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Article

Demographic influences on digital service perceptions and satisfaction at World Heritage Sites in Chinese coastal cities: An empirical analysis

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Abstract: This study investigates how digital transformation influences visitor satisfaction at 12 World Heritage Sites (WHS) across eight coastal provinces in Eastern and Southern China. Utilizing 402 valid survey responses, it explores the impact of demographic factors—education, age, and income—on visitors' perceptions of digital services, particularly focusing on usability, quality, and overall experience. The findings reveal that younger, higher-income, and STEM-educated visitors express significantly higher satisfaction with digital services, while older, lower-income visitors report lower levels of engagement and satisfaction. This research highlights the need for tailored digital strategies that cater to diverse demographic groups, ensuring the balance between technological innovation and the preservation of cultural authenticity at heritage sites. The originality of this study lies in its focus on non-Western contexts, particularly China's rapidly developing coastal regions, which have been largely overlooked in the global discourse on digital tourism. By applying established theoretical frameworks—such as the Technology Acceptance Model (TAM) and Expectation-Confirmation Theory (ECT)—to a non-Western setting, this research fills a crucial gap in the literature. The insights provided offer actionable recommendations for heritage site managers to enhance visitor engagement, adapt digital services to demographic variations, and promote sustainable tourism development.

Keywords: digital transformation; visitor satisfaction; World Heritage Sites; demographic analysis; tourism management
JEL Classification: O33; L86; D12; Z32; J11; L83

1. Introduction

World Heritage Sites were chosen for this study due to their cultural and historical significance, as well as their role as key tourism destinations. These sites attract large numbers of visitors, making them ideal for evaluating how digital technologies, such as augmented reality (AR), virtual reality (VR), and mobile applications, enhance visitor engagement while preserving cultural authenticity. The challenges faced by WHS managers in balancing technological innovation with heritage preservation are particularly pronounced in China, where rapid economic growth intersects with a deep-rooted cultural heritage. This provides a unique context not sufficiently explored in existing research (Bilgili and Koc, 2021; Gursoy et al., 2022).

The digital transformation of the tourism industry has significantly reshaped how visitors engage with cultural heritage sites. Technologies such as AR, VR, and mobile applications offer immersive and interactive ways to explore historical and cultural narratives (Aldoseri et al., 2023). These technologies not only enhance visitor engagement but also contribute to sustainable tourism by balancing visitor

participation with site preservation (Filipiak et al., 2023; Zhang et al., 2022). While extensive research has been conducted on the application of digital tools at WHS in Western contexts, particularly focusing on visitor satisfaction and engagement (Gursoy et al., 2022; Loureiro and Nascimento, 2021), there remains a significant gap in understanding how these technologies are perceived in non-Western countries, such as China (Rahman and Muktadir, 2021).

As of 2024, China is home to 57 World Heritage Sites, many of which are located in economically developed coastal provinces. These regions present a unique context where rapid economic growth and a rich cultural heritage intersect, providing fertile ground for studying the application of digital technologies in heritage tourism (Loureiro and Nascimento, 2021; Olya, 2023). However, balancing technological innovation with the preservation of cultural authenticity remains a major challenge for WHS managers in China, a challenge that is less emphasized in the existing literature. Most research on digital services in tourism focuses on Western countries, where the cultural and technological contexts are more aligned with rapid digital adoption (Bilgili and Koc, 2021). Therefore, understanding how digital services influence visitor satisfaction in a non-Western context is crucial for developing globally applicable digital strategies (Luo et al., 2023).

This study aims to fill this gap by examining how demographic factors—such as education, age, and income—shape visitors' perceptions of digital services at WHS in China's eastern and southern coastal regions. By analyzing 402 valid survey responses from 12 WHS, this research provides the first in-depth analysis of visitor satisfaction with digital services in Chinese coastal cities, offering valuable insights into how different demographic groups engage with and evaluate these technologies (Filipiak et al., 2023; Zhang et al., 2022). The focus on non-Western data represents a significant contribution to the global discourse on digital tourism, moving beyond the Western-centric narratives that dominate the field (Olya, 2023; Rahman and Muktadir, 2021).

In particular, this study seeks to address two critical research gaps: (1) the lack of comprehensive studies on the intersection of digital transformation and cultural heritage management in non-Western countries, and (2) the limited exploration of how demographic factors influence digital service perceptions at WHS (Zhang et al., 2022). The findings of this research not only advance theoretical models such as the Technology Acceptance Model (TAM) and Expectation-Confirmation Theory (ECT) by applying them in a non-Western context but also provide actionable recommendations for heritage site managers to develop tailored digital strategies that enhance visitor satisfaction while maintaining cultural authenticity (Venkatesh and Davis, 2000; Yu et al., 2023).

By bridging these gaps, this research offers a novel perspective on how demographic differences influence the effectiveness of digital tools at WHS, thereby contributing both to the theoretical understanding of digital service adoption in tourism and the practical management of heritage sites globally. In doing so, this study offers significant implications for both researchers and practitioners seeking to integrate digital technologies in ways that are sensitive to cultural and demographic variations (Ch'ng et al., 2023; Loureiro and Nascimento, 2021).

2. Literature review

This literature review critically examines key research areas related to digital transformation, visitor satisfaction, and heritage site management, focusing on World Heritage Sites (WHS). It explores how digital technologies have influenced visitor engagement and satisfaction at WHS, particularly in tourism settings where maintaining cultural authenticity and site preservation are essential (Bilgili and Koc, 2021; Gursoy et al., 2022). Additionally, the review examines the role of demographic factors such as age, income, and education in shaping visitors' interactions with digital services. Special attention is given to studies within China's coastal cities, where rapid tourism growth presents unique challenges for heritage management (Loureiro and Nascimento, 2021; Zhang et al., 2022).

The review is structured to guide readers through key findings in the adoption of digital technologies in tourism, particularly at heritage sites. It highlights how demographic differences influence the use of these technologies, providing a basis for understanding the varying impacts on visitor satisfaction (Yu et al., 2023). Although this review touches on key concepts relevant to the study, detailed discussion of the theoretical framework is reserved for the next chapter, where the research questions and hypotheses will be grounded in established models. This provides a clear foundation for the empirical analysis that follows in subsequent sections.

2.1. World heritage site status and tourism

The application of digital technologies has profoundly impacted global tourism, particularly in cultural heritage tourism (Balakrishnan et al., 2023; Elshaer et al., 2024). In recent years, technologies such as augmented reality (AR), virtual reality (VR), and mobile applications have been widely adopted at World Heritage Sites (WHS), significantly enhancing visitor engagement and experience (Gursoy et al., 2022; Zhang et al., 2022). These tools offer visitors personalized and interactive ways to explore cultural and historical narratives, while also helping to manage visitor flow and preserve the integrity of heritage sites (Doborjeh et al., 2022; Filipiak et al., 2023).

However, much of the existing research focuses on the implementation of these technologies in Western countries, where the infrastructure and cultural context favor rapid adoption. In contrast, non-Western countries, particularly China, face unique challenges (Martos and Szabó, 2023). In China, the rapid growth of the tourism sector has made digital transformation an essential strategy for increasing the appeal of WHS. While digital technologies have begun to be applied in WHS in China's eastern and southern coastal cities, the research on these applications remains limited, especially regarding how to balance technological innovation with the preservation of cultural authenticity (El Archi et al.,2023; Loureiro and Nascimento, 2021).

