



## Research article

# The implications of industry 4.0 for the tourism sector: A systematic literature review

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## ABSTRACT

The tourism sector is presently facing new challenges resulting from the increasing digitalization of society. Boosted by industry 4.0, new tourism dynamics are emerging. Nonetheless, the real significance of this revolutionary trend and its implications still lack further development. Aiming to assess the state-of-the-art about the digital transformation on the tourism sector, triggered by the 4.0 paradigm, the present study followed a systematic literature review approach, adopting the PRISMA protocol guidelines. A total of 44 manuscripts were considered relevant for analysis. The findings illustrate that the 4.0 paradigm is being embraced from three main perspectives: the visitor-technology interaction and its influence on decision-making, the digital competencies in tourism students, and the technology penetration in different sub-sectors of the supply chain. However, studies conceptualizing the 4.0 paradigm in the tourism sector are lacking, beyond empirical research on areas such as digital skills, pros and cons of industry 4.0 technologies, and spatial consequences.

## 1. Introduction

Technological developments have been present in our civilization since early ages. Nonetheless, as commonly addressed, technology can be traced to the first industrial revolution, a period known for establishing the foundations of modern science and society [1]. Presently, a new era marked by emerging, digital, and constantly changing technologies rules and defines the path through which modern society should move, disrupting and influencing everyday life [2]. This ongoing digital transformation process needs to be fully understood, guaranteeing that all the changes occurring are adequately addressed, while challenges are overtaken, and the potential benefits are spread through all sectors of society [2].

For instance, the hasty and continuous technological evolutionary process within the industrial context triggered disruptive moments that led to the emergence of new paradigms. Four milestones within the industrial context are known [3,4]: first, the mechanization of processes through the development of the steam engine and use of steam power (First Industrial Revolution); second, the emergence of electricity, steel production, and petroleum exploration, triggering mass production and reaching its peak with the production of the first car model by Ford (Second Industrial Revolution); third, the development and implementation of electronics and information technologies connected with the Internet, resulting in the automation and computerization of processes (Third Industrial

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Revolution). More recently, the fourth industrial revolution broke out, providing the basis for the emergence of a new paradigm that is disrupting the economic and social structures – Industry 4.0 (I4.0) [5–8].

The term I4.0 has its foundations in a national strategic initiative established by the German government in 2011 [3,9,10], aiming to improve digital manufacturing through the digitization and interconnection of products, value chains, and business models [9]. Despite some conceptual indefiniteness [6], the I4.0 implies that everything within the industrial context is connected and able to communicate and process data autonomously, forming an intelligent value chain [11]. This is enabled by a combination of several information and communication technologies (ICTs) operating in a cyber-physical system (CPS), where both digital and real worlds converge [10,11].

There is no general agreement regarding the main technologies associated with I4.0. However, some of the most common among the literature and constituting the pillars of technological advancement, are the following: artificial intelligence (AI) and autonomous robots, blockchain, simulation, internet of things (IoT), cybersecurity, cloud, additive manufacturing, augmented reality (AR), and big data analytics [10–12].

New digital dynamics are being triggered by the 4.0 paradigm in several economic sectors, including tourism [13]. This is not new, as technological developments always took part in the tourism value chain from an early age [1]. The most recent and ongoing digital revolution encompasses daily challenges for the sector, disrupting the established business models and bringing new actors and ways of thinking to the picture [1,14]. In this sense, [14] prospect is that the fourth industrial revolution will establish new trends and entail numerous challenges to the tourism industry in the short and mid-run. Among these, the big five themes will be AI, big data, hybrid cloud, the IoT, and mobile. At the same time, data privacy and security, environmental sustainability, and integrity will represent tourism stakeholders' most critical challenges. These expectations position technological innovation as each player's main target, as [15] claim. Accordingly, businesses must be aware of the potentialities and consequences of ICT innovations, which constantly change demand and supply dynamics. On the other hand, the demand expectations and propensity to adopt the technology must be measured as the technology's adequacy will determine visitors' satisfaction.

This growing value of technology seems to have been influenced by the 4.0 industrial paradigm, perhaps triggering the beginning of the tourism 4.0 (T4.0) era. Nonetheless, few studies have embraced the 4.0 paradigm within tourism [e.g., 16,17]. To Ref. [16] T4.0 is a new ecosystem relying on smart technologies and connected to the principles of I4.0, specifically interoperability, virtualization, decentralization, real-time data gathering and analysis capability, service orientation, and modularity. Consistent with the I4.0 framework, the technologies applied in the tourism context converge and merge both virtual and physical worlds, establishing the main pillars of a new tourism ecosystem. However, the term T4.0 seems to be built on adopting new technologies while disregarding, at first sight, the sustainability dimension, a vital feature for implementing more balanced tourism development models. It is precisely the point highlighted by Ref. [17]. Although the approach to the concept resembles that of I4.0, that is, tourism experiences mediated by interconnected technologies, the study warns that most of the 4.0 solutions were not developed to assist visitors and might even oppositely affect tourist experiences. As so, the authors propose developing a system centered on the human experience to mediate the effects of 4.0 technologies and incorporate sustainability principles, particularly social and economic dimensions. Nonetheless, the concept needs further clarification, as several questions remain to be answered, particularly if the I4.0 principles are suitable for the tourism sector and in which tourism fields the 4.0 paradigm has prevailed at this point.

Based on these insights, the present study intends to discuss the 4.0 paradigm within the tourism sector through a theoretical and reflexive approach, since I4.0 in service sectors still lacks a more in-depth review [18]. Following a systematic literature review structure, the main goal of this study is to comprehend the ongoing digital transformation of the tourism sector, based on the new digital paradigm triggered by the fourth industrial revolution. Thus, the following two research questions were formulated: (1) *which tourism sub-sectors and fields are embracing this digital transformation triggered by the 4.0 paradigm?* and (2) *which pillars of Industry 4.0 are being introduced to change and transform the tourism sector?* To date, no research underlining these topics is known, except for the study by Ref. [8]. Through a comprehensive literature review approach, the latter aimed to analyze the potential benefits and challenges of the fourth industrial revolution in the hospitality and tourism industry. The study only captured the potentialities and negative aspects of the fourth industrial revolution in the hospitality industry, through several examples of hospitality firms, not providing an overall panorama of the tourism sector. Recognizing the valuable lessons retrieved from Ref. [8], the present study differs from the latter by extending the analysis to other fields within tourism. Thus, this work is expected to generate valuable contributions to academics and managers, particularly by demonstrating how I4.0 is being steadily transferred to the tourism industry, mainly through the implementation of technologies with direct implications in the tourist experience, business operations, and destination management. It also unveils the necessity of adapting tourism courses to a growing digital reality which will prevail in the future and in which today's students will have a prominent role. Moreover, the insights of the reviewed works will also address the guidelines for future research.

## 2. Methodology

### 2.1. Data collection

This review examines the academic literature published until 2022 (inclusive) addressing the implications of I4.0 within the tourism sector. A systematic literature review was implemented to assess the available publications on this subject according to specific search and selection criteria [19]. As systematic reviews are more prone to bias [20], the adopted literature search process followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA 2020) guidelines [21]. The formulation of a protocol enables a clear, accurate, and transparent systematic review process, contributing to lessening arbitrariness during data collection and interpretation [20,21]. The search protocol, identifying both inclusion and exclusion criteria, is presented in Fig. 1.

The SCOPUS and Web of Science (WOS) databases were used to identify relevant scientific works. Two steps were followed to identify suitable search terms. First, landmark studies regarding the topics under analysis were examined, defining the rationale and theoretical framework [22]. For instance, seminal literature concerning the industry 4.0 topic [e.g., 5,6,7] allowed the identification of several related keywords as “cyber-physical systems”, “fourth industrial revolution”, “industrie 4.0”, “I4.0”, or “smart manufacturing”. Secondly, after retrieving the potential search terms from the literature, the researchers debated and tested different code combinations [23]. The final search string was defined as: “industry 4.0” OR “i4.0” OR “fourth industrial revolution” OR “4th industrial revolution” AND “tour\*” OR “visitor\*” OR “travel\*”. As presented in Fig. 1, the asterisk wildcard symbol (\*) was used in the three terms related to the tourism activity, enabling search for word variations, e.g., tourism, tourist, tourists; visitor, visitors; travel, traveler, travelers, traveling.

This process employed the above-mentioned keywords to search within three sections of the articles: abstract, title and keywords. A total of 435 records was generated. A first filter was applied to exclude documents with minimal contribution to empirical knowledge [24], specifically conference reviews, reviews, editorials, and short surveys. Secondly, only records written in English, Portuguese, and Spanish were considered for analysis, guaranteeing the effectiveness of the review. Also, the search was not limited to a specific period due to the topic’s novelty. Finally, the researchers individually screened each document, analyzing the title, abstract, and keywords to ensure its significance and value for the study. If this step was inconclusive, the full text was reviewed for further clarity and assessment of the document’s relatedness to the subject. Studies were rejected mainly due to the insufficient linkage or incapacity to establish a coherent relationship between industry 4.0 and tourism. In addition, those using certain constructs (e.g., industry 4.0, the fourth industrial revolution, tourism 4.0, innovation) more like a buzzword instead of addressing and discussing them rationally were also removed. Completed the screening process, 355 records were excluded, making 80 documents eligible for analysis. Afterwards, additional 36 publications were discarded as they were unavailable, duplicated in the same database, and/or vaguely presented the topics, thus representing no added value for the analysis and discussion. The final number of documents included for analysis was 44.

2.2. Data analysis

The documents within the final sample were subjected to meticulous analysis. First, a descriptive analysis, followed by discussion, was employed, including the distribution of documents over time, the main publication sources and subject areas, the geographical scope by authors’ affiliation, and the main theoretical framework. Additionally, a network analysis based on keyword co-occurrence was performed using the VOSviewer software. Secondly, a content analysis was applied to both theoretical and empirical works, although with a particular emphasis on the latter, mainly due to their contribution to knowledge creation, unlike the marginal relevance of theoretical articles [24,25].

