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Digital transformation in volcano tourism: A systematic review of marketing, engagement, risk, and sustainability

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Abstract - Digital transformation increasingly shapes how tourism destinations are promoted, experienced, interpreted, and managed, yet evidence in volcano tourism remains fragmented across marketing, visitor engagement, safety, and sustainability research. This systematic literature review examined Scopus-indexed journal articles published within the 2015–2025 review period. Following PRISMA 2020, 80 records were identified and 14 studies met the final eligibility criteria. Descriptive bibliometric profiling and thematic synthesis showed that eligible publications emerged from 2020 onward and remained geographically concentrated. Three principal domains were identified: digital destination marketing and branding; technology-enabled visitor experience and interpretation; and digital safety, resilience, and visitor management. Across these domains, digital strategies contribute through four pathways: promotion and branding, interpretation and experience, safety and resilience, and responsible or sustainable tourism. The synthesis further identifies an attractiveness–risk duality, positions visitor–destination engagement as an integrative conceptual bridge, and highlights the hybrid digital–physical information environment as an important boundary condition. Sustainability emerges as a cross-cutting but insufficiently measured outcome. An integrative framework is proposed linking digital capabilities, functional domains, visitor–destination engagement, and responsible and sustainable volcano tourism. Future research should integrate the complete visitor journey, evaluate technology effectiveness, operationalize sustainability outcomes, and expand cross-destination comparisons.

Keywords: digital marketing, digital transformation, volcano tourism, digital destination marketing, visitor engagement, risk communication, sustainable tourism

1. Introduction

Digital transformation has reshaped tourism by changing how destinations communicate, create value, and interact with visitors across the travel journey. Social media, mobile platforms, immersive technologies, destination websites, eWOM, and user-generated content influence destination awareness and travel decisions before visitation, facilitate navigation, interpretation, and interaction on site, and support post-visit content sharing and value co-creation. These

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developments move tourism beyond conventional promotion toward a more connected ecosystem in which visitors, destinations, businesses, and other stakeholders jointly shape tourism experiences and destination value (Abbasi et al., 2023; Alsharif et al., 2024; Bekele & Raj, 2025; Gutierriz et al., 2025).

This transformation is especially significant in volcano tourism, where destination attractiveness coexists with environmental uncertainty, landscape fragility, and natural hazards. Volcanic destinations offer distinctive geoheritage, educational, scenic, and adventure experiences, yet they also require visitors and managers to respond to changing conditions and safety requirements. Digital technologies therefore perform a dual function: enhancing interpretation and visitor engagement while supporting preparedness, wayfinding, risk awareness, and safety communication (Pasquaré Mariotto et al., 2021; Sasaki et al., 2022; Suryawan et al., 2025). This attractiveness–risk combination distinguishes volcano tourism from many conventional destination contexts.

Despite these opportunities, the relevant literature remains fragmented across relatively separate streams. Digital destination marketing studies emphasize online representation, destination image, branding, and promotion; visitor-technology research focuses more heavily on QR codes, WebGIS, mobile applications, virtual geotrails, and immersive interpretation; and another stream addresses safety, resilience, conservation, and destination management (Alberico et al., 2023; Mariotto et al., 2022; Nomikou et al., 2023; Tiago et al., 2021). Risk and visitor-safety research is also insufficiently integrated with destination branding and marketing objectives. Consequently, limited synthesis explains how these functions operate collectively across the visitor journey—from pre-visit discovery and information search to on-site interpretation, experience, and safety communication and subsequent digital engagement. Existing evidence also suggests that digital communication should complement rather than automatically replace physical visitor-management mechanisms in safety-sensitive environments (Sasaki et al., 2022; Suryawan et al., 2025). This fragmentation constitutes the central research gap addressed by the present review.

A systematic literature review (SLR) is appropriate because it enables dispersed evidence to be identified and synthesized through an explicit and reproducible procedure while revealing recurring themes, limitations, and relationships across previously separated research streams (Sauer & Seuring, 2023). Accordingly, this study reviews Scopus-indexed research from 2015–2025 on digital marketing and technology-enabled visitor engagement in volcano tourism. It examines digital destination promotion and branding, interpretation and experience, safety and visitor management, and their potential contribution to responsible and sustainable tourism. The study adopts an ecosystem-oriented view in which technological capabilities interact with visitor engagement and destination-management practices, while sustainability is treated as a cross-cutting destination outcome rather than an automatic consequence of digitalization (Alberico et al., 2023; Alsharif et al., 2024; Gutierriz et al., 2025; Zhang & Deng, 2024).

The study is guided by four research questions:

RQ1. How has research on digital marketing and technology-enabled visitor engagement in volcano tourism evolved between 2015 and 2025?

RQ2. What digital marketing strategies and technology-enabled visitor engagement approaches have been applied in volcano tourism destinations?

RQ3. How do these digital strategies and technologies contribute to destination promotion and branding, visitor engagement and experience, safety and visitor management, and responsible or sustainable volcano tourism?

RQ4. What research gaps, theoretical and practical implications, and future research directions emerge from the existing literature on digital transformation in volcano tourism?

