform: Amsterdam developed an open data platform, in which tourists, homeowners, and researchers can get access to anonymized visitor data. This openness develops trust in the community as well as allows problem-solving and innovation.

Sustainable Transportation Incentives: Bike-sharing, electric boat shuttles, and public transport should be accepted into unified mobility-as-a-service systems, which will then make sustainable modes of transportation more convenient than cars. Live capacity and travel time promotion promotes mode choice optimization.

4.3.3 Sustainability Outcomes

The technology-based strategies of Amsterdam have worked to significant outcomes:

- 15% decrease in visitor concentrations in the majority of densely populated districts.
- Visitor bicycles and public transport 25 percent growth.
- Neighborhoods Residential-tourist interface zones 20% decrease in noise complaints.
- Improved economic value addition to tourism by the community through open data.

What has happened in Amsterdam shows that technology performance requires favorable policy structures. The city integrates intelligent systems with control mechanisms such as short-term rental controls, accommodation development controls, and cruise visitor controls. Such an integrated is effective compared to technology.

4.4 Comparative Analysis

The comparison of the three cases allows identifying a number of patterns:

Governance Models: Singapore has a centralized model that allows quick implementation, but poor participation by the community. Barcelo and Amsterdam use more participative frameworks, which slows execution however, creating more robust community support.

Technology Integration: All three cities focus on system integration as opposed to stand alone solutions. The best implementations are linking numerous streams of data and aligning in the transport, energy, waste, and visitor management areas.

Sustainability Focus: Amsterdam is the city that most explicitly emphasizes the quality of life of residents and environmental safety as opposed to the increase in visitor numbers. The city of Barcelona is a place that has struck a balance between sustainability and economic goals. Singapore focuses on effectiveness and capacity optimization under environmental limitations.

Scalability Difficulties: The three cities are enjoying the wide financial resources, sophisticated digital infrastructure and advanced governance capacity which most of the developing destinations cannot offer.

5. Discussion

5.1 Technology as Sustainability Enabler

In the case studies, it is shown that smart city technologies can greatly contribute to sustainable tourism management in case they are implemented in a proper manner. Key mechanisms include:

Real-Time Adaptive Management: Conventional planning is based on previous data and regular evaluations. IoT and AI give an opportunity to monitor and make adjustments continuously, so managers can take action to adapt to the ever-changing conditions in real time. This feature can be especially helpful to regulate unstable inflows of visitors and avoid cases of acute crowding.

Predictive Capacity: Machine learning models detect the patterns that cannot be analyzed by humans and are able to make proactive actions prior to the emergence of issues. Predictive maintenance minimizes infrastructure crashes, demand forecasting would allocate resources efficiently and scenario simulation would help in evidence-based planning.

System Optimization: Data analytics identify the inefficiencies in the complicated urban systems. The efficiency gains of 15-30% by smart lighting, waste management, and energy systems are realized by optimization of operations, benefits that directly affect sustainability and cost reduction of operations.

Behavior Influence: Visitors can be influenced to behave in a certain way through personalized recommendations, real-time capacity information, and incentive structures to influence their behavior digital platforms. Pushing tourists to greener options (off-peak seasons, other destinations, sustainable travel) spreads the effects out evenly in space and time.

5.2 Critical Success Factors

It has been analyzed that there are a few aspects that are important in successful implementation of smart tourism:

Integrated Infrastructure: Single technologies will not provide much value. Making sensors, analytics and intervention systems collaborate is a key ingredient to success. The digital twin of Singapore is also the example of this integration since various streams of data are integrated into the coherent systems of decision-support.

Data Governance: Privacy issues and trust of the community necessitate very strong data governance structures. The trust that Amsterdam has developed through its open data platform and its open communication has led to success whereas Barcelona has experienced opposition to the issue of surveillance in the community. Well-defined data collection, anonymization, access, and use policies are necessary.

Stakeholder Engagement: There are various stakeholders who are impacted by technology implementation; residents, businesses, visitors, workers. Effective cities use participatory mechanisms that make sure that technology implementation and application are influenced by a broad range of voices. Top-down methods expose the community to resistance which will compromise implementation performance.