The novelty of the topic requires the development of a classification framework to guarantee the feasibility of the procedure [24] based on a methodic process where categories and topics gradually emerge during the articles’ review process [25]. To facilitate this procedure, each document information (e.g., title, topic under analysis, objectives, methodology, findings, main conclusions,

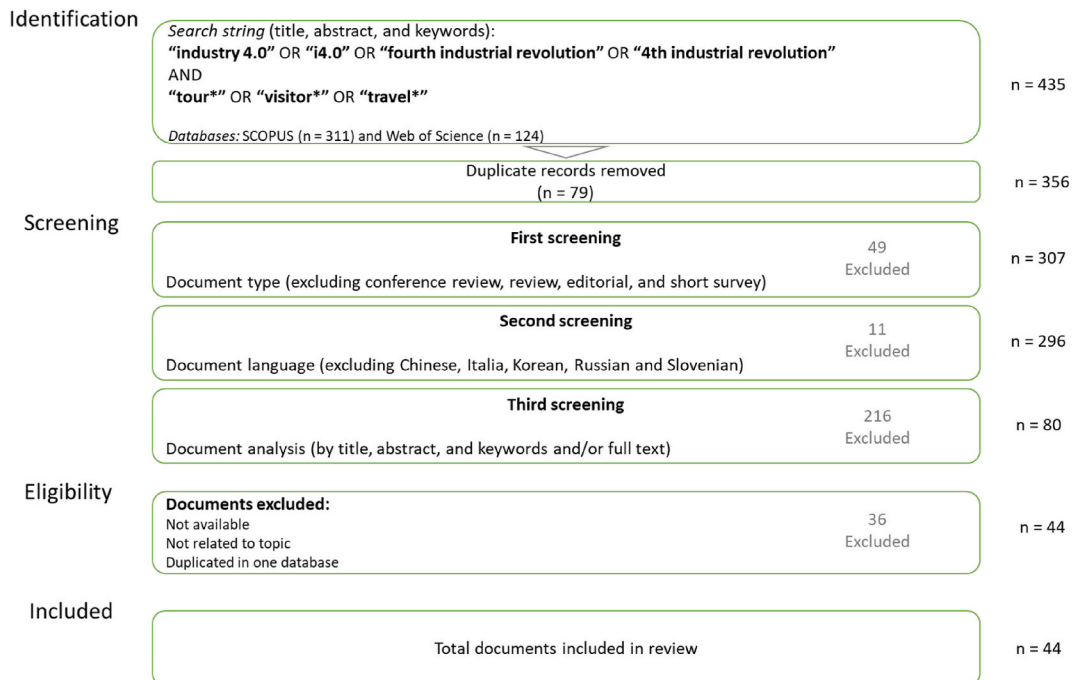


Fig. 1. Literature search process.

technologies under study) was systematized and coded [25,26]. The content analysis approach applied in this study followed the rationale of previous systematic reviews [e.g., 24,25,26]. It worked as an analytic framework to capture the tourism subsectors in which the I4.0 has been flourishing and the emerging technologies that are gaining increasing attention. Following the coding process, the articles were first reviewed by one researcher who designated them to suitable research topics. This classification was later revised and discussed among the authors to ensure the method's efficacy and reduce potential bias, promoting some adjustments to the initial classification and guaranteeing its optimization. In this regard, the relationship between I4.0 and tourism is outlined according to three main fields: demand, education, and supply.

### 3. Findings and discussion

#### 3.1. Publications by year, source, and subject area

Combining the subjects under analysis, 44 publications were retrieved from two of the most renowned international scientific databases. The first related publication reports to 2016 (Fig. 2), even though the topic I4.0 was first introduced at the beginning of 2010s. Steady growth in the number of publications is observed until 2022, excluding 2017, when no documents were found. The last three years concentrate around 75 % of the total number of publications, with an aggregate of 33 documents. Due to the growing relevance of these topics and the continuous digitalization of the tourism sector, it is expected that the upcoming years will register an increase in the quality and quantity of publications.

No significant results are reported concerning the distribution of documents per source, meaning that there is not a substantial number of publications concentrated in a single source or group of sources (Table 1). Specifically, the publications were distributed by 36 journals or proceedings, with nearly 80 % of the journals publishing no more than one document, while only eight published two studies. This is suggestive of the absence of journals specialized in these themes or is symptomatic of the high transversality of the research topic and its emerging relevance. The journals and proceedings were distributed into 18 subject areas, matching both SCOPUS and WOS classifications. It should be mentioned that the same document might have been classified into more than one field, according to the journal's scope. Three categories stand out from the remaining, particularly "Business, Management and Accounting", with 17 publications, and "Social Sciences" and "Computer Science", with 14 and 13 publications, respectively.

#### 3.2. Research methods and main topics under analysis

The topic's novelty justifies an overview of the research methods implemented by the authors to understand which approaches are prevalent and/or gaining relevance within the academic context. The research methodology is available in Table 1. Empirical studies are the most representative ones in the sample ( $n = 20$ , 45.5 %), distributed by quantitative ( $n = 10$ , 22.7 %), qualitative ( $n = 7$ , 15.9 %), and mixed approaches ( $n = 3$ , 6.8 %). Most quantitative studies applied questionnaires to collect data ( $n = 8$ , 18.2 %), followed by alternative methods, such as experiments and foresight. Studies based on questionnaires were mainly used to study the demand side, specifically the implications of technology on visitors' behavior during the three phases of a tourism trip [e.g., 27,28,29,30,31,32]. Questionnaires were also employed to examine the digitalization process within the educational context [e.g., 33, 34] and to analyze the adaptation of small and medium businesses to technologies [e.g., 35]. The foresight method was used to develop a technological platform to improve sustainable management practices in a tourism destination [e.g., 36]. On the other hand, interviews represented more than half of the studies included in the qualitative category ( $n = 4$ , 8.9 %), followed by netnography and ethnography methods. Interviews were particularly useful in examining technology competencies [e.g., 37] and implementation [e.g., 38] within the

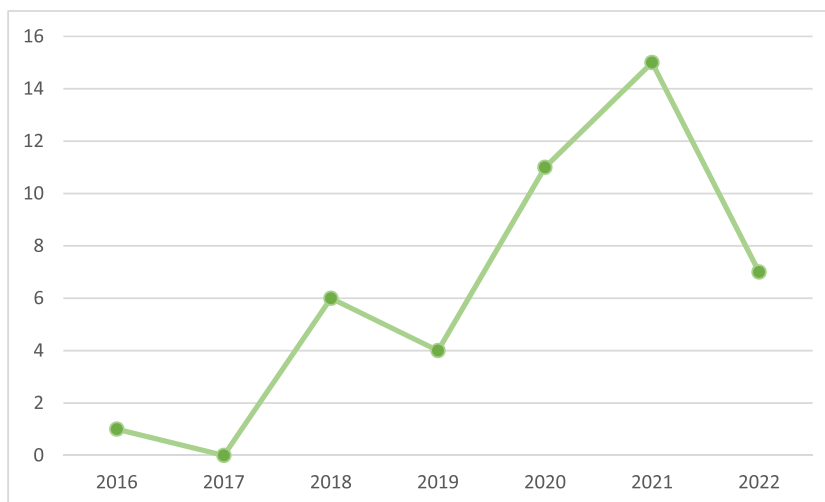


Fig. 2. Number of publications considered for analysis from 2016 to 2022.

**Table 1**  
Authors by source and subject area.

| Publication Source  | Author(s)                        | Subject area  | Research Methodology                            | Sample and methods  | Data analysis techniques  | Dependent variable  | Independent variable  |
|---|----------------------------------|---|---|---|---|---|---|
| Journal of Engineering Science and Technology                               | Ana et al. (2021)                | Engineering   | Literature review                               | n.a.  | n.a.  | n.a.  | n.a.  |
| Proceedings of EDULEARN18 Conference  | Bertacchini et al. (2018)        | Education Educational Research  | Quantitative Questionnaire-based and experiment | Questionnaire from tourism degree students  | Descriptive analysis  | n.a.  | n.a.  |
| The European Proceedings of Social & Behavioural Sciences                   | Bilgili & Ozkul (2019)           | Business, Management and Accounting   | Quantitative Questionnaire-based                | 67 questionnaires from hotel guests   | Descriptive analysis  | n.a.  | n.a.  |
| Journal of Hospitality, Leisure, Sport & Tourism Education                  | Bilotta et al. (2021)            | Business, Management and Accounting; Social Sciences                          | Quantitative Questionnaire-based                | 30 questionnaires from 30 students from the course degree in tourism science  |   | n.a.  | n.a.  |
| IEEE  | Bodkhe et al. (2019)             | Computer Science; Engineering; Decision Sciences                              | Theoretical                                     | n.a.  | n.a.  | n.a.  |   |
| Procedia Computer Science   | Calero-Sanz et al. (2022)        | Computer Science; Engineering   | Qualitative Online review-based                 | Online reviews related to service robots in the hospitality sector  | Content analysis through machine learning models  | n.a.  | n.a.  |
| The Emerald Handbook of Entrepreneurship in Tourism, Travel and Hospitality | Chiloane-Tsoka (2018)            | Business, Management and Accounting; Economics, Econometrics and Finance      | Literature review                               | n.a.  | n.a.  | n.a.  | n.a.  |
| PACIS 2019 Proceedings  | Chung, Jia, Xiaorui & Koo (2019) | Computer Science  | Quantitative Questionnaire-based                | 145 questionnaires from visitors visiting heritage sites  | Structural equation modelling   | Augmented reality satisfaction  | Usefulness<br>Ease of use   |
| GeoJournal of Tourism and Geosites  | Dey et al. (2022)                | Earth and Planetary Sciences; Social Sciences                                 | Quantitative Questionnaire-based                | 100 questionnaires from college students  | Structural equation modelling   | Pro-environmental behaviour   | Enjoyment<br>Positive affectivity<br>Negative affectivity<br>Environmental concern<br>Perceived effectiveness |
| Tourism Recreation Research   | Dhakal & Tjokro (2021)           | Business, Management and Accounting; Social Sciences; Environmental Science   | Mixed Questionnaire and interview-based         | 81 questionnaires from tour and travel agents, hotels and restaurants; and 11 interviews from tourism enterprises managers  | Descriptive statistical analysis, Two-by-two cross-tabulations, Chi-squared, and Kruskal – Wallis | Organisational attributes<br>Perceptions of 4IR-related opportunities<br>Perceived impacts of the 4IR on the sector | Enterprise type<br>Number of staff<br>Technological stage   |
| Sustainability  | Flórez et al. (2022)             | Computer Science; Energy; Engineering; Environmental Science; Social Sciences | Quantitative Foresight method                   | Foresight method with tourism experts, ecologists, business-people, representatives from the community, government, and experts in innovation and technology, with the application of a questionnaire |   | n.a.  | n.a.  |