Together, the RQs move from mapping the development of the field and identifying digital approaches to explaining their visitor and destination contributions and establishing an evidence-based research agenda.

The study makes three principal contributions. First, it integrates digital destination marketing and visitor-facing technologies within a single analytical perspective on volcano

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tourism. Second, it highlights the distinctive dual role of digital transformation, in which promotion and experience enhancement coexist with risk communication, visitor safety, and environmental responsibility. Third, it proposes an integrative framework linking digital destination marketing and technology-enabled visitor engagement with three functional domains—promotion and branding, interpretation and experience, and risk communication, safety, and visitor management—followed by visitor–destination engagement and broader responsible and sustainable tourism outcomes. The framework is a conceptual synthesis of the reviewed evidence rather than a statistically tested causal model, providing a basis for future empirical investigation.

Digital transformation in tourism extends beyond the adoption of individual technologies to broader changes in how destinations, visitors, businesses, and other stakeholders create and exchange value. Digital platforms, mobile technologies, immersive media, and smart-tourism applications increasingly connect destination communication, service delivery, visitor interaction, and management within a broader tourism ecosystem (Alsharif et al., 2024; Bekele & Raj, 2025; Gutierriz et al., 2025). Within this ecosystem, digital destination marketing shapes visibility, destination image, reputation, and participatory brand creation through websites, social media, electronic word-of-mouth, and user-generated content (Abbasi et al., 2023; Graziano & Albanese, 2020; Tiago et al., 2021). These interactions extend across the visitor journey: digital channels influence awareness and information search before travel, support interpretation and navigation on site, and enable post-visit content sharing and brand co-creation. Digital transformation should therefore be examined according to the visitor and destination functions enabled by technology rather than technological novelty alone (Rodrigues et al., 2024; Zhang & Deng, 2024).

Technology-enabled visitor engagement concerns how digital interfaces facilitate information access, interpretation, interaction, immersion, navigation, learning, and participation. In volcanic and geoheritage destinations, this is particularly relevant because geological processes and landscape histories may be difficult to observe or interpret directly. QR codes, WebGIS, mobile applications, virtual tours, and immersive technologies can connect physical landscapes with spatial, visual, and explanatory content, extending visitor access beyond conventional interpretation (Mariotto et al., 2022; Pasquaré Mariotto et al., 2021). Engagement is therefore treated here as a functional and relational concept rather than a technology-specific construct. It may occur before, during, and after visitation through information seeking, digitally mediated experiences, interaction with safety information, and participatory communication. This perspective allows heterogeneous technologies to be compared according to the functions they perform within the visitor–destination relationship without assuming that technological sophistication automatically produces superior outcomes.

Volcano tourism adds a distinctive risk-sensitive context to digital transformation. Volcanic destinations combine geoheritage, scenery, education, and adventure with environmental uncertainty, landscape fragility, access restrictions, and potential hazards. This creates an attractiveness–risk duality in which persuasive communication designed to generate destination interest must coexist with protective communication concerning preparedness, safety, and responsible behaviour (Ong et al., 2023; Sasaki et al., 2022; Suryawan et al., 2025). Digital risk communication may extend the reach and timeliness of alerts, wayfinding, hazard information, and emergency guidance, but it should not be assumed to replace physical information systems. Evidence from volcanic settings indicates the continuing importance of on-site information, suggesting a hybrid digital–physical information environment in which websites, applications, alerts, signage, guides, and destination infrastructure operate complementarily (Sasaki et al., 2022). This contextual condition is important because the value of digital systems depends on how they are embedded within wider visitor-management and destination-information architectures.

Responsible and sustainable volcano tourism is treated as a broader destination outcome rather than a separate technology category. Digital interpretation and visitor-management systems may support conservation awareness, responsible behaviour, heritage preservation,

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community participation, resilience, and local benefits, yet these effects require empirical verification rather than being inferred from technology adoption alone (Alberico et al., 2023; Zhang & Deng, 2024). Visitor–destination engagement provides an integrative lens for organizing these relationships through information access, interaction, immersion, risk awareness, and participatory communication.

The literature on tourism digitalisation consistently demonstrates that digital transformation has become an important mechanism for strengthening sustainable tourism development. Digital technologies support tourism organisations and destinations by improving operational efficiency, innovation, stakeholder engagement, marketing, and the delivery of sustainable tourism experiences. Systematic reviews emphasise that tourism digitalisation is closely connected with the achievement of economic, social, and environmental sustainability, although successful implementation depends on organisational capabilities and stakeholder collaboration (Rodrigues et al., 2022; Gutierriz et al., 2023; Elkhwesky et al., 2022; Bratić et al., 2025).

A closely related theme concerns the relationship between digital transformation and sustainability across organisations and industries. Digital transformation can facilitate sustainability by enabling data-driven decision-making, resource efficiency, innovation, stakeholder participation, and new business models. However, digitalisation does not automatically produce sustainable outcomes; its effectiveness depends on appropriate capabilities, technologies, organisational strategies, and stakeholder involvement. This perspective is particularly relevant for tourism businesses and destinations seeking to integrate technological development with long-term sustainability objectives (Gomez-Trujillo & Gonzalez-Perez, 2021; Feroz et al., 2021; Martínez-Peláez et al., 2023; Guandalini, 2022; Melo et al., 2023; Nyagadza, 2022).