Compared to Western countries, China's WHS face challenges such as safeguarding cultural identity, ensuring the effectiveness of cultural communication, and understanding how diverse demographic groups perceive and interact with digital services (Bilgili and Koc, 2021; Szabó et al., 2021). Similar challenges have been observed in other non-Western countries, such as Indonesia and Turkey, where cultural adaptation and usability of digital tools remain significant issues (Genc and Gulertekin, 2023; Rahman and Muktadir, 2021). These cases highlight the need for a

more comprehensive analysis of digital services, particularly in relation to how demographic factors influence visitor satisfaction in non-Western contexts (Szabó et al., 2011).

While studies from Western countries provide valuable data and theoretical insights into the use of digital technologies at WHS, non-Western contexts remain underrepresented. By focusing on WHS in China's coastal regions, this study fills this gap by exploring how demographic factors, such as education, age, and income, influence visitor perceptions of digital services. Through integrating global perspectives and comparing technological and cultural adaptations in both Western and non-Western contexts, this research contributes new theoretical and practical insights into the global application of digital services at heritage sites.

2.2. Education and digital perceptions

Educational background significantly influences how visitors interact with digital services at World Heritage Sites (WHS). Visitors with a STEM (Science, Technology, Engineering, and Mathematics) background tend to prioritize technical precision and usability, expecting digital tools to offer seamless performance, particularly in terms of complex features and intuitive interfaces (Li and Jiang, 2022; Rahman and Muktadir, 2021; VO et al., 2020). Madzík et al. (2023) found that STEM visitors report higher satisfaction when technical sophistication is balanced with usability, reflecting their dual need for complexity and accessibility. Johnson and Smith (2023) further confirmed that STEM-educated visitors often prioritize functional accuracy over aesthetic design in digital services, highlighting their focus on technical performance.

In contrast, non-STEM visitors, particularly those from the humanities and social sciences, place greater value on cultural and educational content than on technical features. Loureiro and Nascimento (2021) and Rather et al. (2024) found that these visitors seek digital tools that enhance their understanding of the site's historical and cultural narratives, prioritizing meaningful content over technological advancement. Pérez et al. (2022) and Zsarnoczky (2018) similarly observed that non-STEM visitors prefer immersive and culturally enriching content, demonstrating a consistent preference for cultural depth over technical complexity. This divergence in expectations between STEM and non-STEM visitors poses a challenge for designing digital tools that cater to both groups.

While many studies have focused on these dynamics in Western contexts, there is limited research exploring how educational background shapes digital perceptions in non-Western environments. Ch'ng et al. (2023) found that STEM-educated visitors in China, like their Western counterparts, value advanced technological features but often express frustration with usability issues. Polishchuk et al. (2023) also noted that even sophisticated digital tools can lead to dissatisfaction among STEM visitors if usability is not prioritized, suggesting that technical complexity alone does not ensure a positive experience.

For non-STEM visitors in China, Chen et al. (2024) and Yu et al. (2023) found that, much like their Western counterparts, these visitors prioritize cultural immersion and storytelling in their digital experiences, seeking tools that enhance their engagement with the heritage site's cultural aspects. This global trend among non-

STEM visitors reinforces the idea that cultural content, rather than technical functionality, drives their satisfaction.

Despite the clear distinctions between these two groups, existing literature tends to examine STEM and non-STEM visitors separately without addressing how digital tools can be designed to satisfy both. Wang et al. (2024) suggested that integrating advanced technical functionality with immersive cultural content could bridge the gap between these groups, offering a solution that caters to diverse educational backgrounds.

This study uses correlation analysis to examine the relationship between visitors' educational background and their perceptions of digital services. The data is drawn from World Heritage Sites (WHS) located in the eastern and southern coastal cities of China, representing a unique non-Western context. The research focuses on comparing the preferences of STEM-educated visitors, who tend to value technical complexity and functional accuracy, with those of non-STEM visitors, who prioritize cultural narratives and immersive digital content. By analyzing data from these regions, the study not only uncovers the correlation between educational background and digital service satisfaction but also provides novel insights into how educational differences manifest in a non-Western context.

2.3. Age and digital engagement

Age plays a significant role in shaping how visitors engage with digital tools at World Heritage Sites (WHS). Younger visitors, particularly those aged 18–34, are generally more adept at using digital technologies like mobile apps and augmented reality (AR). Studies have shown that younger visitors expect interactive and personalized features that enhance their experiences, seeking seamless integration of technology into their visit (Fisu at al., 2024; Tasci et al., 2022; Wang et al., 2024). Li and Jiang (2023) further found that this group prefers dynamic and engaging content, which aligns with their familiarity with digital tools in everyday life.

Conversely, older visitors (55+), often face challenges with navigating complex digital interfaces, leading to lower satisfaction and engagement. Research consistently shows that this group prefers simpler, more intuitive designs, focusing on ease of use and clarity (Rahman and Muktadir, 2021; VO et al., 2020). Genc and Gulertekin (2023) emphasized that older visitors may struggle with unfamiliar technologies, which reduces their ability to fully engage with digital tools, reinforcing the need for simplified digital services that reduce cognitive load.

While the gap between younger and older visitors in terms of digital engagement is well-documented, existing studies often examine these groups separately without offering integrated strategies to cater to both. For instance, Polishchuk et al. (2023) noted that digital tools optimized for younger users' needs can alienate older visitors, and vice versa. Smith and Johnson (2022) suggested that user-friendly design elements, such as clear navigation and straightforward instructions, can help bridge the gap, enabling older visitors to engage more confidently with digital services while maintaining the advanced features that younger visitors expect.

Despite these findings, there remains a lack of comprehensive strategies for designing digital tools that effectively cater to both younger and older visitors. Most

research isolates the challenges faced by each age group rather than exploring how digital services can be designed to accommodate the needs of both simultaneously.

This research aims to explore the correlation between visitors' age and their engagement with digital services at WHS, based on data from eastern and southern coastal cities in China, which provide a unique non-Western visitor profile. The study focuses on the differences between younger visitors (aged 18–34), who are more technologically adept, and older visitors (aged 55 and above), who may face challenges in using advanced digital tools. By analyzing these age-related differences in a non-Western context, the study seeks to identify how age influences digital tool usage and satisfaction at heritage sites.

2.4. Income levels and satisfaction

Income levels significantly influence how visitors perceive and engage with digital services at World Heritage Sites (WHS). Higher-income visitors generally have greater exposure to advanced technologies and tend to expect more sophisticated and personalized digital experiences (Polishchuk et al., 2023; Yersüren and Özel, 2024). These visitors associate complexity and innovation in digital services with added value, leading to higher satisfaction when these features are present (Cranmer et al., 2023; Rahman and Muktadir, 2021). Li et al. (2022) found that high-income visitors particularly appreciate premium digital features, such as augmented reality (AR) and virtual reality (VR), which enhance their engagement through personalized experiences (Susanto et al., 2022).

Conversely, lower-income visitors tend to prioritize simplicity and ease of use over advanced technological features. Research shows that this group is more likely to disengage from overly complex digital services (Genc and Gulertekin, 2023). VO et al. (2020) found that user-friendly interfaces tailored to lower-income visitors' preferences significantly increase satisfaction. For these visitors, excessive complexity may detract from the user experience, as they often seek straightforward, accessible digital tools that minimize cognitive load (Yu et al., 2023; Zhang and Szabó, 2024).

