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Internet of Things and Big Data Analytics for Risk Management in Digital Tourism Ecosystems

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Abstract: Participation and inclusion in the business ecosystem have emerged as a growing trend for company collaboration in areas such as innovation, product development, and research. Collaborations can take many forms, ranging from the traditional value chain to strategic alliances, corporate networks, and digital ecosystems. The Internet of Things (IoT) and Big Data Analytics (BDA) play key roles in developing smart tourism destinations by delivering efficient management solutions, increased public safety, and improved operational efficiency while managing different risks and challenges, while also being a source of such risks and challenges. The objective of this article was to investigate the potential of IoT and BDA to properly control the risks associated with participants in a tourism destination's digital ecosystem. The authors used the systematic literature review (SLR) method to examine scientific and applied articles on this subject. As a result, the main risks of the digital tourism ecosystem (DTE) as a whole and of the IoT and BDA technologies used in it were identified and classified; the features of DTE that affect risk management in it were distinguished; IoT technologies and their applications used in DTE were outlined; and the roles of DTE participants and the possible IoT technologies that can successfully address the risks associated with a given role were defined.

Keywords: risk management; IoT; Big Data Analytics; digital ecosystem; digital tourism ecosystem; smart tourism destination

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1. Introduction

Participation and inclusion in the business ecosystem is a growing trend for company collaboration, particularly in areas such as innovation, product development, research and development, etc. (Porter and Millar 1985; Moore 1993). Traditional value chain collaborations have evolved into strategic alliances and corporate networks, and are now shifting into digital ecosystems.

The term ecosystem can be interpreted in several ways (Adner 2006): as an affiliation, focusing on the architecture and density of the network (Autio and Thomas 2013; Rong and Shi 2015), and as structure, emphasizing the set of individuals who construct it.

The tourism sector, as one of the leaders in digital transformation, perceives collaboration through a digital ecosystem as critical to its survival and success.

The development of a smart tourism destination (TD) is assisted by the development of a suitable digital ecosystem (DE) to serve it. A DE consists of several heterogeneous and diverse participants who communicate via a common digital platform and aim to develop an innovative digital service that adds value to both the system as a whole and each of the entities that build it. This encourages competition and collaboration among interested parties, which adds value to the economy, society, and environment for all parties involved (Ritchie and Crouch 2003). A digital tourism ecosystem (DTE) can also be defined as a network of services that involves numerous players and resources aimed at collaborative value creation, and its development and survival are frequently challenging and complex

tasks that are accompanied by multiple risks (Adner 2006; Gao et al. 2022). These risks are mostly induced by the interconnection of DE participants, which is a prerequisite for the partners' dependency and influence on the business success of the other companies within the DE.

IoT is a main factor in the creation and functioning of intelligent environments (Cook and Das 2007), contributing to resource efficiency, higher productivity, and improved quality of life for humankind (Gomez et al. 2017).

IoT and BDA are two emerging modern technologies that have the potential to provide effective management solutions for participants in the smart tourism destination DE. The benefits are represented in various ways. The first is the capability of providing users with efficient, adaptable, and mobile services based on significantly improved analysis, forecasting, and planning of the dynamic environment. IoT technologies automate data collection and logging and make them available to the public. This results in the improvement and digitization of business processes, goods, and services, as well as the formation of entirely new processes, products, and services for businesses. IoT technologies for identification and tracking (radio frequency identification, wired and wireless sensors, electronic product codes, etc.), situational awareness (real-time information based on the current traffic situation), etc., contribute to increased public safety, regulatory compliance and smart management, rapid responses to unexpected events, and other applications. BDA enables the development of highly customized travel experiences by evaluating vast amounts of data from sources, like traveler preferences, past behaviors, and market trends. Nowadays, recommendations for accommodation, activities, and destinations are created specifically for each traveler, increasing satisfaction and promoting brand loyalty. Tourism organizations are simultaneously given predictive capabilities by BDA, enabling them to adjust pricing strategies in real time, optimize resource usage, and raise occupancy rates. Its scalability not only promotes profitability but also guarantees a comfortable and affordable trip for travelers. Moreover, BDA's insights into customer ratings and feedback allow for proactive problem-solving and service improvements, enhancing overall service quality (Agrawal et al. 2022). BDA also makes a substantial contribution to the operational efficiency and sustainability of the digital tourism ecosystem. It improves operational optimization by accessing data such as occupancy rates, energy consumption, and personnel schedules. As a result, tourism businesses achieve cost-effective and environmentally responsible resource allocation, aligning with broader sustainability aims. Furthermore, by identifying security threats, health problems, natural disasters, and cybersecurity weaknesses, BDA functions as a significant risk management tool. It enables tourism organizations to take preventative measures, protecting both visitors and their operations (Stylos et al. 2021). Additional benefits of incorporating IoT and BDA include increased operational efficiency and effectiveness as a result of user self-service capabilities, as well as lower personnel expenses.