Digital marketing and destination branding represent another important research cluster. Digital platforms provide tourism destinations with opportunities to strengthen brand identity, communicate sustainability values, reach targeted audiences, and develop more interactive relationships with tourists. Sustainable branding increasingly depends on the strategic integration of digital technologies and marketing practices rather than on conventional promotional activities alone. Recent studies also indicate that sustainable digital marketing remains an emerging field with considerable opportunities for further research, particularly concerning destination competitiveness, consumer engagement, and responsible tourism communication (Alhaddar & Kummitha, 2025; Mandagi et al., 2026).

Research on emerging technologies further illustrates how tourism is being transformed through Industry 4.0. Technologies such as artificial intelligence, immersive technologies, big data, and the metaverse are creating new possibilities for tourism management, marketing, customer experience, and destination development. The metaverse, in particular, has been identified as a potentially disruptive technology capable of reshaping tourism marketing and management, while Industry 4.0 technologies more broadly contribute to innovative and sustainable tourism practices (Buhalis et al., 2023; Bratić et al., 2025).

Digital transformation is also connected with broader issues of inclusion, institutional development, administration, and organisational efficiency. Digitalisation can improve access to services, administrative accuracy, processing speed, and compliance, while broader digital societal transformation may also create new opportunities and challenges for inclusion and development (Sunkad, 2026; Septiadana et al., 2025). These findings suggest that tourism digitalisation should not be viewed solely as a marketing instrument but as a multidimensional transformation affecting organisational processes and wider social and economic development.

A further group of studies focuses on sustainable and community-based tourism development. Community participation, institutional roles, local wisdom, collaborative governance, and sustainable management are repeatedly identified as important foundations for developing tourism destinations. Tourism development becomes more sustainable when local communities and institutions actively participate in planning, management, and decision-

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making, particularly in rural and cultural tourism destinations (Sibarani & Christin, 2023; Hattori et al., 2023; Sitepu et al., 2023; Kairi et al., 2023; Kairi et al., 2023; Usman & Sam, 2026).

Studies of Balinese tourism provide concrete evidence of how local culture, sustainability, and tourism innovation can be integrated. Penglipuran Village, for example, demonstrates how cultural traditions, local wisdom, Tri Hita Karana, and Sapta Pesona can contribute to the creation of a distinctive and sustainable tourism destination. Similarly, tourism experiences can combine Balinese traditions with sustainability principles and global tourism trends, while culinary innovation can transform local food into products with stronger hospitality and tourism positioning (Sumartini et al., 2026; Budiarta et al., 2024; Arjana et al., 2025; Saputra et al., 2026).

Finally, studies in tourism marketing and destination development highlight the importance of marketing planning, customer relationships, tourism attractions, and destination development strategies. Effective marketing planning, customer satisfaction, brand trust, distinctive attractions, and strategic destination management can strengthen tourism competitiveness and visitor loyalty. These studies complement the digital transformation literature by demonstrating that technological innovation needs to be supported by sound marketing strategies, quality tourism products, community participation, and sustainable destination management (Ogu, 2024; Maheswari et al., 2025; Wajdi et al., 2023; Susanto et al., 2023; Pantiyasa et al., 2023).

The literature indicates a gradual shift from viewing digitalisation as a technological intervention toward understanding it as an integrated strategy linking sustainability, marketing, innovation, organisational transformation, community participation, and destination development. The strongest research opportunity lies in connecting digital marketing and digital transformation with locally grounded sustainable tourism practices, particularly in destinations where cultural heritage, community participation, and environmental sustainability are central to tourism development (Rodrigues et al., 2022; Alhaddar & Kummitha, 2025; Mandagi et al., 2026; Sumartini et al., 2026).

Accordingly, this review conceptually positions digital transformation in volcano tourism as a multi-functional visitor–destination process involving two broad capability groups—digital destination marketing and technology-enabled visitor engagement—operating through promotion and branding, interpretation and experience, and risk communication, safety, and visitor management. These functions may intersect and may contribute to responsible and sustainable outcomes under the attractiveness–risk and hybrid digital–physical conditions described above. This positioning guides the synthesis but does not impose a predetermined causal model; the integrative framework presented later emerges from the systematic review evidence.

2. Method

2.1 Research Design and Analytical Approach

This study employed a systematic literature review (SLR) following PRISMA 2020, supported by descriptive bibliometric profiling and thematic synthesis (Page et al., 2021; Sauer & Seuring, 2023). Descriptive profiling summarized publication year, destination geography, and principal technology categories, while thematic synthesis examined digital strategies, visitor functions, destination contributions, sustainability implications, and research gaps. Given the final corpus of 14 studies, network-based bibliometric techniques were not used because they were not appropriate to the size and analytical purpose of the dataset (Öztürk et al., 2024). The four research questions presented in the Introduction guided data extraction and analysis.