Despite clear differences in the expectations and preferences of various income groups, much of the current research focuses on either high-income or low-income visitors in isolation, without offering comprehensive strategies to cater to both. Smith and Zhang (2023) suggested that creating scalable digital tools, balancing simplicity with advanced features, can bridge this gap. Similarly, Khalil et al. (2023) noted that customizable digital services enhance engagement by allowing visitors to choose their preferred level of interaction, ensuring inclusivity across income levels.

However, there remains a gap in understanding how to design digital services that provide value to both high- and low-income visitors simultaneously.

This study examines the correlation between visitors' income levels and their satisfaction with digital services at WHS, using data from China's eastern and southern coastal cities. The analysis focuses on how higher-income visitors prefer advanced, personalized digital features, while lower-income visitors prioritize simplicity and ease of use. By quantifying the relationship between income levels and digital service satisfaction in a non-Western context, the study provides valuable insights into how different income groups experience digital tools at heritage sites.

2.5. Research gaps and study objectives

Current research on the use of digital tools such as augmented reality (AR) and virtual reality (VR) at World Heritage Sites (WHS) is predominantly Western-centric, often overlooking the unique cultural and technological challenges faced by non-Western heritage sites. Specifically, studies have largely focused on the rapid adoption of these technologies in Western contexts where digital infrastructure is well-established, and cultural narratives are often aligned with Western technological advancements (Bilgili and Koc, 2021). This leaves a significant gap in understanding how these technologies are perceived and used in non-Western countries, particularly in China's coastal regions, where balancing cultural authenticity with technological innovation presents a unique challenge (Loureiro and Nascimento, 2021).

Despite the increasing focus on digital tourism, little attention has been paid to how demographic factors—such as age, education, and income—affect visitors' perceptions of digital services at WHS in non-Western contexts. Existing literature has focused primarily on how younger, tech-savvy visitors interact with digital services, while older visitors or those from non-technical backgrounds remain underrepresented in research. Similarly, income-based differences in digital service expectations and satisfaction have not been comprehensively explored, particularly in regions where economic disparities might affect access to or engagement with advanced digital features.

This study seeks to address this gap by examining how demographic factors such as age, education, and income influence visitor perceptions of digital services at World Heritage Sites in China's eastern and southern coastal cities. In doing so, it provides insights into how cultural and demographic variations impact the usability, quality, and overall experience of digital technologies, an area that remains underexplored in current research. Unlike previous studies that have focused solely on technological adoption, this research integrates non-Western perspectives, providing a novel contribution to both digital tourism and heritage site management.

The primary objective of this study is to offer actionable insights for WHS managers on how to tailor digital strategies to diverse visitor groups. By focusing on demographic factors such as educational background, income, and age, this research offers a comprehensive framework for enhancing visitor engagement through culturally relevant and accessible digital services. This is critical for ensuring that digital transformation efforts at WHS in non-Western contexts not only meet the expectations of tech-savvy younger visitors but also provide meaningful, user-friendly experiences for older and less digitally literate groups.

3. Methodology

This study employs a robust methodological framework to investigate the impact of digital transformation on visitor experiences at World Heritage Sites in Chinese coastal cities, using systematic approaches common in tourism research (Kumar et al., 2024; Siddaway et al., 2019). The following sections detail the data collection process, variable definitions, and analytical methods, structured according to best practices in digital transformation studies (Liberati et al., 2009; Mariani and Baggio, 2022). This structured approach ensures the research is comprehensive and rigorous, offering

valuable insights into how educational background, age, and income influence visitors' perceptions and satisfaction with digital services, consistent with findings in related fields (Boes et al., 2016; Madzík et al., 2023).

3.1. Research background

The digital transformation of global tourism, particularly in cultural heritage tourism, has made the application of digital technologies essential for enhancing visitor experiences. Technologies such as augmented reality (AR), virtual reality (VR), and mobile applications enable visitors to explore historical and cultural narratives more deeply while helping to manage visitor flows and engagement at World Heritage Sites (WHS) (Gursoy et al., 2022; Zhang et al., 2022). These digital tools not only increase engagement through interactive and immersive experiences but also contribute to the sustainable development of heritage sites by balancing conservation with visitor participation (Cuomo et al., 2021; Filipiak et al., 2023). While the application of digital technologies in tourism has been widely studied, limited research focuses on their use at WHS, particularly in China's coastal regions (Bilgili and Koc, 2021; Oka and Subadra, 2024).

As one of the largest hosts of World Heritage Sites, China had 57 WHS as of 2024, with many located in the economically developed eastern and southern coastal provinces. These regions, with their unique geographic advantages and economic growth, attract a large number of domestic and international tourists, driving the development of heritage tourism. However, balancing the preservation of cultural authenticity with the implementation of digital services to enhance visitor satisfaction remains a significant challenge for these sites (Loureiro and Nascimento, 2021). Although the application of digital tools has been extensively studied in other regions, the specific challenges and needs faced by WHS in non-Western countries, especially in China's coastal cities, have not been adequately explored.

Most existing research focuses on the impact of digital technologies on visitor experiences in Western contexts, overlooking the cultural differences that affect technology acceptance and satisfaction (Rahman and Muktadir, 2021). Moreover, the influence of demographic factors—such as educational background, age, and income—on visitor perceptions of digital services, particularly in the Chinese cultural context, has yet to be systematically analyzed (Li and Jiang, 2023). This study aims to fill this gap by analyzing 402 valid survey responses from 12 WHS across eastern and southern coastal China to investigate how demographic differences shape visitor perceptions of and satisfaction with digital services.

By conducting a thorough analysis of non-Western data from WHS in China's coastal regions, this research provides a new perspective on the digital management of heritage tourism globally. The findings offer significant practical insights for heritage site managers seeking to enhance visitor engagement and satisfaction by developing personalized digital strategies based on diverse demographic characteristics. The originality of this study lies in its focus on the application of digital services in Chinese heritage tourism and its theoretical contributions to understanding the role of cultural and demographic factors in shaping visitor perceptions of technology. This offers a new framework for designing and implementing digital

services at WHS worldwide.

3.2. Theoretical framework

This section provides a detailed examination of the theoretical foundations that underpin the analysis of digital services, visitor perception, and visitor satisfaction in the context of World Heritage Sites (WHS). The framework draws upon the Technology Acceptance Model (TAM) and Expectation-Confirmation Theory (ECT) to explain how visitors interact with and evaluate digital tools such as Augmented Reality (AR) and Virtual Reality (VR) (Gursoy et al., 2022; Olya, 2023). By integrating these models, the study explores how demographic factors such as age, education, and technological familiarity influence the acceptance and satisfaction of digital services (Loureiro and Nascimento, 2021; Zhang et al., 2022). The following subsections discuss these theories in detail, offering insights into the role of digital services in modern tourism, how visitor perceptions shape technology use, and how satisfaction is derived from the alignment between expectations and experiences.