IoT and BDA are developing as powerful tools in many fields of information processing and administration, including information security. These technologies, when incorporated into security systems, are capable of detecting attacks in advance by registering abnormal network behavior, forecasting attacks, and evaluating attack origins. Furthermore, IoT and BDA can offer answers to a wide range of risks and challenges.

This article explores the potential of IoT and BDA for the risk management of DE participants in a smart tourism destination.

Our research focuses on IoT and BDA for two reasons: on the one hand, they give direct or indirect solutions to some of the risks systematized by us for the DE participants of a smart tourism destination, and on the other, they are a source of certain risks and challenges.

There are currently no scientific papers that particularly address the issue of our field of research. Individual publications focus on the capabilities of IoT to facilitate the development of digital tourism ecosystems, as well as the advantages of using BDA for risk management in tourism destinations, but there is no comprehensive scientific work on this topic that reflects the symbiosis, synergy, and interdependence of these two technologies.

The goal of this article is to (a) identify and systematize risks for the participants of a smart tourism destination; (b) identify possible IoT and BDA opportunities for risk management objectives; and (c) highlight the risks and challenges of using these technologies.

2. Methodology

To achieve the objective of our study, we applied the method of a systematic literature review (SLR) (Kitchenham et al. 2009) of scientific and applied publications on the subject. Figure 1 represents our research approach.

For SLR, we defined the following three research questions:

RQ1. What are the risks for the participants in the digital ecosystem of a smart tourism destination?
RQ2. What are the main IoT technologies and applications used in smart TDs?
RQ3. Which technologies already used in DEs of smart TDs can be applied by participants to counter the typical risks?

We chose the Scopus and Google Scholar databases as search sources since they are multidisciplinary and the most extensive. We ran a search on RQ1 and RQ2, and the answers to RQ3 were systematized based on the RQ1 and RQ2 results.

The search process was carried out in the period of February–June 2023 on the following keywords:

- For *RQ1:* risk* AND in AND tourism.
- For *RQ2*: tourist* AND IoT OR internet AND of AND things.

From the obtained results, publications that had no connection with the conducted research; were weakly related to RQ1 and RQ2; were not in English; included a study of literary sources with the purpose of bibliometric analysis; and did not have a research thesis were excluded.

We identified twelve publications as a result of the search and application of the exclusion criteria in which the risks in DEs of smart TDs (RQ1) are discussed in various aspects, and two publications in which the potential of using IoT in tourism is presented in a structured form (RQ2). The results of the analysis were systematized and presented in tabular form (RQ3).

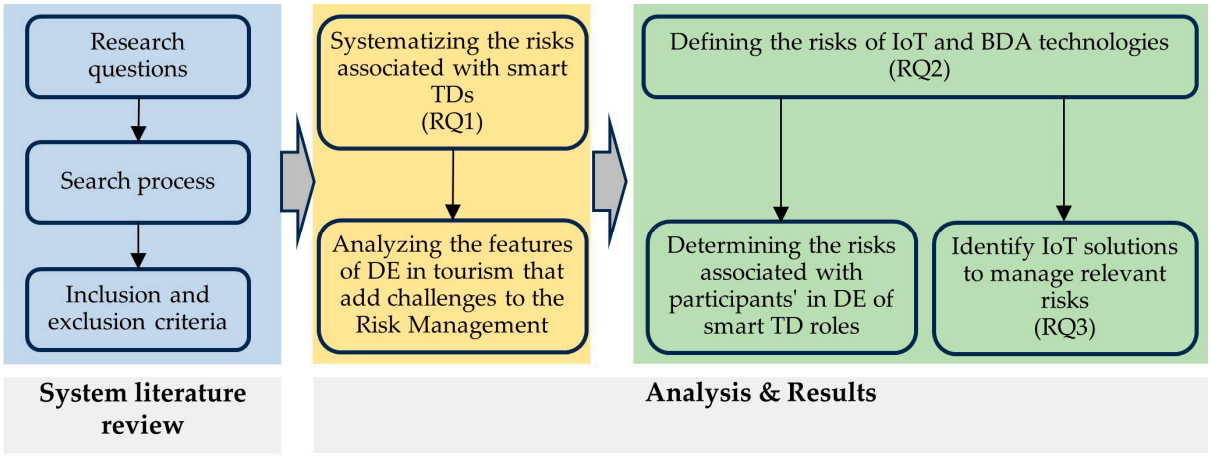

Figure 1. Research approach. Source: authors' interpretation.