2.2 Search Strategy and Eligibility

The literature search was conducted in Scopus on 11 August 2026 and covered publications from 2015 to 2025, excluding 2026 so that the review ended with the most recent complete publication year. Scopus was used as a single, consistent retrieval environment, while recognizing that database coverage varies across disciplines (Gusenbauer, 2022). The search combined three concepts: digital marketing or technology-enabled engagement, tourism or destination contexts, and volcanic environments. No restrictions were applied for subject area, country, journal title,

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citation count, or open-access status, and sustainability was not required as a search term because it could emerge as an outcome rather than as indexing terminology.

Final Scopus search string:

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TITLE-ABS-KEY(
("digital marketing" OR "online marketing" OR "internet marketing" OR "social media marketing" OR "e-marketing"
OR "tourism marketing" OR "destination marketing" OR "place branding" OR "destination branding" OR
"online branding" OR "digital promotion" OR "online promotion" OR "digital communication" OR "online destination
image" OR "web reputation" OR "social media" OR "electronic word of mouth" OR ewom OR
"user-generated content" OR "online review*" OR "digital engagement" OR "visitor engagement" OR "digital visitor
experience" OR "smart tourism" OR website* OR "mobile app*" OR "mobile application*" OR "digital platform*" OR
"QR code*" OR webgis OR "web GIS" OR "virtual tour*" OR "virtual geotrail*" OR "interactive map*" OR "digital
interpretation" OR "digital wayfinding" OR "augmented reality" OR "virtual reality" OR "mixed reality" OR
"immersive technolog*" OR hololens)
AND
(touris* OR destination* OR visitor* OR travel* OR geotouris* OR ecotouris* OR geopark* OR geoheritage OR "natural
heritage" OR hiking )
AND
(volcano* OR volcanic OR volcanism)  )
AND PUBYEAR AFT 2014 AND PUBYEAR BEF 2026 AND DOCTYPE(ar)  AND SRCTYPE(j)  AND
LANGUAGE(english)
```

Eligible records were English-language peer-reviewed journal articles in which a volcanic setting, substantive tourism or visitor context, and digital marketing or visitor-facing technology were meaningfully connected to the study objective, analysis, or findings. Studies were excluded when the volcanic context was incidental, the work primarily concerned geology, engineering, hazard science, or classroom education without substantive tourism relevance, digital technology was used only for scientific monitoring or data collection, or digital applications were merely proposed as future recommendations.

2.3 Study Selection and PRISMA Procedure

The final Scopus query returned 80 records. Applying the 2015–2025 period retained 69 records; restricting the document type to journal articles retained 35, and the journal-source criterion caused no further exclusions. The English-language criterion retained 34 records, and duplicate checking using DOI, Scopus EID, and normalized titles identified no duplicates. Title, abstract, and keyword screening retained 16 records for eligibility verification, from which two were excluded: one proposed digital facilities as future geotourism initiatives without substantively examining them, and one focused primarily on volcanic geoheritage education without sufficient tourism or visitor relevance. The final corpus therefore comprised 14 studies (Figure 1). During manuscript preparation, the 16 eligibility candidates were re-verified against the same predefined criteria because detailed historical exclusion notes were no longer fully accessible. No new criteria were introduced; one candidate was re-verified from its abstract and bibliographic record because full text was unavailable during the audit.

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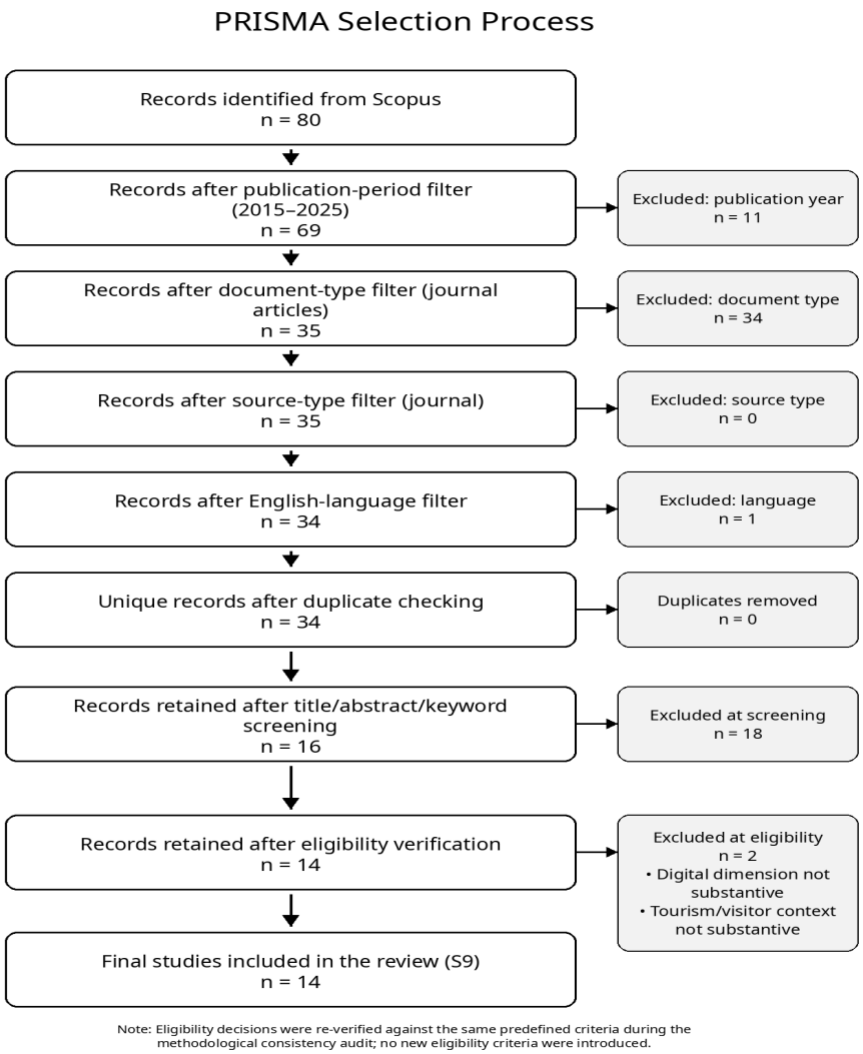

Figure 1. PRISMA Selection Process

2.4 Data Extraction and Analysis

A structured extraction matrix recorded bibliographic information, destination context, research design, digital strategy or technology, tourism function, visitor outcome, sustainability or responsibility dimension, theoretical and practical implications, and stated or inferred research gaps. Coding was initially deductive from the research questions and then refined inductively as recurring patterns emerged; contradictory evidence and boundary conditions were retained rather than forced into uniformly positive themes (Kushnir, 2025). Descriptive profiling addressed RQ1, while thematic synthesis addressed RQ2–RQ4 by comparing digital approaches, visitor and destination functions, contribution pathways, and recurring gaps across studies. Because study designs, technologies, contexts, and outcomes were heterogeneous, no meta-analysis or pooled effect-size estimation was undertaken. No standardized methodological-quality or risk-of-bias scoring instrument was applied.

3. Results and Discussion

3.1 Results

3.1.1 Research Profile and Development of the Field

The final corpus comprised 14 peer-reviewed journal articles, with eligible studies appearing only from 2020 onward despite the 2015–2025 search period. Publication activity was uneven and