3.2.1. Digital services in tourism

Digital services in tourism, including technologies like Augmented Reality (AR), Virtual Reality (VR), and mobile applications, offer immersive and interactive ways for visitors to engage with cultural and natural heritage (Khalil et al., 2023). These services are critical for enhancing visitor experiences, providing real-time and personalized content that deepens understanding and interaction with the site. In the context of World Heritage Sites (WHS), digital services allow visitors to explore remote areas and access enriched storytelling. Previous studies show that digital tools like AR and VR significantly improve visitor engagement and satisfaction (Buhalis and Sinarta, 2019; Sigala, 2021). In this study, AR was used for historical storytelling, while VR allowed virtual access to sensitive natural sites.

3.2.2. Visitor perception of digital services

The Technology Acceptance Model (TAM), introduced by Fred Davis in 1989, explains how users come to accept and use technology. TAM identifies two key factors: perceived ease of use and perceived usefulness. These factors shape how visitors interact with digital tools, such as AR and VR, at WHS (Giglitto et al., 2023). In this study, younger and more tech-savvy visitors found these tools highly useful for enhancing their experience, while older visitors preferred simpler, less interactive technologies. The TAM framework is essential for understanding how demographic differences influence the adoption of digital services at WHS (Davis, 1989; Venkatesh and Davis, 2000).

3.2.3. Visitor satisfaction with digital services

The Expectation-Confirmation Theory (ECT), developed by Richard L. Oliver in 1980, suggests that satisfaction is based on how well an experience meets or exceeds pre-existing expectations. In this study, visitor satisfaction with digital services was closely linked to how well AR and VR tools aligned with their expectations (Luo et al., 2023). Younger visitors, expecting highly immersive experiences, were more satisfied when these expectations were met. In contrast, older visitors expressed satisfaction with simpler, easier-to-use tools. ECT provides a strong framework for

understanding how expectation management affects satisfaction with digital services at WHS (Bhattacherjee, 2001; Oliver, 1980).

3.3. Key studies in the field

Research on digital services in tourism has grown, with studies examining how education, age, and income impact visitor engagement with AR, VR, and mobile applications at World Heritage Sites (WHS). These studies provide a basis for understanding the role of demographic factors in technology adoption.

3.3.1. Digital tools and visitor engagement

AR and VR have been shown to enhance visitor engagement by providing immersive experiences, especially for younger visitors familiar with technology, while older visitors often struggle with ease of use (Mariani et al., 2023). Visitors with higher education and income levels report greater satisfaction with digital tools in tourism (Liu, 2020). Additionally, younger visitors (18–34) are more likely to engage with mobile applications, while older visitors need help interacting with them (Langley, 2022).

3.3.2. Demographic factors and technology adoption

Research has demonstrated that education, age, and income influence how users perceive the ease of use and usefulness of technology (Venkatesh et al., 2012). Younger, better-educated users tend to adopt digital tools more readily and find them more beneficial. Higher-income visitors are more likely to engage with premium digital services, while lower-income visitors rely more on free, basic features (Ivanov and Webster, 2020).

3.3.3. Digital services at World Heritage Sites

At WHS, digital tools like AR and VR can enhance learning and preserve site integrity, although older and lower-income visitors may struggle with these technologies (Smith et al., 2021). Digital marketing and online reputation management also increase satisfaction, particularly among younger and more educated visitors (Zhang and Tang, 2022).

3.4. Main variables and dimensions

This study explores the relationships between several independent demographic variables—education, age, and income—and dependent variables that measure visitor perceptions of digital services at World Heritage Sites (WHS). The dependent variables include the usability, quality, and overall experience with digital services such as Augmented Reality (AR), Virtual Reality (VR), and mobile applications (Gursoy et al., 2022; Loureiro and Nascimento, 2021; Yu et al., 2023; Zhang et al., 2022).

Education serves as a key independent variable influencing how visitors engage with digital tools. It is expected that individuals with a background in Science, Technology, Engineering, and Mathematics (STEM) will report higher satisfaction and perceive these tools as more usable compared to visitors from non-STEM fields (Ch'ng et al., 2023; Madzík et al., 2023; Olya, 2023; Rahman and Muktadir, 2021). Educational background was categorized based on whether participants studied in

STEM or non-STEM disciplines, allowing for an analysis of how technological literacy affects their experiences with digital services (dependent variables: usability, quality, and experience) (Li and Jiang, 2022; Polishchuk et al., 2023).

Age is another independent variable that likely affects digital engagement. Younger visitors, typically more familiar with digital technologies, are expected to rate usability and satisfaction more positively (Li and Jiang, 2023; Tasci et al., 2022; Wang et al., 2024). Visitors were grouped into five age brackets: 18–24, 25–34, 35–44, 45–54, and 55+, enabling the study to examine how age influences their perceptions of the usability, quality, and overall experience of digital services (Fisu et al., 2024; Genc and Gulertekin, 2023; VO et al., 2020).

Income is the third independent variable expected to impact visitor perceptions. Visitors with higher incomes may have more exposure to premium digital services, leading to more positive evaluations of the usability and quality of AR and VR technologies (Cranmer et al., 2023; Li et al., 2022; Susanto et al., 2022). Income was categorized into five brackets: below 3000 CNY, 3000–5000 CNY, 5001–8000 CNY, 8001–12,000 CNY, and above 12,000 CNY. This segmentation provides insights into how financial resources correlate with satisfaction, usability, and overall experience (Khalil et al., 2023; Yersüren and Özel, 2024; Zhang and Szabó, 2024).

By examining these relationships, the study seeks to understand how the independent variables—education, age, and income—affect the dependent variables—usability, quality, and overall experience of digital services at WHS. This analysis will offer valuable insights into optimizing digital tools to cater to diverse visitor demographics (Buhalis et al., 2023).

3.5. Data collection

Data for this study was collected from December 2023 to May 2024 via an online survey distributed through the wjx.cn platform. The survey targeted visitors to 12 World Heritage Sites across eight coastal provinces in eastern and southern China. Screening questions ensured that only respondents who had visited one of these sites within the past year participated. IP address locking was implemented to prevent duplicate responses and ensure data integrity.

The survey was primarily quantitative, consisting of a five-point Likert scale to measure visitor perceptions of digital service usability, quality, and satisfaction. Additionally, multiple-choice questions collected demographic information, such as age, education, and income, which were essential for analyzing how different demographic groups experienced and rated digital services. To complement the quantitative data, open-ended questions were included to gather qualitative insights into visitors' specific experiences with digital technologies, allowing respondents to provide more detailed feedback on how these tools influenced their overall experience.

This focus on quantitative data enabled the collection of standardized and comparable responses across a large sample, allowing for rigorous statistical analysis. The approach provided clear insights into how demographic factors influence perceptions of digital tools at World Heritage Sites. Although qualitative data was not gathered in this phase, future research could incorporate qualitative methods to explore more nuanced visitor experiences.

In line with established practices in tourism research (Liu et al., 2023; Mariani et al., 2018), the survey yielded 402 valid responses, with approximately 50 responses from each of the targeted cities, as shown in **Table 1**. This diverse dataset enabled a comprehensive analysis of how education, age, and income influenced visitor engagement with digital tools.

Table 1. Sample distribution in coastal provinces in eastern and southern China.

Province	Quantity	Percentage
Fujian	51	12.69%
Guangdong	51	12.69%
Guangxi	50	12.44%
Hebei	50	12.44%
Jiangsu	50	12.44%
Liaoning	50	12.44%
Shandong	50	12.44%
Zhejiang	50	12.44%

Source: Author's research data.