3. Results

3.1. Risks of Digital Tourism Ecosystems

In this article, we use Mitchell's definition to define DE risks in tourism (Mitchell 1995), "Risks are defined as a combination of the probability of loss and the significance of that loss", as this distinguishes risks from challenges, uncertainties, difficulties, and other

closely related notions. Furthermore, this definition enables participants to estimate the severity of various risks, which is an important aspect of risk management (Dorfman 1998).

For the easier study of the risks and the determination of those of them that have a direct impact on the creation and development of the digital ecosystem in tourism, they should be classified.

The classification of risks is the subject of numerous authors' scientific research, who propose various criteria through which to divide them.

According to the level of risk within the organization it affects (Fliaster and Dellermann 2016; Allan et al. 2007; Basel Committee on Banking Supervision 2001; Embrechts and Puccetti 2006; Embrechts et al. 2009), the risks are defined as *strategic; risk of change/project risk; operational risk; unforeseen risk; and risks of the global environment*.

Within the various strategic alliances formed (Fliaster and Dellermann 2016; Das and Teng 1998), they are defined as *relational risk and performance risk*.

From the perspective of business networks and achieving sustainable development, the following risks are defined (Fliaster and Dellermann 2016): *ecosystem characteristics risk and digital technology risk*.

From the angle of the business ecosystem, we distinguish the following (Adner 2006; Parida et al. 2016; Pierce 2009): *interdependence risk; integration risk; risk of opportunistic behaviour; power imbalance*.

Based on the specifics of the digital tourism ecosystem, the following groups of risks are distinguished (Lenkenhoff et al. 2018): *organizational, technological, social, cultural, economic, and ecological*.

Risk classification

We consider that, while relatively extensive, none of the classifications presented in Section 3.1 entirely cover all of the risks that participants in the digital tourism ecosystem may encounter; so, we offer our classification, dividing the risks into the following groups:

1. **Strategic risk—**This type of risk presents itself at the global corporate level and has a long-term impact on the development of the enterprise's organizational strategy. We can also include the particular risk of change/the project in it because it impacts all levels of management, but the decisions on a technology change or project are also made by senior management.
2. **Organizational risk—**This originates mostly from the digital ecosystem's characteristics as a form of network or business alliance in which various parties engage. It is difficult to identify each partner's function, place, and tasks within the framework of the DES; challenging coordination between participants; the diverse organizational structure of the players in the DES; and the distinct attitudes to work, communication, and decision-making in organizations. The ecosystem's open borders increase individual members' independence and are a prerequisite for the following risks:
    - ***Relational risk***—This refers to the cooperative relationship and the possibility that the ecosystem's partner will not follow the previously established rules and roles.
    - ***Performance risk***—This refers to the probability that the alliance's strategic objectives will not be met, even though the partners' cooperation is excellent. The ecosystem's inability to achieve its objectives has a detrimental impact on all of its partners.
    - ***Interdependence risk***—This is defined as the uncertainty caused by the coordination of ecosystem actors with new entries to it. As a result, one or more participants fail to meet their responsibilities. This threat grows in direct proportion to the number of ecosystem participants, severely limiting chances for innovation or product manufacturing.
    - ***Risk of opportunistic behavior***—This represents the prevalent risk in the field of global product development. To cut costs, ecosystem participants may oppose one another. As a result of this risk, the competitiveness of the ecosystem and

its participants is lowered, the DES's links are broken, and the ecosystem is practically destroyed.
- ***Power imbalance***—This is connected to the previous risk since it occurs when the more powerful organization changes the conditions, functioning, or roles in the DES without the knowledge or approval of the others. This causes financial difficulties for the ecosystem's smaller members.