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peaked in 2023 rather than showing continuous annual growth (Table 1). Geographically, the corpus was concentrated in Italy (four studies), Greece and Indonesia (two each), with one study each from Japan, New Zealand, Ecuador, Spain, and the Philippines, plus one comparative study covering Iceland, the Azores, and the Canary Islands. This distribution indicates a small, geographically concentrated field centered on volcanic islands, geoparks, protected landscapes, and hazard-sensitive destinations where promotion, interpretation, conservation, and visitor management intersect.

Table 1. Distribution of the Final Studies by Publication Year

Year	Number of Studies	Percentage
2020	3	21.4%
2021	2	14.3%
2022	2	14.3%
2023	4	28.6%
2024	0	0.0%
2025	3	21.4%
Total	14	100%

Source: Authors' synthesis

RQ1: Evolution of Research on Digital Marketing and Technology-Enabled Visitor Engagement

The chronological evidence indicates a shift from relatively separate applications of destination representation and heritage visualization toward more integrated visitor-oriented systems. Early eligible studies established two main strands: digital branding and destination representation through online narratives and websites, and technology-enabled interpretation through virtual geotrails and immersive visualization (Asgary et al., 2020; Gravis et al., 2020; Graziano & Albanese, 2020; Tiago et al., 2021). From 2021–2022, WebGIS, QR-linked geostops, and safety-information research increasingly connected digital technologies with on-site interpretation and visitor behaviour (Mariotto et al., 2022; Pasquaré Mariotto et al., 2021; Sasaki et al., 2022).

By 2023, the field had broadened toward destination-development platforms, geopark promotion, digitally supported visitor services, and post-eruption behavioural research (Alberico et al., 2023; Nomikou et al., 2023; Ong et al., 2023; Yanis et al., 2023). The 2025 studies further extended this trajectory through technology-enhanced hiking services, interactive geoscientific applications, and virtual heritage experiences that connected interpretation with safety, conservation, and responsible tourism (Beato Bergua et al., 2025; Salazar-Del-Pozo et al., 2025; Suryawan et al., 2025). Overall, the corpus shows diversification from communication and visualization toward multi-functional digital systems spanning promotion, interpretation, engagement, safety, and destination stewardship.

RQ2: Digital Marketing Strategies and Technology-Enabled Visitor Engagement Approaches

The thematic synthesis identified three principal domains: digital destination marketing and branding; technology-enabled visitor experience and interpretation; and digital safety, resilience, and visitor management. These domains overlap in practice because individual technologies can perform multiple functions. To avoid double counting, Table 2 assigns each study to one primary domain while recognizing secondary cross-domain linkages.

Table 2. Main Thematic Domains Identified in the Final Corpus

Thematic Domain	Main Strategies / Technologies	Studies (n)

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Digital destination marketing and branding	Official websites; online destination image; web reputation; online branding; brand co-creation; social-media promotion; post-disaster promotional communication	5
Technology-enabled visitor experience and interpretation	QR codes; mobile applications; WebGIS; virtual geotrails; virtual tours; AR/VR	6
Digital safety, resilience, and visitor management	Mobile alerts; wayfinding; emergency reporting; volcanic-risk information; immersive hazard visualization	3

Source: Authors' thematic coding

3.1.2 Digital Destination Marketing and Branding

Digital destination marketing and branding encompasses online destination image, web reputation, institutional and user-generated content, official destination platforms, and post-disaster promotional communication. Mount Etna and the comparative island study show that destination meaning is co-created across institutional, commercial, editorial, and visitor-generated sources (Graziano & Albanese, 2020; Tiago et al., 2021). Nisyros and Iboih further illustrate how websites, applications, QR codes, and WebGIS can combine promotion with destination information and visitor services (Nomikou et al., 2023; Yanis et al., 2023). At Taal Volcano, a media construct incorporating social-media advertising, promotional materials, safety-related information, and content sharing was significantly associated with revisit intention ($\beta = 0.234$, $p = 0.007$), linking digital promotion with post-eruption behavioural response (Ong et al., 2023).

3.1.3 Technology-Enabled Visitor Experience and Interpretation

