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THE POTENTIAL OF DIGITAL TECHNOLOGIES FOR ORGANIZING ENVIRONMENTALLY RESPONSIBLE TOURISM IN SMART CITIES

Abstract. *The role of digital technologies in the development of environmentally responsible tourism within the context of smart cities is explored in the article. The re-search objective of identifying the main areas of application of digital solutions in this area and analyzing their impact on the sustainable development of smart city tourism is achieved in the article. A review of modern scientific literature was conducted to identify key trends and directions for further research regarding the implementation of digital solutions in this field. The main negative impacts of traditional tourism on the urban environment are summarized. A comprehensive analysis of digital technologies in the context of environmental sustainability of tourism, in particular in identifying four key areas of their application: information and communication technologies for tourists; transport systems and logistics; urban environment monitoring and management systems; analytics, artificial intelligence, and decision support determined the scientific novelty of the article. It is demonstrated that these technologies not only enhance the quality of the tourist experience but also enable travel planning with environmental criteria in mind, significantly reducing negative environmental impacts and promoting the rational use of urban resources. The practical value of the article is the formation of theoretical and methodological foundations for the development of digital tools that contribute to the formation of a culture of conscious consumption of tourist services, support for the strategy of sustainable development of cities and improvement of their ecological condition.*

Keywords: *Urban tourism, Environmentally responsible tourism, Smart cities, Digital technologies.*



1. Introduction

Tourism is one of the leading sectors of the global economy. For Ukraine, especially in the context of war, it is an important factor in the economic resilience of certain regions. However, tourism places increased pressure on the environment, including pollution of air and water resources, deterioration of ecosystems, increased resource consumption, and overload of transport and municipal infrastructure. Excessive tourist loads cause damage not only to natural areas but also to cities that receive a large numbers of tourists. In response to these challenges, the development of environmentally responsible tourism, aimed at minimizing negative impacts on natural resources and protecting the environment, is becoming increasingly relevant.

For Ukraine, which is currently developing post-war recovery plans, the priority is not only the restoration of infrastructure destroyed but also the development of cities based on the Smart City concept. This concept relies on the widespread implementation of digital technologies to improve citizens' quality of life. The introduction of smart technologies in the tourism sector contributes not only to infrastructure development but also to fostering responsible tourist behavior, which is an important factor in preserving the urban environment.

Despite the growing interest in digital solutions in tourism, the issue of integrating smart technologies within the context of urban environmental sustainability remains insufficiently studied. The aim of this article is to investigate the role of digital technologies in the development of environmentally responsible tourism in smart cities, as well as to analyze case studies of their implementation.

Recent scientific studies indicate a growing interest within the academic community regarding the role of digital services in transforming tourism under the frameworks of smart city and sustainable development concepts. Most authors [1, 2, 5, 8, 9] emphasize that digital technologies — particularly artificial intelligence, big data, and virtual reality — open new opportunities to enhance the efficiency of tourism services, optimize resource use, and reduce negative environmental impact. Researchers pay special attention to the application of artificial intelligence in the tourism sector. Specifically, Bingöl and Yang [1] and Tuo Y. [15] consider artificial intelligence a key tool for ecological management in smart destinations, highlighting its potential in optimizing resource consumption and forecasting tourist flows. Chan, C.-S. and colleagues [2] explored how pre-trip virtual reality (VR) experiences and the use of smart devices during on-site visits can enhance the tourism experience for individuals with hearing impairments on Yim Tin Tsai Island (Hong Kong). The study also provides practical recommendations for the design of VR applications and the effective use of smart devices to improve the accessibility of tourist routes.

Many authors, including Samancioglu et al. [11] and Zhang et al. [18], emphasize the important role

of big data analytics in resource coordination and the digital sustainability of cities. At the same time, they note potential challenges related to data management and privacy that may hinder the adoption of such technologies in tourism. Stroumpoulis et al. [13] and Ionescu and Sârbu [6] have studied the impact of digital solutions on improving the quality of tourism services, particularly in mobility, navigation, and informational support for travelers. Grincheva [4] and Madeira et al. [7] highlight the significance of smart analytics and creative approaches in shaping sustainable urban environments in the context of tourism. A comprehensive analysis of successful examples of smart technology implementation in the tourism sector across different countries is also important, especially concerning the development of mobile applications, sensor networks, and environmental monitoring [4, 5, 8, 12, 17]. Hashim, H. [5] conducted an in-depth analysis of the role of e-government in advancing smart city initiatives in Saudi Arabia, with particular emphasis on the integration of ICT, the Internet of Things, big data, and cloud computing technologies. The study identifies critical challenges — such as cybersecurity concerns, infrastructure interoperability, citizen trust, and regulatory frameworks — and offers strategic recommendations and best practice guidelines aimed at overcoming these obstacles and enhancing the efficiency, transparency, and sustainability of urban governance.