3. **Technological risks**—The primary issue is creating interoperability between the DES's heterogeneous architectures, platforms, and infrastructure components. This makes it difficult to store, transfer, and process data and information. The three DES features that cause technological risks are ***modularity, convergence, and generativity:***
   - Modularity—A DES is built as a multi-layered modular architecture that aims to bring previously distinct components together to create new value. The architecture is not predetermined; rather, it emerges via third-party interactions with the platform. A lack of planning leads to complexity in innovation and, as a result, the risk of ecosystem failure.
   - Convergence—This refers to bringing together previously different industries, pre-generated user experiences, physical and digital components, and previously separated user experiences. As a result, new connections are made between previously unrelated knowledge and ecosystem participants, and the heterogeneity of newly formed knowledge, as well as innovation tools, is raised. This significantly increases the DES's complexity, as well as the dangers of participant conflict and failure.
   - Generativity—This refers to an innovation's unanticipated consequences. As the platform becomes too dispersed and fragmented, it becomes unappealing to potential participants. This decreases the worth of every single member of the ecosystem. The lack of certain economic, social, and technological restrictions increases the risk of undesired inter-organizational interactions.

Furthermore, the dual nature of technologies such as IoT and BD Analytics is a source of risks and challenges.

4. **Socio-cultural risks**—These are primarily caused by the type of DES, which is tourism, and is the outcome of tourism activity at the destination. In most cases, these are risks related to stress for residents; negative attitudes of locals toward the tourism ecosystem; increased crime; a low level of security for tourists; health problems caused by the spread of some diseases by tourists; damage to cultural sites; improper planning of tourist destinations related to event tourism; and oversaturation with tourists, which exacerbates the other problems.
5. **Ecological and environmental risks**—These are divided into two different groups:
   - ***Risk arising from the global environment***—This is essentially an unpredictable risk. This category includes natural disasters such as earthquakes, floods, hurricanes, etc., as well as those caused by human activity—war, terrorist attacks, etc.
   - ***Risks caused by the impact of tourism DES on the environment***: This refers to the destruction of local resources; reduction in biodiversity; excessive water and electricity usage; impaired drinking water and air quality; pollution; poor waste collection and disposal; high noise levels; changes in the natural ecosystem as a result of human activities; and climate change.
6. **Economic risks**—In essence, these are primarily operational and refer to the high costs of restoring and repairing destroyed objects; the loss of local jobs as a result of new people arriving at the destination; an increase in the prices of essential goods, as well as housing and land; seasonal employment and seasonal unemployment; money leakages as a result of tourist activity; the growth of the gray economy, etc.

3.2. Features of the Digital Tourism Ecosystem That Complicate Smart Tourism Destination Risk Management

The DE features of smart tourism destinations that are possible sources of risks and challenges are many and varied, and must be evaluated and taken into account when considering engaging in DEs. In this regard, we identify the following characteristics: the nature of the tourism business ecosystem; the characteristics of DE; the types of DE used; the business models adopted; the roles played by participants in the tourist destination's DE; the details of technical solutions, etc.

(a) The smart tourism destination business ecosystem consists of both *physical* (e.g., mobile phones, various vehicles, sensors, etc.) and *digital* (e.g., digital content, software, digital services, mobile services, etc.) components that interact with one another to create value for consumers (Kolloch and Golker 2016). The challenge is to create and sustain an environment in which these factors do not contradict one another, but rather, complement each other and contribute to the quality of tourism services. DEs of smart TDs offers solutions for managing the tourist destination in conditions of pandemic crises (Petrova and Tairov 2022).

(b) A DTE, being a *network structure*, faces the same risks and challenges that these structures encounter in terms of strategy, organization, and technology (Petrova et al. 2022). The fact that participants voluntarily give up control over certain resources for the sake of the joint activity of partners interacting in the decentralized network is a distinguishing aspect of the DE business model. This is a possible risky scenario.

(c) A DTE is a combination of two types of DE (Petrova et al. 2022). The majority of the services provided by the tourism destination's DE are information services and products. In this case, DE supports the service's production and consumption processes from beginning to end, and so contains both *a production and a consumer component*. The first is related to the manufacturing and selling of goods and services based on a range of data collection and analysis capabilities, while the second is focused on the connections formed and maintained following the purchase of a good or service (Subramaniam 2020). A DTE's two components "create interdependencies among entities that complement the data generated by product usage" (Subramaniam 2020) and can be the source of multiple types of data.