Technology-enabled visitor experience and interpretation is the largest domain and includes QR codes, WebGIS, mobile applications, virtual geotrails, virtual tours, and immersive technologies. Across Mount Etna, Santorini, Campi Flegrei, Jacomar, Napo Sumaco, and related geoheritage settings, these tools connect physical landscapes with spatial, visual, and explanatory content, broadening access to geological interpretation and interactive visitor experiences (Alberico et al., 2023; Beato Bergua et al., 2025; Mariotto et al., 2022; Pasquaré Mariotto et al., 2021; Salazar-Del-Pozo et al., 2025). The recurring contribution is therefore functional—improved information access, interpretation, interaction, and reach—rather than technological novelty alone.

3.1.4 Digital Safety, Resilience, and Visitor Management

Digital safety, resilience, and visitor management includes alerts, offline wayfinding, emergency reporting, volcanic-risk information, and immersive hazard visualization. Semeru demonstrates demand for integrated digital safety services, while HoloVulcano illustrates the use of immersive visualization for awareness and preparedness (Asgary et al., 2020; Suryawan et al., 2025). Mount Aso provides an important boundary condition: on-site information was more strongly associated with safety-seeking behaviour than prior website or volcanic-alert checking, indicating that digital systems should complement rather than replace physical communication infrastructure (Sasaki et al., 2022).

RQ3: Contributions to Promotion and Branding, Visitor Experience, Safety and Visitor Management, and Responsible or Sustainable Volcano Tourism

Across the three thematic domains, digital strategies contribute through four interconnected pathways: destination promotion and branding, visitor interpretation and experience, safety and resilience, and sustainability or responsible tourism (Table 3). These pathways are not mutually exclusive but represent recurring functions across the visitor journey.

Table 3. Contribution Pathways of Digital Technologies in Volcano Tourism

Contribution Pathway	Primary Function

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Destination promotion and branding	Visibility, destination image, web reputation, brand differentiation, co-creation, promotional communication, and revisit intention
Visitor interpretation and experience	Interactive information, virtual access, immersion, geological interpretation, learning, and engagement
Safety and resilience	Risk information, preparedness, alerts, wayfinding, safety assessment, and emergency communication
Sustainability and responsible tourism	Conservation awareness, low-impact visitation, heritage preservation, community participation, visitor management, and destination resilience

Source: Authors' synthesis

Promotion and branding contribute through destination visibility, image formation, web reputation, participatory content, and behavioural response; the Taal case further shows that promotional media can remain relevant to revisit intention under post-eruption conditions (Graziano & Albanese, 2020; Ong et al., 2023; Tiago et al., 2021). Interpretation and experience are supported by QR codes, WebGIS, mobile applications, virtual geotrails, and immersive technologies that extend access to geological information and complement physical visitation (Mariotto et al., 2022; Pasquaré Mariotto et al., 2021; Yanis et al., 2023).

Safety and resilience contributions arise through risk information, alerts, wayfinding, preparedness, and emergency communication. Mount Aso shows that on-site information may be more influential than pre-visit digital information for safety-seeking behaviour, supporting a complementary digital–physical approach (Sasaki et al., 2022; Suryawan et al., 2025). Sustainability cuts across the other pathways through conservation awareness, low-impact visitation, heritage preservation, visitor management, community participation, and resilience (Alberico et al., 2023; Gravis et al., 2020; Salazar-Del-Pozo et al., 2025). However, the corpus provides stronger evidence for intended or intermediate sustainability contributions than for long-term measured environmental or socio-economic impacts.

RQ4: Research Gaps, Theoretical and Practical Implications, and Future Research Directions

3.1.5 Research Gaps and Future Research Directions

The synthesis reveals several interrelated research gaps. First, digital destination marketing, visitor-facing technologies, safety communication, and post-visit behaviour remain insufficiently integrated across the complete visitor journey. Although the Taal study demonstrates that promotional media, disaster concern, safety-related information, and revisit intention can be examined within a common behavioural framework, such cross-functional approaches remain limited; Semeru and Mount Aso further highlight the importance of integrating digital services with risk and safety communication (Ong et al., 2023; Sasaki et al., 2022; Suryawan et al., 2025). Second, the literature emphasizes technological implementation more strongly than comparative effectiveness, creating a need for experimental, quasi-experimental, longitudinal, and cross-destination evaluations of visitor learning, behaviour, safety, and management outcomes.