Overall, scholars adopt a comprehensive approach to studying digital technologies in tourism, considering technological, social, economic, and environmental aspects of the process. At the same time, they emphasize that technological innovations alone do not guarantee responsible tourist behavior or an increased level of ecological awareness.

The literature identifies several promising directions for future research. These include modeling the impact of technologies on tourist ecosystems under climate change conditions and integrating digital tools into sustainable development strategies. However, these directions are still in an active stage of development and require analysis of practical case studies and objective assessment of their effectiveness.

2. Materials and Methods

To achieve the stated aim, the study employed a set of general scientific research methods. The methods of analysis and synthesis were applied to systematize contemporary scientific literature on environmentally responsible tourism, the smart city concept, and digital technologies. The abstract-logical method was used to identify the main negative impacts of traditional tourism on the urban environment. The dialectical method served to formulate theoretical generalizations regarding the potential for implementing digital technologies in environmentally responsible tourism, to identify the related challenges, and to outline possible solutions. Comparative analysis enabled a case study of smart city practices in introducing digital services aimed

at reducing the environmental impacts of tourism. Graphical and tabular methods were used to present the research findings in a visual form. No software or code implementations were applied in this study.

3. Results and Discussion

To substantiate the objectives of using digital technologies in the tourism sector, it is first necessary to analyze the main environmental problems caused by traditional tourism activities in cities. The negative impact of tourism on a destination due to an excessive number of visitors — experienced both by local residents (through a decline in quality of life) and by the tourists themselves — is known as over-tourism. This phenomenon is characterized by exceeding the permissible tourism load on the urban environment, leading to environmental degradation and increased social tension. At the same time, even a relatively small number of tourists can pose challenges for a city, particularly by overloading infrastructure and creating other issues, examples of which are presented in Figure 1.

Thus, traditional tourism activities in cities can cause a wide range of negative environmental and infrastructural impacts. The impact of tourism is felt at all stages of providing tourist services — both primary (transportation, accommodation, catering, excursion services) and auxiliary (souvenir trade, medical services, animation, vehicle rental, etc.).

One approach to minimizing the negative impact of tourism on the urban ecosystem is the implementation

of environmentally responsible tourism (also known as eco-friendly tourism), which is viewed as a transformation of traditional tourism that incorporates principles of environmental sustainability. The concept of this approach is to minimize the ecological footprint of tourism activities through the application of resource-saving, energy-efficient, and nature-oriented practices. Unlike ecotourism, which focuses on visiting natural sites and preserving the natural environment, environmentally responsible tourism integrates ecological principles into the operation of the existing tourism system without fully transforming the organization of tourism or the destination, including the city. This form of tourism aims to meet tourists’ needs with minimal negative impact on the natural and socio-cultural environment, rational use of resources, and support for biodiversity conservation.

Key practices of this approach include optimizing transportation routes; using low-carbon-footprint transportation; employing environmentally safe materials in the construction and maintenance of tourist facilities; implementing energy-saving technologies at all stages of tourist services; reducing water and electricity consumption; managing waste responsibly; developing a circular economy; and maintaining biodiversity, among others.

Thus, environmentally responsible tourism is a practical response to the challenges of sustainable development in urbanized environments, particularly within the Smart City concept. A Smart City actively