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Table 1 (continued)

| Publication Source  | Author(s)                         | Subject area   | Research Methodology                                    | Sample and methods   | Data analysis techniques                   | Dependent variable                         | Independent variable                                     |
|---|-----------------------------------|--|---|--|--|--|--|
| ACM International Conference Proceeding Series  | Hoi (2020)                        | Computer Science   | Theoretical   | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| Journal of Hospitality and Tourism Technology   | Hsu & Teng (2022)                 | Social sciences  | Qualitative Interview-based                             | 26 semistructured interviews with governmental, industrial and academic experts                      | Thematic analysis                          | n.a.                                       | n.a.   |
| Proceedings of ICESoS 2016  | Ivanovic et al. (2016)            | Public Administration  | Theoretical   | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| International Journal of Engineering & Technology   | Jwa (2018)                        | Computer Science; Environmental Science; Engineering; Biochemistry; Genetics and Molecular Biology; Chemical Engineering | Theoretical   | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| Journal of Engineering and Applied Sciences   | Kang & Jwa (2018)                 | Engineering  | Theoretical   | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| Journal of Asian Finance, Economics and Business  | Khristianto et al. (2021)         | Business, Management and Accounting; Economics, Econometrics and Finance   | Quantitative Questionnaire-based                        | 175 questionnaires from directors and managers of small and medium tour operators                    | Structural equation modelling              | Innovation Competitive advantage           | Market sensing capability<br>IT competency<br>Innovation |
| Journal of Interdisciplinary research   | Kordos & Berkovic (2020)          | Science Technology   | Qualitative Interview-based and secondary data analysis | Structured interviews with hotel managers<br>Secondary data retrieved from governmental institutions | Comparative analysis and logical deduction | n.a.                                       | n.a.   |
| Worldwide Hospitality and Tourism Themes  | Loureiro (2018)                   | Business, Management and Accounting; Social Sciences; Environmental Science<br>Agriculture                               | Theoretical   | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| Scientific Papers Series- Management, Economic Engineering in Agriculture and Rural Development | Lulcheva & Komitov (2020)         | Agriculture  | Theoretical   | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| IEEE  | Makoondall-Chadee et al. (2021)   | Business, Management and Accounting; Computer Science; Decision Sciences; Mathematics                                    | Literature review                                       | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| Sustainability  | Maquera et al. (2022)             | Computer Science; Energy; Engineering; Environmental Science; Social Sciences  | Qualitative Interview-based and field work              | Interviews with stakeholders (tourists, local businessmen, and residents)                            | Content analysis                           | n.a.                                       | n.a.   |
| International Journal of Contemporary Hospitality Management                                    | Mariani et al. (2021)             | Business, Management and Accounting  | Qualitative Interview-based and field work              | Field work and interviews with destination managers and CEOs of DMOs and convention bureaus          | Content analysis<br>Conceptual model       | n.a.                                       | n.a.   |
| African Journal of Hospitality, Tourism and Leisure   | Matikiti-Manyevere & Rambe (2022) | Business, Management and Accounting; Social Sciences   | Literature review                                       | n.a.   | n.a.                                       | n.a.                                       | n.a.   |
| South African Journal of Economic and Management Sciences                                       | Mgiba & Chilya (2020)             | Business, Management and Accounting; Economics, Econometrics and Finance   | Quantitative Questionnaire-based                        | 400 questionnaires from visitors   | Structural equation modelling              | Loyalty<br>Satisfaction or dissatisfaction | 4th industrial revolution environment                    |

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Table 1 (continued)

| Publication Source   | Author(s)                | Subject area   | Research Methodology                               | Sample and methods  | Data analysis techniques   | Dependent variable  | Independent variable   |
|--|--------------------------|--|--|---|--|---|--|
|  |                          |  |  |   |  | Online-based intention to visit<br>Reputation<br>Pre-visit experience | Reputation<br>Pre-visit experience<br>Online-based intention to visit<br>Satisfaction or dissatisfaction |
| Communitas   | Mgiba (2021)             | Communication  | Quantitative<br>Questionnaire-based                | 235 questionnaires from visitors  | Structural equation modelling  | Loyalty intentions  | 4th industrial revolution environment<br>Reputation<br>Pre-visit experience                              |
| Iberian Journal of Information Systems and Technologies                    | Molano et al. (2020)     | Computer Science                                     | Theoretical  | n.a.  | n.a.   | n.a.  | n.a.   |
| African Journal of Hospitality, Tourism and Leisure                        | Nengovhela et al. (2020) | Business, Management and Accounting; Social Sciences | Quantitative<br>Questionnaire-based                | 208 questionnaires from visitors  | Confirmatory factor analysis   | n.a.  | n.a.   |
| Tourism  | Onyango & Kesa (2018)    | Business, Management and Accounting                  | Theoretical  | n.a.  | n.a.   | n.a.  | n.a.   |
| Tourism Planning & Development   | Orea-Giner et al. (2021) | Business, Management and Accounting; Social Sciences | Qualitative<br>Online review and roundtable-based  | 5000 online reviews related to museums attributes; and roundtable discussion with 7 experts (museum and tourism professionals)  | Text mining analysis   | n.a.  | n.a.   |
| Journal of Hospitality and Tourism Technology                              | Osei et al. (2020)       | Social sciences                                      | Literature review                                  | n.a.  | n.a.   | n.a.  | n.a.   |
| Information Technology & Tourism   | Pencarelli (2020)        | Computer Science; Social Sciences                    | Theoretical  | n.a.  | n.a.   | n.a.  | n.a.   |
| IOP Conference Series: Earth and Environmental Science                     | Prasetyo et al. (2020)   | Environmental Science; Earth and Planetary Sciences  | Mixed<br>Questionnaire, focus group and simulation | 100 questionnaires from residents; Focus group with local elites (traditional leaders, religious leaders, community leaders, heads of resorts, and representatives of the general public); and participatory rural appraisal through simulation | Univariate statistical analysis<br>Content analysis                                | n.a.  | n.a.   |
| International Journal of Contemporary Hospitality Management               | Rana et al. (2022)       | Business, Management and Accounting                  | Literature review                                  | n.a.  | n.a.   | n.a.  | n.a.   |
| Proceedings of the 54th Hawaii International Conference on System Sciences | Riemer & Seymour (2021)  | Engineering  | Theoretical  | n.a.  | n.a.   | n.a.  | n.a.   |
| International Journal of Event and Festival Management                     | Ryan et al. (2020)       | Business, Management and Accounting                  | Mixed<br>Online comments and questionnaire-based   | 234 online posts from a LinkedIn group; and 52 questionnaires from academic members   | Thematic analysis (qualitative)<br>Descriptive statistical analysis (quantitative) | n.a.  | n.a.   |

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Table 1 (continued)

| Publication Source                                     | Author(s)                   | Subject area   | Research Methodology    | Sample and methods   | Data analysis techniques                     | Dependent variable | Independent variable |
|--|-----------------------------|--|-------------------------|--|--|--------------------|----------------------|
| Smart Innovation, Systems and Technologies             | Sá et al. (2021)            | Computer Science; Decision Sciences  | Theoretical             | n.a.   | n.a.   | n.a.               | n.a.                 |
| Springer Proceedings in Business and Economics         | Sarigiannidis et al. (2021) | Business, Management and Accounting; Economics, Econometrics and Finance   | Theoretical             | n.a.   | n.a.   | n.a.               | n.a.                 |
| Tourism, Hospitality & Event Management                | Sifolo & Henama (2021)      | Business, Management and Accounting; Social Sciences; Environmental Science; Economics, Econometrics and Finance | Theoretical             | n.a.   | n.a.   | n.a.               | n.a.                 |
| Information Technology & Tourism                       | Stankov & Gretzel (2020)    | Business, Management and Accounting; Computer Science  | Theoretical             | n.a.   | n.a.   | n.a.               | n.a.                 |
| IOP Conference Series: Earth and Environmental Science | Timoshenko (2021)           | Environmental Science; Earth and Planetary Sciences  | Theoretical             | n.a.   | n.a.   | n.a.               | n.a.                 |
| AIP Conference Proceedings                             | Truong et al. (2021)        | Physics and Astronomy  | Qualitative Ethnography | Ethnomusicology and Cultural anthropology to collect and record all the performance and documents related to cultural heritage | Digitization of intangible cultural heritage | n.a.               | n.a.                 |
| Procedia Computer Science                              | Turkay et al. (2019)        | Computer Science   | Theoretical             | n.a.   | n.a.   | n.a.               | n.a.                 |
| Journal of Social Sciences and Humanities              | Wahed et al. (2021)         | Social sciences  | Literature review       | n.a.   | n.a.   | n.a.               | n.a.                 |



hospitality context, to explore the benefits of technology to boost community-based rural tourism [e.g., 39], and to delve into the relationship between innovation and destination competitiveness [e.g., 40]. Additional qualitative studies used similar methods, although with different contexts of application. Netnography-based studies were developed to analyze secondary information retrieved from social media [e.g., 41] and Web pages [e.g., 42], while one study [43] used ethnography methods combined with digitization techniques towards cultural sustainability. There is also a vast number of theoretical studies ( $n = 17$ , 38.6 %) promoting the conceptualization of emerging topics [e.g., 14,16,44], proposing the development of smart solutions for tourism products [45,46], management models [47] and vocational models [48], or simply analyzing the implications of specific technologies from the I4.0 era in the tourism sector [e.g., 13,15,17,49,50,51,52,53,54,55]. This might be partially explained by the fact that T4.0 is not a well-established concept in the literature, while the discussion around the digital transition in the tourism sector is still in process.