Policy Integration: Technology is not the answer to the issues of sustainability. Well developed cities integrate both intelligent systems with complementary policies like visitor limits, zoning rules and economic benefits. Amsterdam illustrates the ability to integrate through technology, applying and enforcing larger sustainability strategies.

Capacity Building: Smart systems are technologically demanding in terms of technical capacity to deploy, operate, and maintain. The cities have to invest in the development of the workforce, knowledge exchange, and institutional learning. There are sustainability risks that come about as a result of external reliance on vendors, unless local capacity is built.

5.3 Challenges and Limitations

Even though the future of smart tourism looks bright, it still has to overcome major obstacles:

Costs of Implementation: To install sensors, platforms and connectivity, initial costs might be high. In Barcelona, the projects of smart city needed more than EUR200 million of technology investments. These expenses are too high to afford by most developing cities.

Digital Divide: Smart tourism systems presuppose smartphones and digital literacy of visitors and residents. This presumption rules out the less technologically advanced communities, which might worsen inequalities.

Privacy and Surveillance: Surveillance on a wide scale brings up valid privacy issues. There must be a balance between managerial efficiency and civil liberties that must be achieved through a delicate balance of governance by the community. Diverse cultural backgrounds have different privacy implications and legal provisions.

Technology Lock-In: Reliance on proprietary systems leads to vendor lock-in. Cities might not be able to change platform or adopt new technologies. These risks are alleviated, not removed by the open standards and interoperability requirements.

Measurability Problems: It is a challenge to capture technology interventions and their impacts on sustainability in the large urban systems. There are various issues that may affect results at the same time, and the comparison of the control is hardly achievable.

5.4 Budget-Constrained Cities Engagement Recommendations.

Smart tourism sustainability can be achieved with cities developing through strategic and phased plans:

5.4.1 Take Advantage of Open-source Solutions.

Open-source smart city platforms provide a way to eliminate the costs of the licensing process and allow customization. FIWARE is a EU-supported development of a free IoT management system applied by more than 400 cities worldwide. The open-source version of analytics such as apache Kafka and tensorflow can perform advanced data processing without the purchase of proprietary software.

5.4.2 attend to the High-Impact, Low-Cost Interventions.

Not every smart tourism application will need costly infrastructure. Visitor information and recommendation mobile apps are inexpensive behavior influencing tools. Without new investments in sensors, collaborations with telecommunications providers can gain access to the already available mobile network data on visitor flows. Analytics on WiFi on an existing infrastructure offer great insights at very low cost.

5.4.3 Strategy of Phased Implementation.

Start the pilot projects in small geographic sphere or application. Show worth and capacity and then expand. This is a risk-reduction strategy, facilitating learning and creating evidence to justify larger investment. The strategy of Barcelona started with pilots at the district level and then city-wide.

5.4.4 Public- Private Partnerships.

Involve business partners to save on expenses and tap experience. Vendors of technology can offer equipment and platforms as a trade-off of showcase opportunities and access to data. Tourism

enterprises have the advantage of a better management on the destination and can give a donation. Hotel industry groups have the opportunity to mobilize investments with members to mutual infrastructure.

5.4.5 Regional Collaboration

The same region can have their destinations share platforms and collectively acquire systems which will give them economies of scale. By organizing smart tourism programs on a regional destination management level, a number of cities can be integrated, making it cheaper to manage destinations as well as allowing the management of visitors at a larger geographic scale.

5.5 Greater Implications on Sustainable Tourism Planning.

Smart tourism is a paradigm shift of destination management, as it changes intuition-based decision-making to an evidence-based one. This change has a number of implications:

Professionalization Technology-enabled management involves specialized skills, which increases the barriers to entry but may result in better management. The destinations should invest in capacity building and offer career opportunities to smart tourism professionals.

Power Dynamics: Analytics and data collection focus on the information and decision-making authority. The participatory governance models have to continue to change to make sure that technology will lead to more accountable democracy rather than become its adversary.