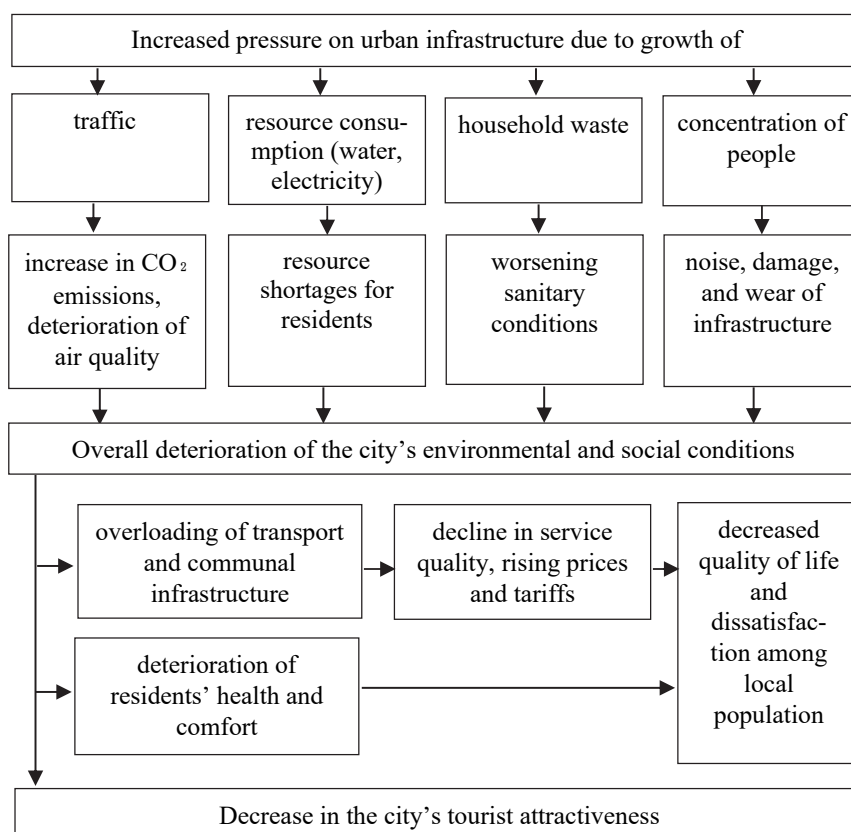


Figure 1. Main Negative Impacts of Traditional Tourism on Modern Cities

Source: developed by the authors

Table 1

Key Directions for the Use of Digital Technologies in the Development of Environmentally Responsible Tourism within Smart Cities

| Digital Technologies | Examples of Programs / Tools | Application in Tourism | Effect on Environmentally Responsible Tourism |
|--|---|--|--|
| Information and Communication Technologies for Tourists | | | |
| Mobile applications for tourists — eco-guides, maps, etc. | AllTrails, iNaturalist, Green Travel App | Providing tourists with ecological information, optimizing movement | Increasing tourists' environmental awareness, reducing negative environmental impact |
| Interactive (digital) maps and information displays | Touch Screen Kiosks, Visit Seattle App, Maze-Map, IndoorAtlas | Real-time tourist information, interactive navigation and engagement | Increasing ecological awareness, promoting responsible tourist behavior |
| Virtual and Augmented Reality (VR/AR) | Google Arts & Culture VR, Timelooper, Sketchfab | Virtual tours, educational and awareness-raising programs | Contributing to the preservation of tourist sites and reducing infrastructure load |
| Geoanalytics, GPS Navigation | QGIS, Kili Technology, Mapbox, HERE Technologies | Routing and monitoring of tourist flows | Prevention of overcrowding, improvement of environmental conditions in tourist areas |
| Transport Systems and Logistics | | | |
| Intelligent Transport Systems (ITS) — Smart Parking Systems, Public Transport Monitoring Systems, Bike/Scooter Sharing Systems, etc. | Parkopedia, Moovit, Transit, Citymapper, Bolt | Optimization of urban mobility | Reduction of emissions and carbon footprint, improvement of traffic flow |
| Intelligent booking systems | Booking.com, Airbnb, Amadeus, Galileo, Sabre | Personalization of offers, demand and availability management, resource optimization (hotels, transport, excursions) | Rational use of resources, reduction of waste, lowering carbon footprint through load optimization |
| Urban Environment Monitoring and Management Systems | | | |
| Sensors, GIS, Monitoring | EnviroSensor, AirVisual (IQAir), Civic Data Lab, PurpleAir, ArcGIS, QGIS | Monitoring of environmental conditions: collection, analysis, and visualization of real-time data; tracking air quality, noise levels, water pollution, and landscape changes | Timely detection of environmental issues, supporting decision-making in environmental management |
| Real-time IoT sensors | Libelium, ThingsBoard, OpenSensors.io, Blynk, PurpleAir | Continuous collection and transmission of environmental data via IoT networks for monitoring urban environments and infrastructure | Operational management of environmental load, rapid response to changes, and reduction of environmental impact |
| Smart lighting, energy-efficient systems | Philips Hue, LIFX, Cree Lighting, Schneider Electric EcoStruxure | Energy saving in tourist areas through automated lighting control and optimization of energy consumption | Reduction of energy use, decrease in greenhouse gas emissions |
| Smart management systems for renewable energy sources | Siemens EnergyIP, Schneider Electric EcoStruxure Grid, General Electric (GE) Grid Solutions, IBM Intelligent Operations Center for Smarter Cities, Enel X | Optimization of energy consumption in tourist infrastructure, integration and management of clean energy sources (solar, wind, etc.) | Reduction of carbon footprint, increased energy efficiency, and stability of energy supply |
| Smart Eco-Tourism Infrastructure | Smart Forest City (Cancún), Green View City Dashboard, EcoCounter, Urban GreenUP, Smart Parks | Integration of digital technologies into the creation and management of green tourism infrastructure: eco-routes, automated irrigation, visitor sensors, vegetation condition monitoring | Development of sustainable urban infrastructure, preservation of biodiversity, increased attractiveness of areas for eco-tourism |