Sustainability is likewise more frequently presented as an intended or intermediate contribution than as a directly measured long-term outcome (Alberico et al., 2023; Gravis et al., 2020; Salazar-Del-Pozo et al., 2025). Future studies should operationalize environmental, social, behavioural, and destination-management indicators while also extending research to underrepresented digital-marketing mechanisms such as influencers, short-form video, paid campaigns, search-engine strategies, and platform-specific engagement. Finally, the geographic concentration of the current corpus supports comparative research across active, dormant, post-eruption, geopark-based, island, and heritage-oriented volcanic destinations. Table 4 summarizes these gaps and corresponding research directions.

Table 4. Priority Research Gaps and Future Research Directions

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Research Gap	Future Research Focus	Suggested Approach
Fragmented marketing and visitor-engagement research	Integrate destination branding, digital interpretation, visitor experience, safety communication, post-visit sharing, and revisit behaviour across the visitor journey	Journey mapping; multi-stage surveys; mixed methods
Limited cross-functional integration of promotion and volcanic-risk communication	Examine how attractiveness, recovery, hazard information, preparedness, and responsible behaviour can be communicated simultaneously	Experiments; SEM; cross-destination comparison
Implementation emphasized more than effectiveness	Compare digital tools with conventional interpretation and measure behavioural and management outcomes	Field experiments; quasi-experiments; longitudinal studies
Sustainability outcomes insufficiently measured	Test effects on conservation behaviour, site pressure, local benefits, responsible visitation, and resilience	Longitudinal monitoring; behavioural measures; impact evaluation
Limited evidence on social and participatory digital marketing	Investigate UGC, eWOM, influencers, short-form video, paid campaigns, and platform-specific strategies	Social-media analytics; experiments; sentiment/content analysis
Geographically concentrated evidence	Compare different volcanic destination types, recovery stages, and governance contexts	Multi-country and cross-destination comparative studies

Source: Authors' synthesis

3.1.6 Theoretical Implications

The synthesis advances the conceptualization of digital transformation in volcano tourism through five interconnected implications. First, it positions digital transformation as a multi-functional visitor–destination process rather than a collection of isolated technologies, integrating promotion and branding, interpretation and experience, and risk communication, safety, and visitor management within a broader destination system. Second, the findings identify an attractiveness–risk duality distinctive to volcanic destinations: digital communication must simultaneously stimulate destination interest and communicate uncertainty, preparedness, environmental sensitivity, and visitor safety. Evidence from Taal, Mount Aso, and Mount Semeru illustrates how persuasive and protective functions can coexist across promotional communication, safety-seeking behaviour, and technology-enabled visitor services (Ong et al., 2023; Sasaki et al., 2022; Suryawan et al., 2025).

Third, visitor–destination engagement provides an integrative conceptual bridge through information access, interaction, immersion, risk awareness, and participatory communication, without implying a statistically established mediating relationship. Two further implications qualify this process. The hybrid digital–physical information environment indicates that digital tools operate alongside signage, guides, interpretation facilities, and other on-site information, particularly in safety-sensitive contexts (Sasaki et al., 2022). In addition, sustainability should be treated as a cross-cutting and empirically testable destination outcome, because the current evidence supports plausible intermediate pathways more strongly than long-term environmental or socio-economic effects (Alberico et al., 2023; Salazar-Del-Pozo et al., 2025; Zhang & Deng, 2024).

Practical and Managerial Implications

For destination managers, digital strategies should be coordinated across the visitor journey rather than separated into marketing, interpretation, and safety initiatives. Pre-visit websites and social media can support destination awareness and recovery communication; on-site QR codes, WebGIS, applications, virtual content, alerts, and offline wayfinding can support interpretation, navigation, and visitor safety; and post-visit user-generated content can extend destination

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communication and brand co-creation. Promotional narratives should coexist with credible risk, preparedness, and visitor-responsibility information across digital and physical touchpoints, particularly because on-site communication may remain influential in volcanic environments (Ong et al., 2023; Sasaki et al., 2022). Digital investment should therefore be evaluated through visitor and destination outcomes—including learning, accessibility, safety behaviour, conservation awareness, visitor management, and local benefits—rather than technological novelty alone, with collaboration among destination managers, communities, scientists, tourism organizations, and emergency-management actors supporting credible and useful content.