Among the three studies applying mixed methods, the digital readiness of tourism supply was discussed through questionnaires and interviews [56], and questionnaires and content analysis of social networks [57]. One additional mixed methods study analyzed how I4.0 could benefit participatory eco-tourism management practices by local communities [58] by applying distinct quantitative and qualitative techniques, such as questionnaires, focus groups, and participatory rural appraisal.

Additionally, seven studies were identified as literature reviews. They are of great importance for the development of future studies as they analyze the potential impacts of the fourth industrial revolution in the tourism industry in distinct settings, such as cultural heritage protection [59], education [60], hospitality [8], pandemic crises [61], small island developing states [62], and social entrepreneurship [63]. Also, the prospects of blockchain are explored in the study by Ref. [64].

### 3.3. Theory-based research

Most papers (81.8 %) did not follow any theory or theoretical framework as background. Out of the 44 documents considered in the analysis, only 9 presents, at least, one theory (Table 2). The technology acceptance model (TAM) was adopted by two studies [28,30], being the most representative one. Then, four more theories were used by the remaining works: the theory of attractive quality [27], the theory of pro-environmental behavior [29], the digital divide theory [56], and the theory of planned behavior [30]. Other authors adopted distinct models or frameworks to develop their work, such as the statistical framework for measuring the sustainability of tourism [47] and the human-centered design approach by Ref. [17]. The elaboration likelihood model was adapted as a theory by Ref. [32] to investigate visitors' decision-making towards smart tourism.

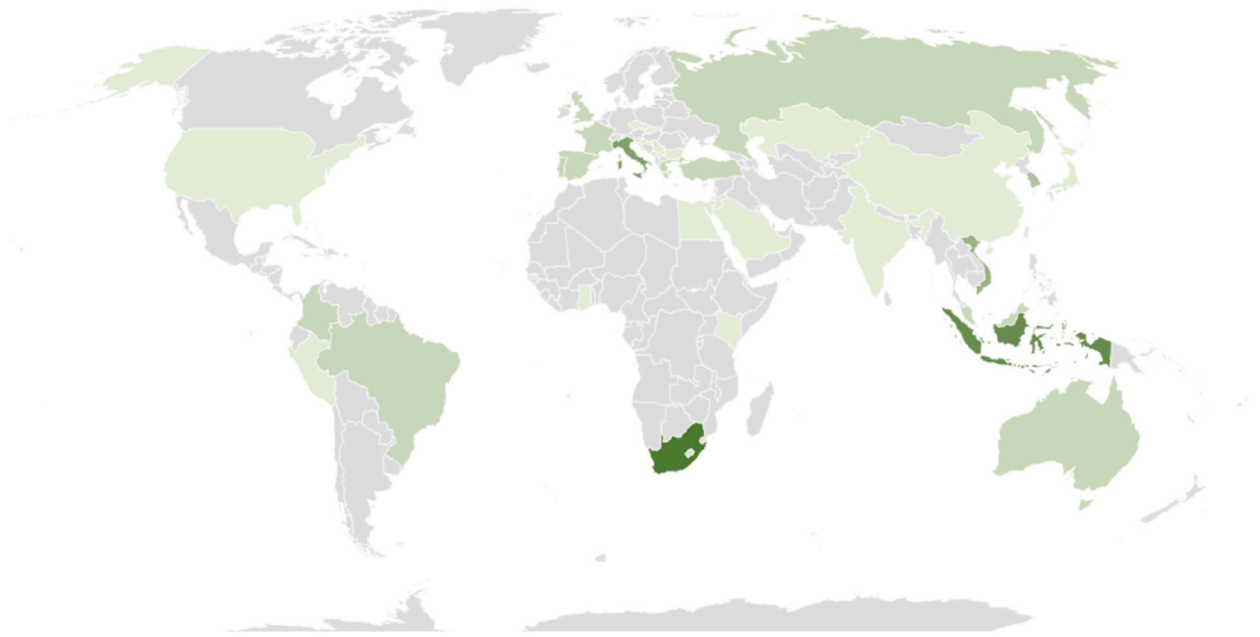
Several reasons might justify the lack of theory-based studies. First, this might be attributed to the novelty of the topic. In fact, as one of the findings of this research, only a few studies have intersected I4.0 and tourism. Beyond that, they had followed a more exploratory approach, rather than grounding their work in existing theories. Second, the above-mentioned interdisciplinary nature of the topic, encompassing distinct areas such as technology, management, or economics, might also make it difficult for researchers to find a theoretical framework that captures the complexities of both domains. Due to the absence of theory-based studies, several theories such as innovation diffusion theory could contribute to extending knowledge regarding visitors' and firms' intention to adopt I4.0 technologies [65]. Similarly, given the growing relevance of sustainable tourism, researchers could apply distinct sustainability theories (e.g., triple bottom line, ecological modernization) to examine how I4.0 technologies can contribute to the distinct sustainability spheres, as done by some studies outside the tourism scope [e.g., 66,67,68].

### 3.4. Publications by region and country of affiliation

An analysis of the distribution of publications by country or region of authors' affiliation was also performed. Fig. 3 illustrates the geographical distribution of studies contributing to realizing the implications of I4.0 on the tourism industry. Globally, studies are spread around the world, particularly in South Africa (13.6 %), Indonesia (11.4 %), and Italy (11.4 %). A macro analysis indicates that both Asia and Europe are the most representative regions, each with 20 studies authored and/or co-authored by scholars affiliated with local institutions. In contrast, the Americas is the least representative region apart from Oceania. Besides Indonesia, the emphasis in the Asian region goes to Vietnam and South Korea, both with three publications. It is also noticed that studies are spread across 11 European countries, suggesting that the topic is gaining increasing attention in this region. Nonetheless, surprisingly, some countries are still behind in the process, particularly Germany, where the I4.0 emerged initially. On the other hand, the lack of research in African countries, except for South Africa, is somehow expected as the region is mainly composed of developing countries that tend to have severe constraints concerning the ICT infrastructure and dissemination, as is the case of Internet connection [69].

**Table 2**  
Theory-driven studies.

| Theories                             | Number of studies | Sources  |
|--------------------------------------|-------------------|--|
| Technology Acceptance Model          | 2                 | Chung, Jia, Xiaorui & Koo (2019); Mgiba (2021) |
| Theory of Attractive Quality         | 1                 | Bilgili & Ozkul (2019)                         |
| Theory of Pro-Environmental Behavior | 1                 | Dey et al. (2022)                              |
| Digital Divide Theory                | 1                 | Dhakal & Tjokro (2021)                         |
| Observational Learning Theory        | 1                 | Mgiba & Chilya (2020)                          |
| Theory of Planned Behaviour          | 1                 | Mgiba (2021)                                   |
| Elaboration Likelihood Model         | 1                 | Nengovhela et al. (2020)                       |



**Fig. 3.** Authorship and co-authorship by region and country of affiliation.

### 3.5. Keyword analysis

Based on the number of co-occurrences and the respective clustering, a keywords network was generated using the VOSviewer software (Fig. 4). In the network visualization, the node size is equivalent to the number of occurrences of each keyword and the connection between the terms is represented by curved lines [70]. Fig. 4 displays a total of 141 keywords composing the network. Of these, only 26 appeared more than once, while only 11 had a minimum of three occurrences. This might be explained by specific limitations, one of which is that some terms are still in an embryo phase and lack theoretical conceptualization. The prevailing terms are “tourism”, “industry 4.0”, and “fourth industrial revolution”, followed by “hospitality”, “smart tourism”, and “technology”, ranging from a maximum of 13 to a minimum of four appearances. A total of 22 clusters were generated using the association strength method for normalization. Two of these were disconnected from the main network, suggesting a lack of connectivity among specific topics (e. g., sustainability, tourist behavior, virtual reality, social skills, electronic rubric) and the main themes in analysis. Besides the inexistence of links between the keywords in these clusters, the considerable distance between these and the network indicates shortage relatedness [70]. Not only the novelty of the topic might explain the high number of clusters, but also the multiplicity of applications of 14.0 in the tourism sector, although it might be questioned the accuracy of associating an industrial term to a services sector [71]. Furthermore, this visualization enabled the identification of the main topics under analysis, thus contributing to categorizing the discussion section into distinct groups. Nonetheless, five clusters stand out. The first cluster with 11 keywords gathers topics related to visitors’ loyalty intention regarding tourism destinations and services. Also with 11 keywords, the second cluster revolves around smart tourism and tourism 4.0 topics, emphasizing the digitalization of tourism experiences. The remaining three clusters aggregate a total of 10 keywords each. Cluster 3 reflects blockchain technology and cryptocurrency within the tourism sector, while cluster 4 is centered on technology for managerial purposes. Finally, the fifth cluster covers topics linked to the challenges and opportunities associated with the fourth industrial revolution.

### 3.6. Content analysis

The content analysis phase enabled the categorization of the studies into three research fields (Table 3). A dominant field represents the studies investigating the 4.0 paradigm from the supply side (54.5 %). Supply-related studies covered a wide variety of subjects (e. g., technology implementation, digital competencies, digital payments, heritage preservation, and decision-making) from distinct perspectives, standing out the hospitality sector and destination management. The research stream reporting on the demand (13.6 %) encompasses studies exploring visitors’ general behavior towards technology, involving sub-topics concerning their attitudes and expectations, decision-making, and acceptance levels. Finally, the least representative research field includes studies exploring the digital transition in the education sector (6.8 %), with particular emphasis on curriculum adaptation.