The survey focused on key aspects of usability, digital marketing effectiveness, and overall user experience, consistent with previous research in digital tourism (Langley, 2022; Liu, 2020). The findings provided valuable insights into how demographic factors shaped visitor satisfaction and engagement with digital services (Szabó and Komáromi-Gergely, 2011).

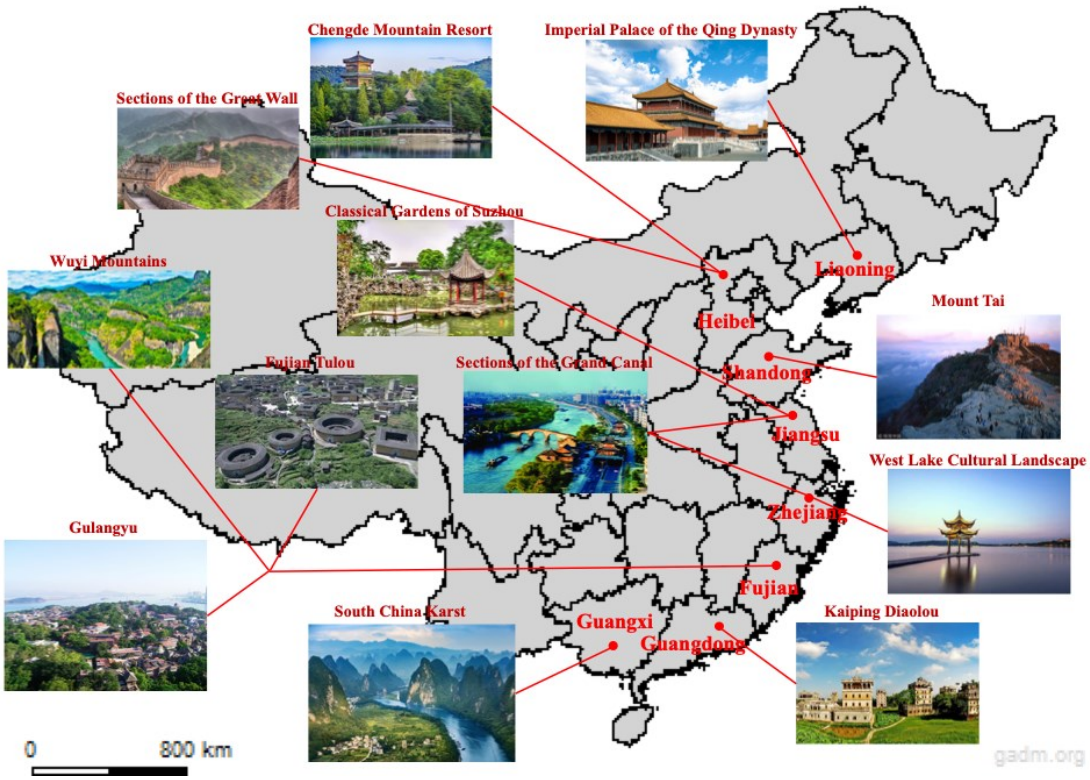

Figure 1. Distribution map of WHS in eastern and southern coastal areas of China.

Source: created by author.

China's eastern and southern coastal provinces host a rich array of World Heritage Sites, encompassing both cultural and natural heritage. These sites include the Imperial Palace of the Qing Dynasty in Liaoning, Chengde Mountain Resort and the Great Wall in Hebei, Mount Tai in Shandong, the Classical Gardens and sections of the Grand Canal in Jiangsu, West Lake in Zhejiang, Fujian Tulou, Wuyi Mountains, Gulangyu in Fujian, Kaiping Diaolou in Guangdong, and the South China Karst in Guangxi. **Figure 1** illustrates the geographical distribution of these locations (Ivanov and Webster, 2020; Liu et al., 2023).

3.6. Research hypotheses and methods

Data analysis was conducted using SPSS software, a widely utilized tool in quantitative social science research (Nam et al., 2023; Rahman and Muktadir, 2021). Descriptive statistics summarized the sample's main characteristics, such as age, education level, and income, which are essential for understanding the demographic influences on perceptions of digital services (Tasci et al., 2022).

3.6.1. Research hypotheses

This study is based on the following hypotheses, derived from the Technology Acceptance Model (TAM) and Expectation-Confirmation Theory (ECT):

- H1: Visitors with higher educational attainment will perceive digital services at World Heritage Sites (WHS) as more usable and useful, and will report higher satisfaction levels.
- H2: Younger visitors will perceive digital services at WHS as more usable and useful compared to older visitors.
- H3: Higher-income visitors will report higher satisfaction with digital services at WHS compared to lower-income visitors.

3.6.2. Data analysis methods

Correlation analysis was the primary method used to assess the relationships between education, age, and income, and visitors' perceptions of digital service usability, usefulness, and satisfaction. Pearson's correlation coefficients were calculated to measure the strength and direction of these relationships, which provided insights into how each demographic factor influenced perceptions of digital services (Zhao et al., 2023).

To ensure the validity of the responses, a screening statement was included to confirm that participants had visited one of the targeted World Heritage Sites within the past 12 months. IP address locking was applied to prevent multiple responses from the same individual, ensuring data reliability. While these measures enhanced response accuracy, future studies could strengthen this by incorporating additional visitor verification methods, such as ticket validation or collaboration with site management.

The analytical framework integrates the Expectation-Confirmation Theory (ECT) and the Technology Acceptance Model (TAM), which suggest that demographic factors—education, age, and income—influence visitors' evaluations of digital tools and overall satisfaction. This approach follows methodologies validated in previous studies (McNeish, 2018), providing a comprehensive understanding of how digital transformation affects visitor experiences at WHS.

4. Data result

The reliability of the survey was assessed using Cronbach's Alpha, with coefficients ranging from 0.921 to 0.925, indicating excellent internal consistency. The corrected item-total correlations fell mostly between 0.5 and 0.6, showing a moderate correlation between individual items and the total score. Minimal changes in the Cronbach Alpha coefficients after item deletion (ranging from 0.921 to 0.923) further confirmed the positive contribution of each item to the overall consistency of the questionnaire. These metrics ensure that the data collected is robust and reliable for analysis (Vaske et al., 2017).

The analysis reveals distinct patterns in how different demographic groups perceive and engage with digital services at World Heritage Sites. Visitors with higher educational backgrounds, particularly in STEM fields, reported higher usability and satisfaction ratings. The 25–34 age group showed the most favorable perceptions, while older visitors, especially those over 55, reported lower levels of satisfaction. Additionally, higher-income visitors consistently rated the digital services more positively compared to lower-income groups. These findings demonstrate how demographic factors, such as education, age, and income, significantly shape visitor experiences and perceptions of digital tools.

4.1. Perceptions of digital services by educational background

Table 2 reveals interesting patterns regarding how visitors from different educational backgrounds perceive the digital services at World Heritage Sites. Visitors with a STEM background consistently rated digital services higher across usability (3.78), quality (3.64), and overall experience (3.74). This suggests that STEM-educated visitors, likely more familiar with technology, find these tools not only easy to use but also enhancing their engagement with the heritage sites. The combination of technical precision and interactive capabilities provided by digital services such as augmented reality (AR) and virtual reality (VR) seems to align with their expectations, contributing to a more enriched experience.