Proposed Integrative Framework

Based on the thematic synthesis, Figure 2 organizes digital transformation in volcano tourism into four interconnected conceptual levels. Digital destination marketing and technology-enabled visitor engagement constitute the digital capabilities at Level 1. These capabilities operate through three core functional domains at Level 2: promotion and branding; interpretation and experience; and risk communication, safety, and visitor management. At Level 3, these functions connect with visitor–destination engagement through information access, interaction, immersion, risk awareness, and participatory engagement. Level 4 represents broader responsible and sustainable volcano tourism outcomes, including conservation awareness, visitor management, responsible behaviour, safety and resilience, and local or community benefits.

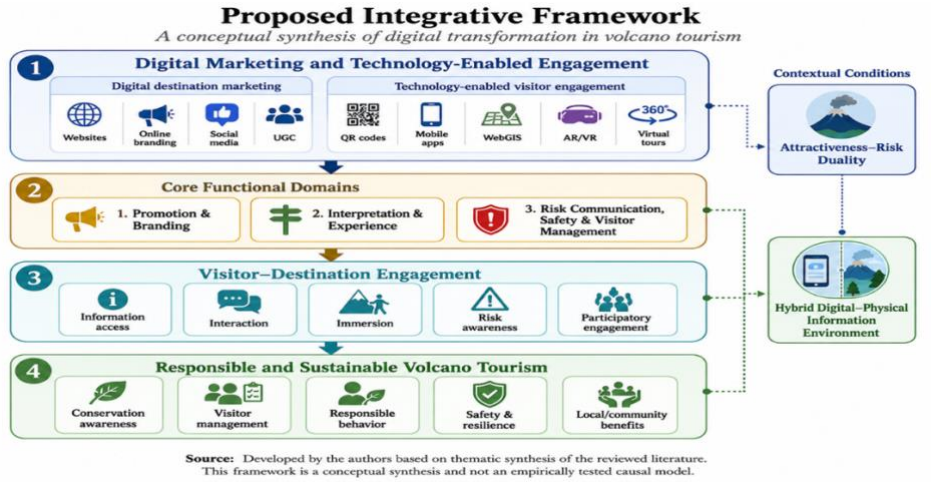

Figure 2. Proposed Integrative Framework of Digital Transformation in Volcano Tourism

Two contextual conditions shape these relationships: the attractiveness–risk duality, in which persuasive destination communication coexists with protective risk communication, and the hybrid digital–physical information environment, in which digital systems operate alongside on-site information and infrastructure. The framework is therefore a conceptual synthesis of the reviewed evidence rather than an empirically tested causal or mediating model. Its purpose is to organize the relationships identified across the corpus and provide a foundation for future research examining whether, how, and under what conditions digital capabilities influence visitor engagement, safety-related behaviour, and responsible or sustainable destination outcomes.

4. Conclusion

This systematic literature review synthesized 14 Scopus-indexed journal articles on digital marketing and technology-enabled visitor engagement in volcano tourism within the 2015–2025 review period. Eligible studies appeared from 2020 onward and showed uneven rather than continuous growth. The evidence clustered into three principal domains: digital destination marketing and branding; technology-enabled visitor experience and interpretation; and digital safety, resilience, and visitor management. Across these domains, digital strategies contribute

through four pathways involving promotion and branding, interpretation and experience, safety and resilience, and responsible or sustainable tourism.

The review indicates that digital transformation in volcano tourism is best understood as a multi-functional visitor–destination process rather than a collection of isolated technologies. A distinctive attractiveness–risk duality requires digital communication to support both destination appeal and protective functions related to uncertainty, preparedness, and visitor safety. Visitor–destination engagement provides an integrative conceptual bridge through information access, interaction, immersion, risk awareness, and participatory communication, while the hybrid digital–physical information environment highlights the continuing importance of on-site communication in safety-sensitive settings. Sustainability emerges as a cross-cutting but insufficiently measured destination outcome.

The proposed framework therefore links digital capabilities, three functional domains, visitor–destination engagement, and responsible and sustainable volcano tourism under these contextual conditions. It is a conceptual synthesis rather than an empirically validated causal model. Future research should test these relationships across the complete visitor journey, compare digital and conventional approaches, evaluate behavioural and management effectiveness, operationalize measurable sustainability outcomes, and extend evidence across more diverse volcanic destinations and digital-marketing practices.

Study Limitations

This review has several methodological limitations. It relied exclusively on Scopus and included only English-language peer-reviewed journal articles, so relevant studies indexed elsewhere or published in other formats or languages may have been missed. The final corpus was small (N = 14), geographically concentrated, and heterogeneous in destination context, research design, technology, and reported outcomes, limiting generalizability and preventing meta-analysis or pooled effect-size estimation. No standardized methodological-quality or risk-of-bias scoring instrument was applied; instead, the synthesis emphasized substantive relevance, recurring patterns, contradictions, and boundary conditions. In addition, detailed historical exclusion notes were not fully accessible during the methodological consistency audit. The same predefined eligibility criteria were retained and no post hoc criteria were introduced, but one candidate record was re-verified using its abstract and bibliographic information because the full text was unavailable. These constraints should be considered when interpreting the review findings.

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