(d) The *type of service supplied* is another source of DTE risk. DTEs are the source of an increasing number of co-created new services that, in addition to being data-based (primarily information services), are realized based on continuous online access to a wide range of data sources, including data analysis services (based on technologies such as Open Data, Big Data, Big Data Analytics, and IoT), and make use of social applications, sensor networks, mobility systems, augmented reality, etc. New participants in DE are disrupting established supply and consumption structures. Suppliers are increasingly providing "experiences instead of services are offered, delivering a full package personalized for users' needs" (Schaffer et al. 2021).

(e) The tourism ecosystem provides services, experiences, and adventures while combining *various business models*. Gao et al. (2022, p. 233) investigate the evolution of tourism destination management and identify four distinct focuses (with corresponding business models) of this management: the delivery of tourism services (on the B2C model); tourist satisfaction (on the B2C model); service innovation (on the B2B model); sharing experience and expertise (on the B2C and C2C models); and the application of new technologies (on B2C and B2B models). Every business model, and especially their combination, is associated with challenges.

(f) TDEs are distinguished by *a variety of participants*. Value creation (experience) involves not only end users (tourists), but also locals, tourism service providers, transportation firms, intermediaries for tourists, digital service providers (telecommunications, banking, and payment services), public institutions, tourism infrastructures (such as theme parks and museums), reservation systems, information centers, and other businesses from various industries (such as healthcare and commerce) that support tourism

(Pencarelli 2020). TDE brings together a range of participants, including industry, various governmental and public–private actors, and participants with economic and social interests (Hillebrand et al. 2015). Every one of them has the potential to be both allies and rivals. "Each of them may have its objectives but none can survive on its own" (Gao et al. 2022). This allows for the creation of conflicts between individual goals, which can pose a risk.

(g) A substantial portion of the risks currently facing TDE participants are technical, and are risks related to the platforms and APIs used: a lack of a strategy for their use by the organization; a lack of new regulations in the affected areas; security risks when systems connect via APIs without considering the specific conditions of the environment; inappropriately selected APIs; infrastructure issues; a lack of trained personnel, etc. (Lenkenhoff et al. 2018; Shishmano et al. 2022).

3.3. Risks of IoT and BDA Technologies

Any emerging technology, in addition to providing new opportunities and benefits (Popova et al. 2022), can also bring some risks. In this section, we will explore the risks of **IoT** and **BDA** for enterprises that use them.

According to Dwivedi et al. (2017), the main benefits of using IoT are a result of the nature of the generated data, which are "big open linked data" with a very high degree of detail collected from heterogeneous sources in real or near-real time. However, it is precisely these features that add complexity to both data management processes and IT infrastructures in enterprises, as well as *risk management*. The improved ability to use and/or integrate data for the needs of various applications and objectives adds new challenges to risk management.

The vast volume of data generated by the IoT is a source of potential concerns. Unexpected expenditure of *additional infrastructure improvements and training* is added to typical IT deployment costs. On the one hand, changes in IT infrastructure are related to fulfilling data needs through IoT and BDA, as well as the need for interoperability and integration (Brous et al. 2017; Scarfò 2014; Yazici 2014; Brous et al. 2020), whereas, on the other hand, they enable the realization of the technology's new capabilities (and corresponding further investments) (Dwivedi et al. 2017). Organizational changes may also be necessary—for processes, decision-making methods, etc. (Verma and Shukla 2019; Brous et al. 2019). Additionally, the deployment and/or optimal use of IoT requires staff knowledge and skills for activities for which they are not ordinarily trained.

Another group of possible challenges and risks is predetermined by the open nature of IoT data. They are *technological and regulatory by nature* and arise from the fact that IoT tools allow the data generated by them to be accessible over the Internet and used by multiple users for different purposes. In this context, systems for publishing, exchanging, and utilizing data must be developed and implemented. The mechanisms are supposed to ensure, on the one hand, that the data are accessible and discoverable (Al-Fuqaha et al. 2015) and, on the other hand, that they are used correctly.

The third aspect of IoT-generated data that presents potential risks is connectivity. Aside from security *threats and data protection* (both public and private), *interoperability* and the large range of protocols used by various types of devices might be a problem (Brous et al. 2020). The heterogeneous nature of the data collected is often highlighted by researchers as a key advantage of IoT, but it may also be a source of problems and risks for IT infrastructure.