| | | | |
|--|--|---|---|
| Smart waste management systems | Bigbelly Solar, Ecube Labs CleanCUBE, Enevo, SmartBin, Evreka | Improving waste collection efficiency through IoT-enabled monitoring, route optimization, and automated waste compaction | Reducing waste volume and pollution, optimizing municipal waste management costs |
| Analytics, Artificial Intelligence, and Decision Support | | | |
| Big Data Analytics | Apache Hadoop, Snowflake, IBM Cognos Analytics, Microsoft Azure Synapse Analytics, Google BigQuery, Smart Tourism Intelligence System (SIT), 3sixty, Smart Destinations Platform | Analysis of large datasets on tourist flows, visitor behavior, and infrastructure load; support for planning and management based on real-time insights. | Evidence-based load planning, prevention of over-tourism, optimization of tourism infrastructure, reduction of environmental impact, and enhancement of sustainability. |
| Artificial Intelligence (AI) and Machine Learning | ChatGPT (OpenAI), Google AI Platform, Bard (Google), Microsoft Azure AI, IBM Watson, TensorFlow, H2O.ai | Analysis of tourist data for demand forecasting; optimization of routes and logistics; service personalization; automatic monitoring of environmental and infrastructure conditions; decision support | Improved forecast accuracy, reduced overcrowding in tourist areas, resource optimization, minimized environmental impact, enhanced efficiency of urban ecosystem management |

Source: summarized by the authors

uses digital technologies and intelligent systems to improve residents’ quality of life, efficiently manage resources, develop infrastructure, ensure environmental sustainability, and promote economic growth [3].

The Smart City concept opens new opportunities to address major environmental and infrastructural challenges related to tourism. Within this framework, tourists are provided with highly automated services — ranging from transportation and booking to navigation. Digital services and intelligent systems enable the collection and processing of large volumes of real-time data, effective resource management, enhancement of tourism service quality, and reduction of ecological footprints.

Digital solutions contribute not only to the improvement of urban infrastructure but also to the promotion of sustainable tourism principles through digital environmental management. An important component of developing environmentally responsible tourism is the involvement of local communities, raising tourists’ environmental awareness, and integrating innovative solutions into urban governance systems, particularly through the implementation of digital monitoring systems, analysis of environmental indicators, and resource management.

The key directions for the use of digital technologies to develop environmentally responsible tourism within smart cities are summarized in Table 1.

According to the data in the table 1, it is important to highlight the multidimensionality and dynamism of digital technologies in shaping environmentally responsible tourism in smart cities.

One of the most effective tools in digital management of the tourism sector is artificial intelligence (AI). AI has long ceased to be merely an “optional feature” and is becoming a key element in the development of

Smart Cities. Its applications are diverse, but special attention is given to chatbots. Many service companies implement intelligent widgets, such as FAQs, to provide prompt responses to common customer inquiries. AI-based chatbots assist tourists in planning their trips: suggesting routes, selecting hotels, optimizing expenses, booking tickets, processing documents, and more.

An example of successful chatbot implementation is TourHelperBot, developed by the Ukrainian Association of Travel Agencies. This bot provides tourists abroad with up-to-date information on accommodations, flight delays, and cancellations, as well as assists in resolving other issues that may arise during their travels.

There are numerous successful cases worldwide of implementing digital technologies within the Smart City concept that contribute to the development of environmentally responsible tourism.

According to the Smart City Index 2024 by Prop-techOS, Paris topped the list of European smart cities. The city actively implements innovative digital solutions, combining modern technologies, infrastructure innovations, and environmental responsibility to achieve sustainable development. [14]

The city-state of Singapore is considered one of the most advanced Smart Cities in the world due to its effective digital governance. Singapore is known for its integrated environmental monitoring system that uses artificial intelligence and IoT sensors to control air quality, water resources, waste management, transportation, and security. The developed digital platforms help tourists plan routes with minimal impact on ecosystems and promote increased environmental awareness among the population. [4]

Vienna (Austria), Barcelona (Spain), and Amsterdam (Netherlands) actively use Big Data to forecast tourist flows and optimize transport infrastructure, as well as

IoT for air quality monitoring, smart lighting, water resource management, and providing digital services to residents. Smart solutions enable the distribution of tourist flows to prevent overtourism and also implement energy-efficient transportation and smart lighting in tourist areas. Toronto (Canada) employs digital technologies in construction, transportation, environmental monitoring, and integrates a Smart Grid system. [3]

One of the key methods for managing tourist flows is setting limits on the number of tourists who can simultaneously visit popular locations. Such measures are applied in many cities worldwide. For example, Venice has an online booking system that controls tourists' access to major attractions and natural sites, helping to avoid excessive strain on urban infrastructure and ecosystems.