#### 3.6.1. Demand

This section discusses the results of six papers addressing topics related to technology acceptance, expectations, and visitors’ behavior. The first papers reflected on how the interaction with fourth industrial revolution technologies in a pre-trip stage or during

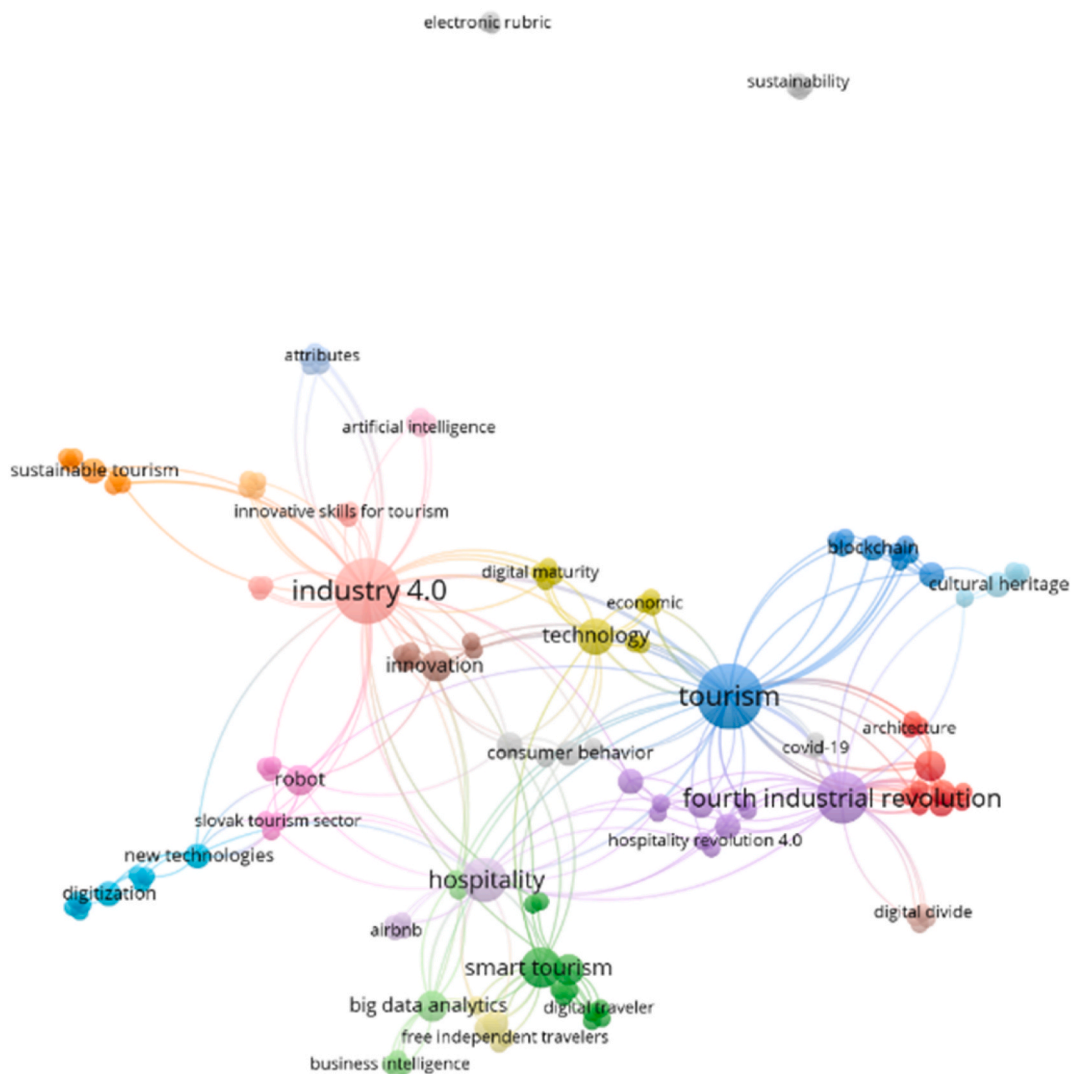


Fig. 4. Keywords network and clustering by co-occurrence.

Table 3

Research fields.

| Publication by Category   | Number of studies |
|---|-------------------|
| <b>Supply</b>   | 24 (54.5 %)       |
| <b>Blockchain and digital payments</b>  |                   |
| Bodkhe et al. (2019); Turkay et al. (2019)  |                   |
| <b>Destination management</b>   |                   |
| Flórez et al. (2022); Maquera et al. (2022); Mariani et al. (2021); Prasetyo et al. (2020); Truong et al. (2021)  |                   |
| <b>Events</b>   |                   |
| Riemer & Seymour (2021); Ryan et al. (2020)   |                   |
| <b>Hospitality</b>  |                   |
| Calero-Sanz et al. (2022); Hsu & Tseng (2022); Kordos & Berkovic (2020); Molano et al. (2020); Onyango & Kesa (2018); Sarigiannidis et al. (2021); Sifolo & Henama (2021) |                   |
| <b>Further stakeholders</b>   |                   |
| Dhakar & Tjokro (2021); Hoi (2020); Jwa (2018); Kang & Jwa (2018); Khristianto et al. (2021); Lulcheva & Komitov (2020); Orea-Giner et al. (2021); Sá et al. (2021)       |                   |
| <b>Demand</b>   | 6 (13.6 %)        |
| Bilgili & Ozkul (2019); Chung, Jia, Xiaorui & Koo (2019); Dey et al. (2022); Mgiba (2021); Mgiba & Chilya (2020); Nengovhela et al. (2020)                                |                   |
| <b>Education</b>  | 3 (6.8 %)         |
| Bertacchini et al. (2018); Bilotta et al. (2021); Timoshenko (2021)   |                   |

the trip influences visitors' loyalty intentions. The first case, brought by Ref. [31], explored the impacts of the fourth industrial revolution (4IR) technologies in the historical Vilakazi Street, Soweto. The study analyzed the influence of technology on the pre-visit experience, visit intentions, visitors' satisfaction, and loyalty intentions. Accordingly, the interaction with virtual technologies in the pre-trip stage was found to positively influence the destination's reputation, stimulating visitors' intention to visit it. Furthermore, as visitors' expectations were met during their experience, a positive loyalty intention (e.g., propensity to revisit and/or recommend the destination) was developed. This means that the use of 4IR technologies to promote and create an image about the destination was effective in the way that the positive experience held by the tourists indicates that no distorted images were advertised during the pre-trip experience. Similarly, [30] analyzed the effects of the 4IR on visitors' loyalty intentions. The study replicates the methodological and contextual approach of [31]. Therefore, the findings are identical. The results indicate that the 4IR promotes tourists' loyalty to a destination. Moreover, engaging with technology before the trip also influences visitors' loyalty and increases a destination's reputation. The findings of these studies converge on one side, indicating that destination managers should encourage visitors to interact with technology, as it seems to be a winning strategy towards future success. Loyalty was also addressed by Ref. [28], studying the consequences of visitors' interaction and satisfaction with AR in cultural heritage sites. The authors found that both usefulness and ease of use of AR products significantly impact visitors' satisfaction with AR, which, in turn, was found to explain the variance in intention to revisit or recommend the destination. The results indicate that visitors' interaction with technology might improve their experience and sense of trust, therefore developing loyalty toward the destination. In synthesis, the fourth industrial revolution environment and the consequent immersive experiences with technologies in the decision-making stage and during the visit have significant implications for visitors' satisfaction, influencing post-travel decisions, such as recommendation and/or intention to return.

Nengovhela et al.'s study [32] was the only exploring how visitors' decision-making is persuaded by smart tourism technology (e.g., websites, mobile apps, geo-tagging, social media, IoT, cloud computing). The study concludes that information quality and relevance, source credibility, ease of use, interactivity, and self-efficacy are the required attributes that smart tourism technologies should have to attract visitors to a specific destination. The study supports the development and design of future smart tools according to these features, so that they can effectively pull visitors to a destination. Although identifying several technologies, the paper mainly focuses on websites and mobile applications, limiting the understanding of the impacts of I4.0. Also in the pre-trip stage, [27] compared guests' attitudes regarding service delivery robots. To do so, the Kano Model was implemented, measuring customers' expectations according to the implementation of robots and automation systems in 13 services (reservation, reception, room service, travel entertainment, housekeeping, F&B, kitchen, technical support, marketing, security, personal care, animation, automatic face recognition, and keyless entry-exit). The results indicate that the human factor tends to prevail in areas where social interaction and personalized services are key elements for quality service (e.g., front desk and kitchen). This seems to be under the customers' expectations regarding the comfort of hospitality services [72]. On the contrary, in the remaining eleven services, the delivery by robots or automation systems would not make a difference for guests, suggesting a certain degree of indifference and minor concerns. Through this approach, managers get the necessary insights to effectively decide which departments should prioritize the digitalization process and the degree of acceptance by future guests. A different approach was implemented by Ref. [29] to address visitors' willingness to adopt pro-environmental behavior through a virtual reality (VR) experiment. The authors concluded that VR immersion effectively measures and stimulates pro-environmental behavioral patterns among potential visitors. This suggests that through VR technology, one can predict visitors' behavior and, therefore, develop effective management strategies and improve a destination's sustainability. Furthermore, this appears to be a versatile solution for managers, particularly by addressing visitors' reactions and behavior in different contexts (e.g., queues at attractions, engagement in pro-environmental practices, and response to insecurity issues).

These studies provide evidence that technologies can be useful tools in managing visitors' expectations and shaping or anticipating their behavior [16]. They also suggest that the integration within this digital environment should be performed as soon as possible to develop proper solutions for visitors at different trip stages [14]. Simultaneously, this interaction with technology seems to foster a close bond between the provider and the visitors, thus enhancing the travel experience and promoting loyalty intentions, as earlier assessed by Refs. [14,16]. Nonetheless, visitors' attitudes towards technology should be carefully measured to deeply understand how technology influences their experiences, thus designing more effective approaches centered on human needs, as suggested by Ref. [17].