Table 2. Evaluation of digital guides' usability, quality, and experience by educational background.

Questions	Types of Educational	Quantities of cases	Mean	Std. Error	Min. value	Max. value
How would you rate the availability of the digital guide or app provided by the World Heritage Site	STEM	107	3.78	0.128	1	5
	Humanities and Arts	114	3.3	0.097	1	5
	Corporate employees	88	3.16	0.099	1	5
	Business and Economics	93	2.81	0.089	1	4
How would you rate the quality of the digital guide or app provided by the World Heritage Site?	STEM	107	3.64	0.134	1	5
	Humanities and Arts	114	3.33	0.105	1	5
	Corporate employees	88	2.97	0.102	1	5
	Business and Economics	93	3.03	0.084	1	4
Did the digital guide or app enhance your experience of the world heritage site?	STEM	107	3.74	0.13	2	5
	Humanities and Arts	114	3.33	0.108	1	5
	Corporate employees	88	3.19	0.098	1	5
	Business and Economics	93	2.8	0.103	1	4

Source: Author's research data.

In contrast, visitors from Humanities and Arts backgrounds rated usability moderately (3.30) but placed a higher emphasis on the quality of the digital content, giving it a score of 3.33. This indicates that while these visitors may not prioritize ease of use as much as their STEM counterparts, they value the cultural and aesthetic dimensions of the digital tools. The rich, visually compelling content that enhances their understanding of the site's artistic and historical significance likely resonates with them more strongly. Their experience ratings (3.33) reflect this focus on the quality of content rather than just the functionality of the tools.

Interestingly, visitors from Social Sciences provided the lowest ratings across all categories—usability (2.81), quality (3.03), and overall experience (2.80). This group may have different expectations from digital services, possibly seeking deeper sociocultural context or interactive features that allow them to explore the broader societal implications of the heritage sites. Their lower ratings suggest that the current digital tools might not be providing the level of narrative or interactivity they expect, particularly in terms of offering a holistic view of the heritage's social impact.

Visitors from Business and Economics backgrounds provided moderate ratings across all categories (usability: 3.16, quality: 2.97, experience: 3.19). This balanced perception suggests that these visitors may approach digital services with more pragmatic expectations, likely focusing on their functional value. For them, the practical aspects of the tools, such as ease of navigation or the efficiency of information delivery, could play a more critical role in shaping their overall satisfaction.

These findings underscore the importance of tailoring digital services to meet the diverse needs of visitors from different educational backgrounds. The data shows that while some visitors value the technological sophistication and interactive capabilities of digital tools, others place greater emphasis on the cultural and aesthetic quality of the content. For heritage sites aiming to improve visitor satisfaction, offering a range of digital experiences that cater to these varying preferences will be crucial. The insights derived from this analysis provide a pathway for more personalized and effective digital services, ultimately enhancing the visitor experience across different demographic groups.

4.2. Perceptions of digital marketing and reputation by age group

The analysis of visitor perceptions by age shows distinct patterns in the evaluation of digital services at heritage sites, with results indicating strong differences in usability, quality, and overall experience ratings across age groups. According to **Table 3**, the 25–34 age group consistently provided the highest ratings, with mean scores of 3.81 for usability, 3.77 for quality, and 3.90 for overall experience. These scores demonstrate that visitors in this age group view digital services as a valuable and integral part of their heritage site experience. The high ratings suggest that this group is not only comfortable using digital tools but also expects these services to enhance their engagement with the site.

Table 3. Evaluation of digital marketing and online reputation management by age group.

Questions	Age	Quantities of cases	Mean	Std. Error	Min. value	Max. value
How effective do you think the digital marketing activities of the world heritage site are?	18–24	52	2.85	0.127	1	4
	25–34	144	3.81	0.103	1	5
	35–44	115	3.2	0.093	1	5
	45–54	64	2.89	0.118	1	4
	55 and above	27	2.59	0.134	2	4
How satisfied are you with the online reputation management of the World Heritage Site?	18–24	52	3.08	0.14	1	5
	25–34	144	3.77	0.1	1	5
	35–44	115	3.17	0.092	1	5
	45–54	64	2.78	0.101	1	4
	55 and above	27	2.63	0.214	1	4
How reliable are the online reviews and comments about the world heritage site?	18–24	52	2.9	0.149	1	5
	25–34	144	3.9	0.098	1	5
	35–44	115	3.29	0.095	1	5
	45–54	64	2.8	0.116	1	4
	55 and above	27	2.59	0.194	1	4
Has a world heritage site's digital marketing and online reputation affected your perception of the world heritage site?	18–24	52	2.85	0.121	1	4
	25–34	144	3.83	0.1	1	5
	35–44	115	3.28	0.098	1	5
	45–54	64	2.92	0.112	1	4
	55 and above	27	2.52	0.154	1	4

Source: Author's research data.

In contrast, the 55+ age group recorded the lowest ratings across all categories, with mean scores of 2.59 for usability, 2.63 for quality, and 2.59 for overall experience. This indicates a clear trend of dissatisfaction with the digital services among older visitors. The data implies that the current design and functionality of the digital guides may not meet the preferences or technological familiarity of this age group. As a result, the digital services provided at heritage sites do not appear to enhance their experience significantly.

Interestingly, the 18–24 age group also reported lower-than-expected satisfaction, with an overall experience rating of 2.90 and a usability rating of 2.85. Despite being a typically tech-savvy group, these visitors appear to have had higher expectations that the current digital tools did not fulfill. This suggests that younger visitors may seek more advanced features, interactivity, or a more immersive experience than what is currently offered.

For the 35–44 and 45–54 age groups, the results fall within a moderate range. The 35–44 age group rated usability at 3.20, quality at 3.17, and overall experience at 3.29, indicating general satisfaction but without the enthusiasm seen in younger age groups. Similarly, the 45–54 age group provided usability and experience ratings around 2.89 and 2.80, reflecting a neutral stance on the effectiveness of digital services. These visitors likely appreciate the convenience of the digital tools but do not find them to be a defining feature of their experience.

These findings confirm that age is a significant factor in shaping perceptions of digital services at heritage sites. Visitors in the 25–34 age group are the most satisfied, finding the tools both easy to use and valuable in enhancing their overall experience. In contrast, the 55+ group finds less utility in these services, as evidenced by their low scores across all categories. Meanwhile, the lower-than-expected satisfaction of the 18–24 age group highlights an opportunity to improve the technological depth and interactivity of digital services to better meet the expectations of younger, tech-savvy visitors. The moderate ratings from middle-aged groups (35–44 and 45–54) suggest that these visitors see the tools as functional but not necessarily transformative.

4.3. Perceptions of satisfaction with digital services by income

Table 4 on income reveals compelling insights into how economic status shapes visitors' satisfaction with digital services at heritage sites. Visitors with an income of over 12,000 CNY consistently gave the highest ratings across all categories: usability (4.26), quality (4.16), and overall experience (4.26). This indicates that wealthier visitors not only find the digital tools easy to use but also feel that these services significantly enhance their overall experience. Their higher ratings likely reflect familiarity with advanced technologies in their daily lives, which allows them to fully appreciate the digital features offered at heritage sites. For this group, the integration of digital services likely matches their expectations of a modern, tech-driven experience, making it a valuable part of their visit.