3.4. Potential of IoT and BDA for Risk Management Objectives

Participants in a tourism destination's digital ecosystem can use a variety of IoT technologies and applications to implement and manage business operations, activities, and communications. Using the suggested methodology, we searched the literature to determine the IoT application areas for tourism destinations. As a result, 12 sources in the literature were discovered that relate to the application of IoT in the tourism industry in

some way (using the keywords IoT and tourism). Also, two of these sources systematized the possibilities for using IoT in tourism destinations. According to Babu et al. (Babu and Subramoniam 2016) rapid growth of new-generation information and data is required for the use of IoT and the promotion of tourism. IoT can be used to manage ticket purchases and control operations, collect data for various purposes, support security, etc. According to Ordóñez et al. (Ordóñez et al. 2020), the usage of IoT is required because information received from tourists via IoT connectivity can be personalized, helping to meet their expectations and turn them into loyal clients. Table 1 presents the main IoT application directions in a digital ecosystem.

Table 1. Main IoT technologies and applications used in the digital ecosystem of a tourism destination.

ID	Technology	Functions	Application in Tourism
T1	RFID for information identification based on a wireless network	Control, monitor, and track tourists through readers and electronic tags	Tourist tracking in risky areas such as parks and reserves
T2	Wireless communication based on information sensation	Send calculated data collected via senses	Controlling the number of tourists based on a certain destination's capacity
T3	Intelligent chips	Gather information transmitted through a wireless network	Transmit data received from chips placed in tickets and other objects carried by travelers. Provide a wide range of statistical information
T4	Transmission of information obtained from various types of sensors via a wireless network	Transmission of information via a unified sensor-based synergistic network	Tourists and DES participants can obtain instant feedback on everything from performance to questions
T5	Electronic product code for information identification	Identification of information that is encoded in the RFID tag	Organizing a group of tourists with similar interests to exchange information about other places and make contact with local tour operators
T6	Information from sensors transmitted through a named object service	The smart environment recognizes and identifies objects using a service network address to acquire information from the Internet for adaptive functionality	Collects information from facilities and transmits it to tourists when they arrive at the destination
T7	Image sensors	Take photos and videos of tourists and objects	Increasing security by controlling the access and movement of tourists
T8	Different types of sensors installed in devices and infrastructure	A variety of sensors for temperature, pressure, smoke, chemical/gas information transmission regarding the status of devices and infrastructure	Collecting critical information in real-time about the condition and operation of devices and infrastructure, ensuring their replacement. guaranteeing that facilities operate safely

Source: adapted by Babu and Subramoniam (2016) and Ordóñez et al. (2020).

Table 2 presents: (1) the roles performed by participants in the digital tourism ecosystem (Schaffer et al. 2021); (2) the risks associated with these roles; and (3) IoT solutions that can be used in the management of the relevant risks. Typical TDE risks are presented in Section 3.1. In Table 2 they are marked as follows: R1—strategic risks; R2—organizational risk; R3—technological risks; R4—socio-cultural risks; R5—ecological and environmental risks; R6—economic risks. The IoT technologies and applications used in the digital ecosystem of a tourism destination are coded in Table 1 (T1 ÷ T8).

Table 2. Risk types and IoT applications adopted by participants in a tourism destination's DE.

Type/Role	Function/Description	Risk Presence and IoT Applications Utilized					
		R1	**R2**	**R3**	**R4**	**R5**	**R6**
Customers							
Tourists	Customers, consuming a variety of travel services and experiences			✓ T1 T2 T4 T5 T6 T7	✓ T1 T2 T3 T7	✓ T2 T7 T8	✓ T3
Intermediaries							
Transportation	Transport travel agents selling transport services	✓ T3	✓ T3 T4 T5 T8	✓ T3 T6 T7	✓ T2 T3 T4 T6	✓ T2 T3 T8	
Hospitality	Travel agents selling accommodation (hotels, guesthouses, campsites, etc.)	✓ T3	✓ T3 T8	✓ T3 T4 T5 T7	✓ T2 T3 T4	✓ T2 T8	✓ T3
Experiences	Travel agents selling experiences, tours, museum visits, etc.	✓ T3	✓ T3 T4 T8	✓ T1 T2 T3 T4 T5 T6	✓ T2 T3 T4	✓ T2 T8	✓ T3
Tour operators and travel agents	Providers of aggregated experiences (package tours)	✓ T2 T3 T5	✓ T3 T4 T8	✓ T1 T2 T3 T4 T5 T6	✓ T2 T3 T4 T5	✓ T2 T8	✓ T3 T5
Providers							
Tourism Experience Providers							
Transportation (public and private)	Transport service providers (airlines, bus tours, cruise ships)	✓ T2 T3 T8	✓ T2 T3 T4 T8	✓ T3 T6 T7 T8	✓ T2 T3 T6	✓ T6 T8	✓ T3
Accommodation	Hospitality service providers (hotels, boarding houses, campsites, etc.)	✓ T3 T8	✓ T3 T4 T8	✓ T3 T4 T5 T6 T7 T8	✓ T2 T3	✓ T2 T3 T8	✓ T3
Gastronomy	Providers of culinary experiences in visitor attractions and tourist destinations	✓ T3 T8	✓ T2 T3 T4 T8	✓ T3 T6 T7 T8	✓ T2 T3	✓ T2 T8	✓ T2 T3