### 3.6.2. Education

Three studies revolve around digital skills in tourism courses [33,34,48]. These articles demonstrate the added value of training tourism students to acquire the necessary technological competencies towards the emerging expansion of the I4.0 framework within the tourism sector [16]. For instance, Ref. [33] designed a pilot course for students of the Tourism Sciences degree at the University of Calabria, aiming to develop competencies in data analysis technologies and to put it into practice to explore visitors' behavior at the Calabria region. By attending the course, students had the opportunity to learn and implement Big Data techniques, such as machine learning and sentiment analysis, retrieving and analyzing data from social networks (e.g., Flickr, Twitter). Such experimental courses are expected to contribute to developing students' technological competencies and knowledge, providing them with the ability to implement novel and, perhaps, effective methodologies on tourism analysis, developing more accurate strategies for managing tourism destinations. Following this pilot approach, [34] explored the adaptation of the tourism education system to the fourth industrial revolution. A teaching experiment was designed to evaluate the adequacy of developing an I4.0 curriculum for tourism students, centered on the I4.0 framework and technologies, and their consequent application in the tourism industry. It is suggested that by encouraging the dissemination of the I4.0 framework in tourism curricula, the role of future professionals will be enhanced, as they will be able to materialize the associated potential of technologies. Design thinking approaches were found to be of great value for developing students' knowledge and skills, as well as being capable of applying suitable techniques and technologies for collecting and

analyzing Big Data. In its turn, [48] followed a theoretical approach aiming to explore the adaptation of pedagogical approaches to the current digital transformation process. The author recognizes that the success and competitiveness of tourism destinations within the T4.0 context are highly connected to the digital competencies and skills. This is why a set of priority elements was highlighted to ensure that students' skills are adapted to the 4.0 paradigm, namely developing high levels of digital literacy, managing digital financial tools, and mastering the use of AR, VR, IoT, and other technological solutions. Simultaneously, by developing such interdisciplinary skills, students ensure their competitiveness in the labor market.

To achieve success, the new digital ecosystem needs to be operationalized by professionals with expertise in innovative approaches related to the 4.0 paradigm [16] so that they can keep up the continuous digital transformation process [34]. Therefore, pioneering educational methodologies adjusted to technology competencies are mandatory and should be employed in the early stages of the academic journey [16]. This will provide the necessary knowledge and skills so that future tourism professionals face digital challenges without major obstacles, thus preventing job losses and/or resistance to adopting new technologies [8].

### 3.6.3. Supply

**3.6.3.1. Blockchain and digital payments.** Blockchain is one key element from I4.0 that is gaining increasing attention from consumers and companies due to its feasibility as a privacy and security solution to store and transfer data [14,49]. Several companies are already adopting this technology as a payment and reservation tool in the tourism sector, with many accepting cryptocurrency for running services [14]. This is the case of at least two initiatives explored by Ref. [49]. The first case is *Dubai Smart Tourism 2.0*, an initiative adopting blockchain in a business-to-business context, where hospitality companies and tour operators operate contracts through the technology. The second case is the *CoolCousin travel company*, which is a decentralized peer-to-peer travel agency operating with cryptocurrency. According to Ref. [13], positive implications are expected from implementing blockchain and cryptocurrencies for payment and transactions, particularly process security and anonymity. Its ease of use is among the main advantages, along with the simplicity of the process when purchasing tourism products in different countries, thus contributing to international tourism and the emergence of companies operating in a wide range of areas. However, some questions related to security issues, legal regulations in different countries, and lack of transparency might delay the full application of digital payments in the tourism industry. This might be partially solved by solutions similar to that proposed by Ref. [49] – *BloHosT*. It consists of a framework in which specific limitations of the blockchain (e.g., scalability, expensive mining procedures, security) are addressed and solved through a smart contract layer, ensuring interoperability and trust among customers and providers.

**3.6.3.2. Destination management.** The destination management topic was discussed in five studies, focusing predominantly on sustainability, particularly the social and cultural dimension, except for [40], which analyzed the role of Big Data in destination competitiveness. The latter explored how destination management organizations (DMOs) can use Big Data for their benefit and how it leads to competitive advantage and productivity advantage. The paper presents a conceptual framework of tourism destination competitive productivity where the novelty is on Big Data and Big Data analytics as critical elements contributing to destination management and competitiveness. Big Data analytics technologies act as driving factors towards digital transformation, providing the ability to monitor the territory, share data with stakeholders, and forecast tourist arrivals and expenditures. Furthermore, they ensure that data from multiple sources is displayed in real-time to decision-makers allowing them to monitor the destination and make accurate decisions.

The study by Ref. [43] mainly focused on applying high technology to preserve the intangible cultural heritage in Vietnam. Specifically, the authors propose appropriate 4.0 technologies to digitize the art of the *Trông Quàn*, a traditional folk song. To accomplish such an objective, ethnomusicology and cultural anthropology methods were implemented to collect and record all the tangible and intangible heritages related to this cultural singing art (e.g., singers' costumes, instruments, musical compositions, performances, crafting practices, teaching and learning processes, spatial environment). Digital technologies, such as 3D digitization, drones, laser scanners, 360-degree cameras, multispectral devices, and movie editor software, support this procedure. The final aim is to develop a set of instruments, such as a website with content about the performing arts, digitized products of the tangible and intangible heritages, and an app for promotion of the *Trông Quàn* singing, ensuring that future generations will be able to contact with it through innovative ways. The added value of this approach is that it seems replicable in several contexts by adopting a pioneering way towards the preservation of cultural traditions, where a primary role to technological solutions is given, additionally contributing to the sustainability of these arts.

Based on the premise that implementing ICTs in rural tourism contexts is still incipient [39], propose developing an intelligent digital platform to enhance community-based rural tourism in Peru. The platform is extremely valuable for every stakeholder (e.g., community, visitors, tourism companies, and State). On one side, it will ensure that the rural communities' culture is preserved while being simultaneously promoted sustainably, attracting responsible visitors. For tourists, it will work as a recommendation system, using artificial intelligence methods, offering a personalized and memorable experience. It also operates as a booking platform and allows direct communication with businesses. Through Big Data analytics, the platform ensures that companies effectively use data retrieved from the surrounding environment to understand visitors' behavioral patterns, establish partnerships with competitors, and develop appropriate products. Simultaneously, it works as a marketing tool, enabling the promotion of companies' products. On the other side, this enables the State to promote the destination's resources and services, while providing insights about the destination dynamics so that decision-makers can perform tourism intelligence.

The study by Ref. [58] focuses on the impact of I4.0 on participatory eco-tourism management practices by local communities,



based on the case of Menipo Island, Indonesia. This was accomplished by attending to the stakeholders’ opinions about the challenges resulting from the I4.0. Accordingly, the marketing strategy was ineffective, particularly in implementing promotional campaigns through social media platforms. Moreover, the lack of equipment (e.g., smartphones, laptops) and inadequate hard skills (e.g., management of social networks) were additional threats to a successful participatory management strategy. The internet network and coverage were also insufficient, limiting the destination’s digital capacity. The study is focused on internet technology, overlooking the true sense of the I4.0 concept. This brings to light the existing digital divide regarding different global regions [73]. While some regions are already evolving towards I4.0 in full, others are still attached to previous technological landmarks, specifically the access to an internet connection.

Still in implementing sustainable tourism strategies [36], propose a framework for developing sustainable tourism in the region of Santurbán Moor, Colombia, highlighting the potential contributions of technology and industry 4.0. In this regard, the results identified digital and technological infrastructures as defective within the territory. Built on these findings, one of the recommendations relies on the implementation of an industry 4.0 platform encompassing artificial intelligence for recommendation systems, digitization of information retrieved from visitors, AR to add value to visitors’ experiences through different levels of immersion, Big Data analytics to facilitate data processing and interpretation, and IoT sensor networks for environmental quality monitorization. The integration of such a technological platform will assist sustainable management practices while contributing to an improved tourist experience, where visitors are also encouraged to generate content and contribute to the co-creation of value.

**3.6.3.3. Events.** Two studies explored the 4IR in the events sector from different perspectives, by presenting distinct methodologies to measure digital maturity and virtual attendance of events. The study by Ref. [57] developed the concept of *Events 4.0* by presenting a methodology to classify the digital maturity of events. An analysis of technology integration in the delivery and experience of events was conducted. On one side, event organizers consider social media engagement, events apps, and CRM as core elements enhancing communication. This guarantees that events can personalize their offers and ensure attendees’ satisfaction, particularly by implementing CRM systems (see Ref. [52]). On the other hand, the results also suggest that engagement with technology during events is an important feature to delegates (e.g., digital booking, website and social media, event apps), despite the low level of familiarity with technologies related to I4.0. However, the findings of this research might be criticized, and the methods applied should be replicated, due to a very low response rate which resulted in a total of 52 participants. Introducing the digital twinning concept, [44] aimed to explore how event organizers can cope with the virtual visitation of digital events. The authors propose a framework measuring users’ interaction based on their level of interaction with the digital setting and with other users. Following, new metrics for measuring the digital experience and engagement level are proposed, from passive engagement with the event (e.g., visiting the website) to full virtual experience (e.g., creation of an avatar, manipulation of the digital environment, interaction and communication with users and the digital environment).

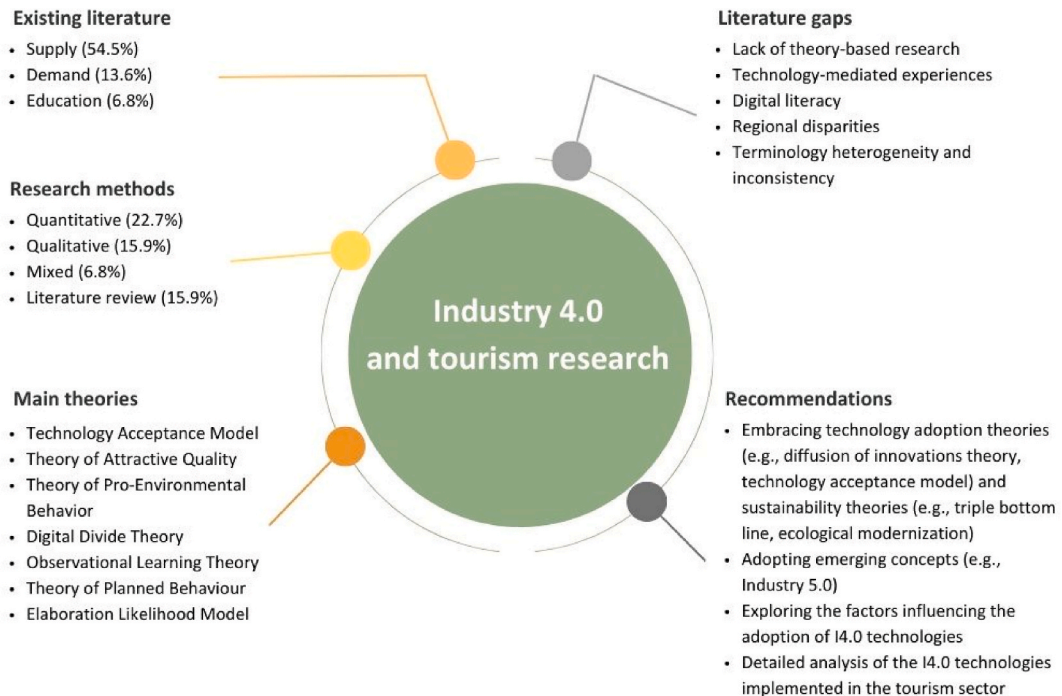


Fig. 5. Summary of key findings.