Table 4. Evaluation of tourist satisfaction with digital services by income level.

Questions	Income	Quantities of cases	Mean	Std. Error	Min. value	Max. value
I am satisfied with the digital services provided by the World Heritage site.	Below 3000 CNY	38	2.66	0.19	1	5
	3000–5000 CNY	109	3.01	0.115	1	5
	5001–8000 CNY	151	3.3	0.098	1	5
	8001–12,000 CNY	85	3.81	0.124	1	5
	More than 12,000 CNY	19	4.26	0.168	3	5
I believe digital transformation has improved my overall visit experience.	Below 3000 CNY	38	2.87	0.165	1	5
	3000–5000 CNY	109	3.1	0.111	1	5
	5001–8000 CNY	151	3.15	0.095	1	5
	8001–12,000 CNY	85	3.62	0.135	1	5
	More than 12,000 CNY	19	4.16	0.22	2	5
Digital experience at the World Heritage site met my expectations.	Below 3000 CNY	38	2.92	0.174	1	5
	3000–5000 CNY	109	3.12	0.1	1	5
	5001–8000 CNY	151	3.09	0.099	1	5
	8001–12,000 CNY	85	3.68	0.125	1	5
	More than 12,000 CNY	19	4.26	0.24	2	5
Digital services add value to the World Heritage site.	Below 3000 CNY	38	2.68	0.193	1	5
	3000–5000 CNY	109	3.13	0.111	1	5
	5001–8000 CNY	151	3.21	0.097	1	5
	8001–12,000 CNY	85	3.58	0.135	1	5
	More than 12,000 CNY	19	4.26	0.2	2	5

Source: Author's research data.

On the other hand, visitors with an income of less than 3000 CNY rated their experience much lower, with scores of 2.66 for usability and 2.92 for overall experience. This suggests that lower-income visitors may not find the digital services as beneficial, perhaps due to less exposure to or comfort with advanced technology. For this group, the digital services might not align with their expectations or might even create a barrier rather than an enhancement to their visit. The discrepancy in satisfaction between the highest and lowest income groups highlights a potential divide in how digital services are perceived and utilized, which could be addressed by making the tools more accessible or intuitive for all visitors, regardless of their technological background.

The 3000–8000 CNY income group represents the middle ground, with moderately positive ratings for usability (3.30) and overall experience (3.09). This suggests that while these visitors appreciate the digital services, they do not see them as significantly transformative to their experience. For this group, digital services may be viewed more as functional tools rather than central to their engagement with the heritage site.

These findings suggest a strong correlation between income and the perceived value of digital services at heritage sites. Wealthier visitors are more likely to fully engage with and appreciate these services, while lower-income visitors may experience a disconnect between the digital offerings and their expectations or comfort with the technology. This variation in satisfaction levels highlights the need for heritage sites to consider how digital services are designed and marketed to different income groups. Making these tools more accessible, user-friendly, and aligned with the diverse expectations of visitors could improve satisfaction across all income levels.

4.4. Open-ended responses on digital technology at World Heritage Sites

In addition to the quantitative survey, respondents were asked open-ended questions to provide more detailed insights into their experiences with digital tools at World Heritage Sites (WHS). These qualitative responses revealed several key themes about how different digital technologies are used across various types of heritage sites.

1) Cultural Heritage Sites:

Many respondents appreciated the use of Augmented Reality (AR) for enhancing storytelling and bringing historical events to life. AR was frequently mentioned at cultural sites, where visitors valued interactive historical reconstructions. One visitor described how AR allowed them to “see the past unfold” in a way that standard exhibits could not.

Some visitors suggested expanding AR features to include multimedia elements, such as audio guides or real-time translations, to further improve engagement.

2) Natural Heritage Sites:

Visitors to natural heritage sites often referenced Virtual Reality (VR) as a tool for exploring remote or restricted areas. VR was praised for providing access to environments that were otherwise difficult to reach, such as remote mountain regions or ecologically sensitive areas. One visitor noted that VR “opened up parts of the site we couldn’t physically visit.”

A few visitors expressed concerns about VR potentially overshadowing the

natural experience, emphasizing the need for balance between virtual elements and the physical environment.

3) Variation in Digital Technology Across Sites:

A common theme across responses was the variation in digital technology sophistication between different WHS. Some respondents highlighted those certain sites had more advanced and immersive digital tools, while others relied on simpler technologies like mobile apps or digital guides. This variation led to differing visitor experiences, with more technologically advanced sites generally receiving more positive feedback about engagement and satisfaction.

Overall, these open-ended responses indicate that different WHS have adopted varying levels of digital technology, and that these choices significantly impact visitor experiences. The qualitative feedback suggests that cultural heritage sites benefit more from AR's ability to enhance historical storytelling, while natural heritage sites find VR useful for offering immersive access to otherwise inaccessible areas. Visitors' preferences for digital tools also varied depending on the site type and the complexity of the technology used.

4.5. Hypothesis evaluation

This section evaluates the three hypotheses formulated for this study based on the collected data. The table below summarizes the status of each hypothesis:

- H1 is supported by the data showing that visitors with higher educational backgrounds, particularly in STEM fields, consistently rated the usability and satisfaction of digital services higher than those from other educational backgrounds.
- H2 is partially supported. While visitors aged 25–34 gave the highest ratings for usability and satisfaction, the 18–24 age group reported lower satisfaction than expected, indicating that younger visitors had higher expectations that were not fully met by the current digital tools.
- H3 is supported by the findings showing that higher-income visitors provided significantly higher satisfaction ratings for digital services compared to lower-income groups, confirming the positive correlation between income level and satisfaction.

5. Discussion

Digital transformation at World Heritage Sites (WHS) offers both opportunities and challenges in enhancing visitor experiences. Key factors such as age, education, and income significantly influence how different demographic groups interact with technologies like Augmented Reality (AR) and Virtual Reality (VR) (Gursoy et al., 2022; Zhang et al., 2022). By applying insights from the Technology Acceptance Model (TAM) and Expectation-Confirmation Theory (ECT), the analysis focuses on aligning digital tools with visitor expectations, ensuring technology enhances engagement without overshadowing the site's cultural or natural significance (Loureiro and Nascimento, 2021; Olya, 2023). These discussions explore visitor satisfaction, technology adaptation to site characteristics, and the strategic implications for managing WHS in the digital age (Yu et al., 2024).

5.1. Digital transformation: Strategic integration and cultural balance

The integration of digital technologies at World Heritage Sites (WHS) must balance innovation with cultural preservation. AR and VR offer immersive experiences that enhance visitor engagement, but these tools must align with the diverse demographics of visitors, particularly in non-Western contexts like China (Filipiak et al., 2023; Zhang et al., 2022). Younger, tech-savvy visitors are generally more satisfied with complex digital tools, while older or less technologically proficient visitors prefer simpler solutions (Gursoy et al., 2022; Yu et al., 2023). Heritage site managers need to offer flexible digital strategies that cater to varying levels of technological literacy.

Cultural authenticity is key for Chinese WHS, where heritage sites are closely tied to national identity. Digital tools should enhance, not overshadow, the cultural value of the site. In contrast, Western contexts may have a stronger alignment between digital adoption and cultural trends, making this balance less of an issue (Bilgili and Koc, 2021). In non-Western regions, digital tools must be carefully integrated to complement the cultural experience (Rahman and Muktadir, 2021).