Table 2. *Cont.*

Type/Role	Function/Description	Risk Presence and IoT Applications Utilized					
		R1	**R2**	**R3**	**R4**	**R5**	**R6**
Activities and attractions	Providers of tourist activities and attractions	✓ T3 T8	✓ T2 T3 T4 T8	✓ T1 T2 T3 T4 T5 T6 T7 T8	✓ T2 T3 T7	✓ T6 T8	✓ T3
Technology Providers							
Digital infrastructure technology providers	Providers of tourist activities and attractions (cloud infrastructure providers; on-premise infrastructure providers)	✓ T2	✓ T2 T4 T8	✓ T1 T2 T3 T4 T5 T6 T7 T8		✓ T2	
Cloud service providers	Offer cloud services		✓ T8	✓ T8			
Data technology providers	Offer relevant data for ecosystem participants		✓ T3 T4	✓ T1 T2 T3 T4 T5 T6 T7 T8			
Software technology providers	Offer suitable software solutions for ecosystem participants		✓ T3 T4	✓ T1 T2 T3 T4 T5 T6 T7 T8			
Analytics technology providers	Offer relevant analytics solutions for ecosystem participants		✓ T4	✓ T2 T3 T5			
Cybersecurity providers	Provide security solutions		✓ T7	✓ T7 T8			✓ T8
Search Engine Optimization (SEO)	Deliver web navigation services, gathering travel options according to the requirements of the users		✓ T3 T4	✓ T3 T5			
Augmented reality (AR), virtual reality (VR), mixed reality (MR)	Offer augmented reality, virtual reality, or immersive reality services		✓ T5	✓ T3 T4 T5	✓ T1 T6		

Table 2. *Cont.*

Type/Role	Function/Description	Risk Presence and IoT Applications Utilized					
		R1	**R2**	**R3**	**R4**	**R5**	**R6**
Artificial intelligence	Offer services or software solutions based on artificial intelligence		✓ T6 T7	✓ T1 T2 T3 T4 T5 T6 T7 T8	✓ T4 T6		
Blockchain	Provide blockchain-based services or software solutions		✓ T1	✓ T1 T3 T4 T5 T7 T8			
Internet of Things	Provide IoT solutions		✓ T2 T5 T6	✓ T1 T2 T3 T4 T5 T6 T7 T8	✓ T4 T5		
Destination marketing organizations	Marketing organizations that present specific tourist regions to potential customers		✓ T2	✓ T3 T4 T5			
Marketing and PR agencies	Specialized agencies for marketing and PR services in tourism		✓ T2	✓ T3 T4 T5			
Social Networks							
Social networks	Provide content and influence travel purchasing decisions			✓ T2 T3	✓ T2 T3		
Online Communities							
Content creators	Capture and deliver content to tourists and influence their decisions		✓ T5	✓ T5 T6	✓ T2 T3 T6		
Ratings	Capture the emotions of tourists and influence their decisions		✓ T5	✓ T5	✓ T2 T3		
Shared services—replace part of the delivery of experiences							
Shared transportation	Transportation services, provided or hired by private entities (a private person using their private car, etc.)			✓ T3	✓ T2 T3		✓ T3 T4
Shared accommodation	Accommodation, provided by private individuals, mostly residents (private apartment rental, etc.)			✓ T3	✓ T2 T3 T6	✓ T3	✓ T3