**3.6.3.4. Hospitality.** The hospitality sub-sector received considerable attention from the literature, perhaps because guests are increasingly expecting and demanding technology-mediated services [74]. Two studies [38,41] address the service automation process to measure guests' expectations and satisfaction regarding service delivery robots. Following [37], explore the role of digital skills in human resources. The studies by Refs. [52,55] discuss the advantages of technologies in hospitality supply chains, while [53] describe the diffusion of I4.0 in the hospitality sector, by briefly mentioning two case studies. Lastly, from a more managerial perspective, [47] provide some insights into the implications of the 4.0 paradigm in environmentally sustainable practices.

Starting with Big Data and artificial intelligence systems, the study by Ref. [41] analyzes how guests' perception of service robots influences hotels' ratings. A methodology built on machine learning models was developed to collect and analyze data retrieved from online reviews (e.g., TripAdvisor). This approach enables decision-makers to identify the type of robots with improved performance and how it impacts guests' satisfaction. The results indicate a more significant impact of the room service robot typology on tourists' satisfaction. This means that there are no major issues in replacing humans with robots, perhaps justified by guests having less interaction or personalization needs in room service delivery. Similarities are found in Ref. [38], exploring automation and robotics in the Slovak tourism sector and labor market. As it is common, the human factor is also prioritized in the Slovakian tourism sector, meaning that robots and automation will not have a significant impact in activities involving a close relationship with the customer (e.g., catering and front-reception) or in positions requiring highly qualified and expertise staff (e.g., management, sales, human resources). However, humans have an increasing replacement tendency in housekeeping operations, which goes along with the results of [41]. Nevertheless, rather than replacing humans, service robots are expected to increase productivity, as they can be complementary in front-desk services (e.g., providing information, facilitating payments) and in restaurants (e.g., digital menus, reservation apps, robot waiters), enabling employees to be allocated to less-time consuming tasks and guaranteeing operational efficiency [8]. Both studies also parallel the earlier mentioned research by Ref. [27], where guests highlighted the importance of the human factor in operations such as catering and front desk. Similar methodologies might be valuable in the upcoming research, as service robots have been demonstrating to be highly versatile in adverse contexts (e.g., pandemic crisis) by ensuring quality and safe services (Seyitoglu & Ivanov, 2020).

The future of hospitality is not dependent only on robots and automation processes. Implementing I4.0 and smart principles encompasses several challenges resulting from different technologies. As mentioned before [e.g., 27,38], qualified professionals guarantee a company's quality and competitiveness, while ensuring the necessary balance between human and technological resources. Accordingly, [37] conclude that competitive workers, in order to guarantee a smooth transition and implementation of I4.0 in the hospitality industry should develop 10 key technological competencies, specifically on basic ICT, information systems and technology integration, cloud computing, Big Data analytics, IoT, robots, additive manufacturing, extended reality and simulation, cybersecurity, and artificial intelligence. This is somehow linked to other studies [33,34,48], emphasizing the educational system's necessary transformation.

The gradual implementation of ICTs in the tourism industry also promoted new developments in the sector's supply chain models. For instance, the study by Ref. [55] provides a theoretical approach regarding the influence of the 4IR in the tourism supply chain in sub-Saharan Africa. Exploring the case of Airbnb as a sharing economy platform, the authors demonstrate the disruptive capacity of technology and how it enhances commercial processes through a novel supply chain model based on a collaborative platform. This corroborates the observation of [8], indicating that 4IR contributes to a smarter, collaborative, and efficient tourism supply chain, materialized, for example, in mobile apps. Precisely within the scope of tourism supply chain, [52] developed a customer relationship management (CRM) system perfectly aligned with the I4.0. Based on sensors to collect data from visitors, the system allows data to be analyzed and managed in real-time, making it possible to design and employ actions according to customers' needs and/or to predict their behaviors. Accordingly, this strategy supported by I4.0 technologies will ensure that firms can manage customers' data effectively and enhance service relationships by anticipating their needs and personalizing their experience.

Providing a broader perspective, [53] explore the dissemination of the 4IR technologies in the hospitality industry of South Africa and Kenya. The escalation of online bookings and platforms calls for alternative approaches and investments in specific areas, such as the recruitment of staff with technological skills and/or effective management of social media platforms (e.g., Facebook, Instagram) as marketing tools. Furthermore, implementing mobile payment systems is also viewed as a must-have solution. Nevertheless, the authors reduce the analysis of the FIR dimensions to mobile and internet services, providing insufficient information about the real implications of the FIR in South Africa and Kenya. As in Ref. [55], the studies reveal no significant achievements despite highlighting the 4IR in the tourism sector. It might be justified by the fact that some countries in analysis lack basic ICTs infrastructures (e.g., access to fiber, internet connection, wi-fi), preventing them from fully responding to the 4IR requirements.

Finally, digital transformation is also a way for businesses to become more sustainable [71]. Centered on the environmental pillar of sustainability, [47] propose a smart framework to measure the environmental performance of the hotel sector through the implementation of an Environmental Management Accounting (EMA) system supported by I4.0 tools (IoT and business intelligence). An EMA system encompasses the collection and analysis of physical data (consumption level of resources) and monetary data (environmental costs) [75]. By implementing an IoT architecture, the system collects data regarding the environmental impact of the hotels' operation, which is converted into monetary units to evaluate the environment-related costs, earnings, and savings. Accordingly, this management tool is expected to improve businesses' environmental sustainability patterns and optimize financial performance. However, the systems lack practical evaluation as the research is theoretical and was not tested.

**3.6.3.5. Further stakeholders.** This section summarizes studies focused on the penetration of I4.0 in distinct stakeholders from the tourism supply chain (e.g., amusement parks, museums, and tour operators). It starts by exploring the implementation of different

technologies into businesses and the expected contributions [42,50,51,54]. Following, the digital maturity of tourism companies is embraced by the studies of [35,56]. The third feature concerns the development of recommendation systems [45,46] based on Big Data analytics.

The study by Ref. [51] shares a theoretical approach concerning the implementation of robots in amusement parks. The authors propose and design an autonomous robot offering a personalized tour for both organized and individual travelers. Specifically, the robot operates according to a pre-defined route throughout which it provides information about each attraction, using cameras and a QR code reader for this purpose, and adapting the language to the linguistic needs of visitors. As robots are instructed by artificial intelligence, the solution is argued to contribute to visitors' satisfaction, personalizing their visit and enhancing the co-creation of value, while allocating human resources to other tasks where robots cannot replace them. This might optimize resources and operations within an organization [38], although debatable, as the general opinion still finds robots a threat to human jobs [76]. The study by Ref. [54] discusses the added value of I4.0 technologies in the wine production and enotourism sectors. The article introduces computational simulation as a helpful tool supporting decision-making, entailing some advantages of implementing such an instrument, e.g., anticipating climate change effects, political changes, price fluctuations, and/or consumption patterns. However, little was added to the discussion when reflecting on I4.0 and enotourism, with the authors limiting the debate, in a tenuous way, to the impact of technologies on the tourism sector. Nonetheless, it is argued that enotourism would benefit from implementing simulation methods in the wine production sector, particularly due to improvements in wine quality and the ability to analyze consumption dynamics. In turn, [42] implemented I4.0 methods to analyze visitors' reviews concerning museums' performance. Using a sample of 5000 reviews retrieved from TripAdvisor, the authors identified the most prominent museum attributes through text mining analysis, enabling them to identify meaningful patterns among the museum visitors' opinions. Through these results, managers can define the areas needing action, while improving the museum's performance and assisting the decision-making process, aiming to improve and personalize visitors' experience.

Hoi [50] clearly shows that both the digital divide and maturity are real issues, and there is an obvious need to clarify concepts, such as the 4.0 paradigm, to promote consistency within this discussion. The author starts by stressing the level of technological implementation for tourism promotion purposes in Vietnam, identifying some of the most common tools (e.g., websites, social media networks, email marketing, mobile devices, online marketing, search engine optimization, blogs, and YouTube). At first sight, it appears that Vietnam is still a few steps behind the 4.0 era. This might be partially justified by the limitations addressed in the paper, specifically related to the lack of a communication strategy between DMOs and businesses, the absence of security guidelines and regulatory procedures concerning data protection, and the lack of investment.

Dhakal and Tjokro's [56] study aim was to compare the 4IR readiness of tourism business in Indonesia, providing further insights into the digital divide between urban and rural destinations. Three major topics were addressed: tourism companies' digital capabilities, tourism companies' preparedness, and the impacts of technologies on jobs. Through a questionnaire and interviews with tourism managers, the study reveals that companies are still in the preliminary phase of adopting 4IR principles and must go through a significant path until they reach the 4IR stage in full, particularly in rural areas. This is consistent with [73], who warn about the digital divide between developed and developing regions. Tourism companies in developed regions also perceive 4IR-related government policies as positive, while recognizing that their staff feel vulnerable and worry about their positions in the future. This might be partially justified by the lack of digital competencies and knowledge, as mentioned earlier [e.g., 33,34,48]. Finally, the study also highlights that those companies in the earlier stages of the digital revolution are those with significant worries concerning replacement and job losses. This issue was identified by Ref. [8] as one of the most relevant challenges inhibiting the adoption of I4.0 technologies by tourism firms. This calls for the benefits of implementing multidisciplinary curriculums in tourism courses, targeting digital skills [34], thus preventing people from losing their jobs. The study by Ref. [35] explores the technological competencies of Indonesian tour operators within the industry 4.0 environment. The results demonstrate that technological competencies stimulate innovation, while innovation enhances competitive advantage. The study highlights the relevance of information acquisition in a context where managerial decisions are ruled by the quality and capacity to interpret data from the surrounding environment. Simultaneously, it warns managers of the necessity of adopting digital tools related to the 4.0 era; otherwise, they will be surpassed by the competitors and will not fit within a constantly changing environment.