These examples demonstrate that digital technologies can become a key tool in implementing environmentally responsible tourism practices in cities striving for sustainable development and improving the quality of life for residents and visitors. The most promising directions for the development of environmentally responsible tourism within Smart City frameworks are digital environmental monitoring, optimization of tourist flows, and integration of digital systems in city management. These digital solutions not only enhance the quality of the tourist experience but also significantly contribute to reducing the ecological footprint on cities.

However, it is important to remember that the use of digital technologies comes with certain challenges. First, there is the issue of data privacy protection: many services collect and process large amounts of personal information (names, contacts, passport and payment details, location, preferences, etc.), making tourists vulnerable to cyberattacks, fraud, and other criminal activities. Additionally, the implementation of digital technologies requires significant energy resources, with the solution being the production of additional

energy from renewable sources. There is also a risk of creating social barriers due to inequality in access to digital technologies, particularly for financial reasons.

4. Conclusions

The study confirms that digital technologies serve as one of the key factors in the development of environmentally responsible tourism within the framework of the smart city concept. They contribute to increasing tourists' environmental awareness and the implementation of sustainable practices in the tourism industry. Through the use of mobile applications, online booking, virtual guides, and other digital tools, tourists are able to plan trips taking into account environmental criteria, selecting optimal routes based on time and distance. This promotes the enhancement of the quality of the tourist experience and significantly reduces the negative impact on the environment, ensuring the rational use of natural resources.

The integration of digital technologies into tourism organization contributes to the formation of a culture of conscious consumption of tourist services, which, in turn, supports the sustainable development strategies of cities and improves their environmental condition. It is recommended that Ukraine study the international experience of leading smart cities in the field of innovative and environmentally responsible tourism and actively implement digital tools to develop this sector.

At the same time, to minimize the negative impact of tourism on the urban environment, it is necessary to apply a comprehensive approach that combines government policies, local initiatives, technological innovations, and the transformation of tourists' behavioral patterns. Further scientific research should focus on the development of integrated digital environmental management systems, the evaluation of the effectiveness of implemented innovations, as well as the study of the impact of modern digital technologies on the sustainable development of tourist smart cities.

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ПОТЕНЦІАЛ ЦИФРОВИХ ТЕХНОЛОГІЙ ДЛЯ ОРГАНІЗАЦІЇ ЕКОЛОГІЧНО ВІДПОВІДАЛЬНОГО ТУРИЗМУ В РОЗУМНИХ МІСТАХ

Анотація. У статті досліджується роль цифрових технологій у розвитку екологічно відповідального туризму в контексті розумних міст. Метою дослідження є виявлення основних напрямів застосування цифрових рішень у цій сфері та аналіз їхнього впливу на сталий розвиток туристичних smart-міст. Проведено огляд сучасної наукової літератури з метою виявлення основних тенденцій і напрямів подальших досліджень щодо впровадження цифрових технологій, а також узагальнено основні негативні наслідки традиційного туризму для міського середовища. Наукова новизна полягає у комплексному аналізі цифрових технологій у контексті екологічної стійкості туризму, зокрема у виокремленні чотирьох ключових напрямів їх застосування: інформаційно-комунікаційні технології для туристів; транспортні системи та логістика; системи моніторингу та управління міським середовищем; аналітика, штучний інтелект і підтримка прийняття рішень. Показано, що впровадження цих технологій не лише підвищує якість туристичного досвіду, а й дозволяє планувати подорожі з урахуванням екологічних критеріїв, суттєво знижує негативний вплив на довкілля та сприяє раціональному використанню міських ресурсів. Практична цінність статті полягає у формуванні теоретично-методичних основ для розвитку цифрових інструментів, які сприяють формуванню культури свідомого споживання туристичних послуг, підтримці стратегій сталого розвитку міст і покращенню їх екологічного стану. Подальші дослідження мають бути спрямовані на розробку інтегрованих систем цифрового екологічного менеджменту, оцінку ефективності інновацій та вивчення впливу сучасних технологій на сталий розвиток туристичних smart-міст.

Ключові слова: Міський туризм, Екологічно відповідальний туризм, Розумні міста, Цифрові технології.