6. Conclusion

6.1 Summary of Key Findings

This study proves that the utilization of smart city technologies, specifically, IoT, AI, and digital twins, can contribute greatly to the sustainable management of urban destinations in tourism. Case studies conducted in Barcelona, Singapore and Amsterdam show that the integrated technological systems can help manage the visitor flow in real-time, optimize the resources and be based on the evidence. The capabilities are transformable into quantifiable sustainability benefits that comprise a reduction in energy usage, congestion, efficiency in the management of waste, and an enhancement in the spatial distribution of visitor impacts.

Nonetheless, technology is not enough to guarantee sustainability. Effective implementations have been found to integrate smart systems with conducive policy frameworks, stakeholder engagement procedures and institutional capability. The quality of governance, acceptance of the community and incorporation into the larger destination strategies are key determinants of the effectiveness of technology interventions.

6.2 Theoretical Contributions

The article has added to the theory of sustainable tourism planning in showing how technology can be used as a facilitating element of adaptive destination management. The results follow systems theory views, the technological interventions produce feedback loops, which lead to improved system intelligence and resilience. The study also builds on the concepts of carrying capacity demonstrating how the ability to manage dynamically based on real time data allows destinations to operate near the limits of carrying capacity and sustainably at the same time through continuous adjustment.

As the case studies demonstrate, smart tourism is not only the adoption of technologies, but the essential shift in the governance of the destination, new skills, processes, and the institutional organization are needed. This point of view will underline that the implementation of the smart tourism is, perhaps, as much the organizational and social issue as it is a technical one.

6.3 Practical Implications

To urban planners and destination managers, this study offers evidence on the use of strategic investment in technology as a sustainability measure. The case studies provide the implementation models as well as unveil the crucial factors to success and pitfalls. The tips on the budget-constrained urban areas show that it is possible to develop advanced smart tourism solutions despite limited budget by making strategic decisions concerning selection of technology platform, implementation plan, and partnering.

According to the policymakers, the benefits of technology need to be maximized, which is best achieved through favorable regulatory and data governance policies, and investment in institutional capacity. The procurement of technology needs to focus on open standards and interoperability so as to prevent vendor lock-in and provide long-term flexibility.

6.4 Future Research Recommendations.

There are a number of research directions that warrant consideration:

Long-Term Impact Studies: The majority of smart tourism applications are not that old. The outcomes of longitudinal research of tracking outcomes after 5-10 years would give information on whether the initial gains can be sustained and what are the unintended effects that will emerge with time.

Creating Context Studies: In this study, well-resourced cities were targeted. The prevalent issues of smart tourism implementation in the developing contexts would be uncovered by systematic analysis and the successful strategies of the adaptation could be determined.

Community Impact Assessment: There is still a need in further research on how smart tourism influences the quality of life of community members, both directly (noise, crowding, etc.) and indirectly (housing, employment level, etc.).

Governance Innovation: Studies need to investigate how participatory forms of governance can be effectively used to enable the inclusion of technical complexity but still be able to achieve democratic accountability and community voice.

Cost-Benefit Analysis: Intensive economic evaluation of the implementation cost and sustainability payoff would serve the purpose of evidence-based decision-making on investment and allow to prioritize the technology interventions better.

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Appendices

Appendix A: Technology Implementation Comparison Matrix

Technology	Barcelona	Singapore	Amsterdam	Primary Sustainability Benefit
IoT Sensors	Extensive pedestrian counting, environmental monitoring	Comprehensive coverage across city-state	WiFi/Bluetooth visitor tracking	Real-time visibility enabling adaptive management
AI/Machine Learning	Predictive crowding models	Crowd analytics, demand forecasting	Visitor flow prediction	Proactive capacity management
Digital Twin	Limited implementation	Complete city digital twin	District-level models	Scenario simulation and planning
Smart Lighting	City-wide adaptive LED system	Tourist area optimization	Historic district efficiency	20-30% energy reduction

Waste Management	Fill-level sensors, route optimization	Integrated waste tracking	Smart bins in tourist zones	25-30% efficiency improvement
Transportation	Integrated mobility platform	AI-powered traffic management	Sustainable mobility incentives	15-30% congestion reduction
Mobile Applications	Official city app with real-time info	Multiple integrated visitor apps	Visitor dispersal recommendations	Behavior influence toward sustainability