The study by Ref. [46] proposes an android application based on tourism Big Data analytics for visitors to use during their travel experience at Jeju Island. The application provides customized travel products, based on collected data from a Big Data intelligence platform – *KT Big Sight*. To personalize and recommend the most appropriate travel experience, data regarding the number of tourists, credit card usage, and the geographic distribution of tourists was collected, particularly in places such as tourist attractions, restaurants, or accommodations. The novelty of the application consists in recommending travel products based on the above-mentioned data, plus personal information provided by the visitor, such as age, gender, transportation preferences, travel time, price range, and local information (e.g., weather, location). Furthermore, a multilingual audio tour guide system is also available for visitors to use during the recommended itinerary. Still on the recommendation topic, [45] propose a smart tourism system consisting of a smart tourism application and a smart tourism server. Similar to the study by Ref. [46], the smart application suggests a travel product to the user through Big Data analytics. No significant differences are reported between the studies of [45,46] as they have identical contents. The most distinguishing piece lies in the fact that [45] presents the smart tourism system framework, schematizing how the app, the server, and the interworking systems interact with each other.

#### 4. Conclusion and implications

The transition to a digital economy is nowadays a growing reality. Political agendas (e.g., *Digital Europe Programme* by the European



Commission; *Turismo 4.0* program by the Portuguese government; *Tourism 4.0 project* in Slovenia; the public-private partnership *Malaysia Smart Tourism 4.0*) are gradually aligned towards the transition to a more digitalized economy and society, aiming to capacitate both businesses and the general population with digital skills as well as to disseminate digital technologies. The digital transformation is a requirement within the actual panorama, but its success and outcomes are still to be measured [77]. Also, the increasing adoption of catch words such as “digitalization”, “smart”, “fourth industrial revolution”, or “4.0”, pushes one to reflect about their meaning within the tourism sector.

Based on this assumption, the impact of the present systematic literature review rests in the interpretation of the implications of the 4.0 paradigm in the tourism sector. A summary of the key findings is presented in Fig. 5. The study reviewed 44 documents published in peer-reviewed journals and proceedings retrieved from SCOPUS and WOS databases, using the PRISMA protocol as guidance for data collection and analysis. The results show that academic research has been discussing the role of the fourth industrial revolution in three main fields within the tourism sector: demand, education, and supply. From the demand perspective, researchers have been predominantly focused on visitor-technology interaction and how it affects visitors' behaviors during a tourism trip. Education-related studies have explored the digital competencies issue in two ways: one perspective addressed the main skills that should be developed to attend to market necessities in the short-run, while a more experimental approach, through the application of pilot programs, analyzed the benefits of introducing I4.0 technologies during the training process, as well as, students' perspectives concerning the importance and usefulness of these tools. The supply research stream was also the most prominent one and encompassed studies reflecting on a high variety of themes. One was the fourth industrial revolution in the hospitality sub-sector, specifically concerning managerial aspects, technology implementation, and product distribution. In a more generic vision, studies reflected on I4.0 readiness of tourism enterprises in distinct settings (e.g., amusement parks, enotourism, events, museums, tour operators). From the destination management side, the literature discussed the added value of technology for the competitiveness of tourism destinations, the role of I4.0 on local and participatory development models, and the potential of I4.0 technologies for environmental and cultural sustainability. Finally, emerging trends such as the implications of blockchain technology and cryptocurrencies in the tourism industry were also explored.

This review contributes to the literature in several ways. First, it is a complement to the study by Ref. [8], which was predominantly focused on the hospitality sub-sector, by synthesizing the academic research around the implications of I4.0 in distinct spheres of the tourism sector. It provides a global panorama concerning the main fields where the 4.0 paradigm has been thriving and the consequent impacts and/or expected results. However, the results show a lack of empirical research. A considerable number of studies were theoretical and did not provide the level of assertiveness and clarification necessary for understanding the real challenges facing the transition from traditional tourism development models to more digital ones. This represents one of the main gaps in the literature. In the continuation, this review identified a major gap regarding the lack of theories sustaining the studies. The findings show that only 18 % of the studies were theory-based, meaning that future research should be aware of this necessity. As suggested, theories related to behavioral intentions, specifically linked with technology adoption (e.g., diffusion of innovations theory, theory of reasoned action, theory of planned behavior, technology acceptance model) or those related to sustainability (e.g., triple bottom line, ecological modernization) might be useful to understand dynamics at both organizational and individual levels.

Another major contribution concerns the identification of the terminology used to describe this digital era. Several terms (e.g., tourism digital transformation, fourth industrial revolution in tourism, tourism 4.0, smart tourism) seem to be used interchangeably, promoting theoretical inconsistencies. Since the original I4.0 concept itself is ambiguous [12], future research is encouraged to provide a coherent conceptual framework, establishing the rationale among the different terminologies. An additional contribution is related to the main research gaps retrieved from the studies analyzed. From the demand side, a topic that seems to be almost left out of discussion concerns tourists' authentic experiences through I4.0 technologies. The studies analyzed in this review were much more focused on the impact of technologies on loyalty intentions and decision-making, but less on how visitors engage with technology during their stay at a tourism destination. Future studies can develop in-deep approaches to this subject by measuring how technologies mediate visitors' experiences while identifying which types of tools are worthy of being implemented by tourism managers. Digital literacy is another subject demanding further development, despite some efforts in that regard [e.g., 33,34,37,48]. Some questions remain to be answered in this field. From the education side, further studies should explore which technological competencies should be lectured in tourism courses and the appropriate methodologies. Furthermore, the training needs of today's workforce and their re-skilling requires further clarification. Perhaps more empirical research should be conducted in a mixed way, listening to employers, employees, and students, to identify the must-have competencies of the future. This certainly would be associated with the assessment of the costs and benefits of the fourth industrial revolution on tourism-related jobs. Despite the argument that digitalization might contribute to diminishing geographical disparities [78], it is irrefutable that some geographical locations still require a higher level of technological penetration [e.g., 50,53,55]. While some of these regions already come up with the necessary foundations to cope with the fourth industrial revolution challenges, others lack primary resources and facilities, such as access to the internet, wi-fi or mobile phone penetration. This calls for further investigation from the supply side, exploring the readiness of territories to integrate the I4.0 framework and detailing the spatial consequences (regional and local) of its development. Simultaneously, it seems to be appropriate to study which determinants act as inhibitors and enablers for the implementation of I4.0.

From the managerial side, this review provides insights about the main tourism fields where I4.0 has been implemented, which can be used as a best practices manual by decision-makers intending to adopt I4.0 technologies. For instance, players in developing regions might find this review as a reference. It suggests that achieving successful digital transformation requires the definition of policies and practices to implement the necessary infrastructural foundations and facilities. Secondly, several clues are also provided for education actors involving the adaptation of school curriculum, specifically the introduction of disciplines able to foster the digital competencies of students. A third contribution highlights the importance of prioritizing investments in digital skills by tourism businesses and

organizations to maintain or gain competitive advantage. This might be through the adoption of initiatives to enhance employees' digital competencies (e.g., pilot or training programs), as well as investments in innovative technologies that can improve operational efficiency and visitor experiences, without neglecting the sustainability side.

The rapid technological advances in the industrial panorama and the urge to stay competitive led to the emergence of new technologies. These constant technological advances led to changes in the original concept of I4.0, providing the basis for the advent of a new generation of I4.0, called Industry 5.0 (I5.0) [79]. While the focus in I4.0 was more technology-oriented, prioritizing technological advancements in manufacturing processes and production efficiency, the emphasis of I5.0 is more on human-machine collaboration [80,81]. Specifically, I5.0 focuses on the well-being of the stakeholders and the surrounding environment. While both paradigms' purpose is to drive innovation and transformation in the industry, I5.0 places greater emphasis on the human element with the idea of a holistic integration of human skills and technological capabilities towards sustainable and inclusive growth [80,81]. As tourism follows these technological innovations, future studies should address this emerging concept and its implications. Once the premise of I5.0 is that humans and technology should join forces, researchers should investigate how I5.0 principles can foster more personalized, immersive, and sustainable experiences for tourists while enhancing the well-being of local communities and preserving destinations. Alternatively, they could also focus on the potentialities of these principles, allied with emerging technologies, on empowering travelers to co-create their experiences in ways that promote authenticity and social responsibility. Furthermore, as in I4.0, academic efforts are needed concerning the implications of transitioning to I5.0 in fields such as education, job skills and workforce dynamics, business models, destination management, and legislation and regulation frameworks.

Systematic literature reviews are not exempted from limitations. This review did not provide full identification and description of the main technologies employed by each study, missing the opportunity to provide a comprehensive overview of the technological landscape within the context of I4.0 and tourism. Future studies may wish to pore over the subject, exploring the technologies discussed in the literature to gain insights into their applications, implications, and potential effects. Future research could address this limitation by conducting a more detailed analysis of the specific Industry 4.0 technologies mentioned in the literature. This might be through categorizing the types of technologies and by examining their roles and impacts within different areas of the tourism sector. Additionally, researchers could explore how the adoption and integration of these technologies vary across different tourism sectors and geographical regions. Despite crossing two databases, an effort could have been made to increase the sample of eligible documents, perhaps through the analysis of the reference list of each document encompassed in the analysis and/or by using additional databases (e.g., DOAJ, Google Scholar). Future research might consider this approach to ensure that studies discussing the topic are not left out during the screening process.

This review has shown the intertwined relationship between I4.0 and the tourism sector, providing a nuanced understanding of how this paradigm is shaping different fields of tourism. Moreover, the study has developed the basis for future research and practical interventions, serving as a foundational resource for policymakers, tourism professionals, and researchers seeking to navigate the complex intersection of digitalization and tourism development in the contemporary landscape.

#### Data availability statement

Data sharing is not applicable for this article as no datasets were generated or analyzed during the current study.

#### CRediT authorship contribution statement

**Vitor Rodrigues:** Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Zélia Breda:** Writing – review & editing, Validation, Supervision. **Carlos Rodrigues:** Writing – review & editing, Validation, Supervision.

#### Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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