Table 2. *Cont.*

Type/Role	Function/Description	Risk Presence and IoT Applications Utilized					
		R1	**R2**	**R3**	**R4**	**R5**	**R6**
Shared experiences	Services provided by private individuals, mostly residents (city tours, etc.)			✓ T2 T3	✓ T2 T3	✓ T3 T6	✓ T3
Shared gastronomy	Local food, provided by private individuals, mostly residents, but not in a restaurant			✓ T3	✓ T2 T3	✓ T3	✓ T2 T3
Public organizations in the tourism sector							
State government institutions, local authorities, and communities	The government of specific categories of participants, as well as the development of norms, rules, and methods. Content sources	✓ T2 T3	✓ T2 T3 T5	✓ T1 T2 T3 T4 T5 T6 T7 T8	✓ T1 T2 T3 T4 T5 T6 T7 T8	✓ T2 T3 T6 T8	✓ T2 T3 T8
Public and private services							
Payments	Online payment, guaranteeing the transaction. The possibility of new business models		✓	✓			
Insurance services	Providing medical coverage, travel assistance, baggage insurance, trip cancellation, etc.		✓ T1	✓ T1 T3	✓ T2 T3 T5	✓ T6 T8	✓ T3
Universities, research institutes	Research and development of innovations, education, training, and expert consultation		✓ T3	✓ T2 T3	✓ T2 T3 T4		

Source: authors' elaboration.

In order to associate the risks with roles in the digital tourist ecosystem and to select relevant IoT applications for each role's risk management, we performed the following steps: (1) risk identification—identifying potential risks for all participants in the digital tourism ecosystem; (2) participant roles—defining the roles and participants within the digital tourism ecosystem; (3) mapping roles to risks—for each defined role, the most frequent and specific risks are determined; (4) IoT application selection—the selection of IoT apps that correspond to the defined risks.

4. Discussion

As a result of identifying the types of risks faced by DE participants of the tourism destination and the opportunities that IoT directly or indirectly offers to solve them (presented in Table 2), it can be concluded that IoT cannot be used by all DE participants of tourist destinations to meet all types of risks and challenges. In terms of risk types, as IoT integrates into objects and accessories worn by tourists, as well as equipment and infrastructure in tourist destinations, the information generated by them is particularly beneficial for countering the risks experienced by users (tourists) and tourism experience providers and public organizations in the tourism sector. Other participants in DTEs, such as participants who support the tourism infrastructure (state and local governments and local communities), and players maintaining direct and indirect contact with tourists (service providers and service intermediaries), can also successfully employ IoT to mitigate risks, although on a smaller scale.

In terms of risk prevention options, the information provided by IoT is most suited to addressing technological and socio-cultural risks, and at the current stage, is the least

beneficial for managing economic and strategic risks. Table 2 shows that the types of risks and the capabilities of IoT to resolve them are nearly the same for DE participants of the respective tourism destination types (intermediaries, tourism experience providers, technology providers, etc.).

Limitations and Future Work

This research primarily focuses on the benefits and potential risks associated with IoT and BDA, overlooking other critical factors affecting tourism industry development and risk management like market competition, regulatory compliance, crisis preparedness, and customer experience. While this research discusses the benefits of IoT and BDA, it does not provide practical guidance on how tourism ecosystem participants can successfully implement these technologies, including considerations for scalability, data privacy, and regulatory compliance; our future research will be in these directions.

5. Conclusions

IoT and BDA are emerging as essential factors in the development of the tourism industry, and they facilitate the creation, operation, and management of smart TDs. The integration of IoT into a smart TD's IT infrastructure, as well as the use of analytical tools such as BDA to process the collected data, offer numerous advantages. The application of these technologies to risk management objectives has great and growing potential.

From a theoretical aspect, the present article contributes to the growth of the literature devoted to DTE risk management issues. It fills thematic gaps by examining the risks associated with participation in DTE, and specifically, classifies risks for DTE participants; analyzes the DTE features that add challenges to the risk management of smart TDs; defines the risks of technologies (IoT and BDA); identifies core IoT technologies and applications used in smart TDs' DEs; and defines the risks associated with the roles of the participants in DTE and IoT solutions that can be used to manage the relevant risks.

From a practical aspect, this article correlates the roles performed by participants in DEs of smart TDs with the risks associated with these roles, and can be used as a guide in evaluating whether to participate in or develop such DTEs.

The implementation of IoT and BDA by the participants in DEs of smart TDs gives a direct or indirect answer to some of the risks we have systematized, but it is also a source of certain risks.

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