Globally, these findings suggest that heritage sites must adopt flexible digital strategies that consider both cultural context and visitor demographics. A one-size-fits-all approach will not work; instead, digital technologies must be adapted to reflect the specific needs of different visitor groups (Olya, 2023; Yu et al., 2023). This research contributes to understanding how digital tools can enhance tourism while preserving cultural heritage.

In conclusion, WHS must balance technological innovation with cultural preservation by offering digital experiences that cater to diverse visitor groups. These findings provide valuable insights for heritage managers seeking to enhance visitor engagement while maintaining the authenticity of cultural sites.

5.2. Visitor satisfaction: Aligning technology with visitor expectations

Visitor satisfaction at World Heritage Sites (WHS) increasingly depends on how well digital technologies meet diverse visitor expectations. Younger, tech-savvy visitors seek immersive and interactive experiences, while older or less tech-proficient visitors prefer simpler, more accessible tools (Aldoseri et al., 2023; Gursoy et al., 2022; Han, 2024). The study shows that satisfaction correlates with technological proficiency: visitors familiar with AR and VR expect more complex experiences, while those less adept at technology are often frustrated by such tools. This highlights the need for heritage sites to offer tiered digital solutions that cater to different groups (Bhattacherjee, 2001; Loureiro and Nascimento, 2021; Venkatesh et al., 2012).

In non-Western contexts like China, digital integration is still evolving. Western visitors may have higher expectations for digital enhancements, while Chinese visitors, especially older or rural ones, may be less accustomed to such technologies. Aligning digital tools with local expectations is crucial for improving satisfaction (Bilgili and Koc, 2021; Zhang and Szabó, 2024).

Globally, these findings underscore the importance of tailoring digital strategies to meet diverse visitor needs. A one-size-fits-all approach is unlikely to succeed; instead, digital offerings should be customized based on demographic characteristics,

ensuring that all visitors have meaningful and accessible experiences (Balakrishnan et al., 2023; Yu et al., 2023).

By aligning digital technologies with visitor expectations, heritage sites can boost satisfaction and foster deeper connections between visitors and the cultural narratives they experience. Offering flexible digital strategies that range from basic to advanced can accommodate diverse visitor needs and ensure satisfaction across different groups.

In conclusion, understanding and aligning technology with visitor expectations is key to enhancing satisfaction. Tailored digital strategies can ensure that both tech-savvy and less proficient visitors have positive, engaging experiences, providing valuable insights for optimizing digital transformation in tourism.

5.3. World heritage sites: Adapting technology to site characteristics

The characteristics of each World Heritage Site (WHS) play a crucial role in determining how digital technologies should be integrated. Sites with complex historical narratives may benefit more from advanced tools like AR and VR, which can help visitors engage with intricate details that might otherwise be missed (Zhang et al., 2022). However, simpler technologies may be more appropriate at sites where the physical experience is paramount, as overuse of digital tools could detract from the authentic atmosphere (Loureiro and Nascimento, 2021).

This study shows that different sites require tailored digital solutions based on their unique cultural and historical significance. For example, at larger or more visually rich sites, immersive technologies can enhance storytelling and visitor engagement. Conversely, for smaller or more spiritually significant sites, the emphasis should be on maintaining an undisturbed, authentic experience (Bilgili and Koc, 2021). Aligning the digital tools with the site's characteristics ensures that visitors not only enjoy their experience but also gain a deeper understanding of the site's cultural value.

Globally, these findings suggest that the success of digital technology in tourism depends heavily on the alignment between the technology and the specific characteristics of the heritage site. Heritage managers need to assess the individual needs of each site to determine which technologies will enhance, rather than detract from, the visitor experience (Gursoy et al., 2022; Rahman and Muktadir, 2021).

In conclusion, adapting digital technologies to the characteristics of each WHS is essential for maximizing their impact. By tailoring digital solutions to the specific needs of the site, heritage managers can ensure that technology enhances visitor engagement while preserving the site's authenticity.

5.4. Demographic analysis: Tailoring digital tools to visitor profiles

Visitor demographics significantly influence how digital tools are perceived and used at World Heritage Sites (WHS). Younger visitors, familiar with digital technology, often expect advanced features such as AR and VR, while older visitors or those with lower technological literacy prefer simpler, more accessible tools (Gursoy et al., 2022; Yu et al., 2023). Tailoring digital tools to these different profiles is essential for enhancing visitor satisfaction.

This study shows that digital strategies must be flexible, offering both basic and

advanced technological experiences. For tech-savvy visitors, immersive experiences like VR provide deeper engagement with the site's cultural narratives. Meanwhile, less technologically proficient visitors benefit more from straightforward tools, such as mobile guides or audio tours (Loureiro and Nascimento, 2021; Venkatesh and Davis, 2000). This approach ensures that all demographic groups can meaningfully engage with the site, regardless of their technological background.

Globally, these findings highlight the need for digital tourism strategies to consider the diverse needs of visitor profiles. A one-size-fits-all approach is inadequate; instead, digital tools must be tailored to the technological capabilities and preferences of different demographic groups (Bilgili and Koc, 2021; Zhang et al., 2022).

In conclusion, tailoring digital tools to the demographic profiles of visitors is key to maximizing engagement and satisfaction. Heritage managers should implement flexible strategies that cater to varying levels of technological literacy, ensuring that all visitors can benefit from digital enhancements.

5.5. Tourism management: Strategic implications for digital transformation

The digital transformation of World Heritage Sites (WHS) has significant strategic implications for tourism management. Digital tools like AR and VR not only enhance visitor engagement but also offer new opportunities for site management to improve visitor flow, provide richer educational experiences, and promote sustainable tourism practices (Gursoy et al., 2022; Zhang et al., 2022).

This study shows that successful digital integration requires a strategic approach, balancing technological innovation with the need to maintain cultural authenticity and site preservation. Managers must carefully choose which technologies to implement, ensuring they align with both the site's characteristics and visitor profiles. By using flexible digital strategies, heritage sites can improve visitor satisfaction while also addressing broader goals, such as reducing overcrowding and preserving the physical site (Bilgili and Koc, 2021; Loureiro and Nascimento, 2021).

Globally, the findings suggest that digital transformation offers valuable tools for improving tourism management, but these technologies must be thoughtfully applied. A targeted approach, tailored to the needs of both the site and its visitors, is essential for maximizing the benefits of digital transformation without compromising the site's integrity (Rahman and Muktadir, 2021; Yu et al., 2023).

In conclusion, the strategic integration of digital tools in tourism management can greatly enhance visitor experiences and operational efficiency. However, managers must carefully balance innovation with preservation to ensure the long-term sustainability of heritage sites.

6. Conclusion

The digital transformation of heritage tourism presents both significant opportunities and challenges, particularly in non-Western contexts like China's coastal regions. This study has provided a comprehensive analysis of how demographic factors—education, age, and income—influence visitors' perceptions of digital

services at 12 World Heritage Sites (WHS) across Eastern and Southern China. By utilizing 402 valid survey responses, the research reveals important insights into how different visitor groups engage with technologies like augmented reality (AR), virtual reality (VR), and mobile applications, highlighting the critical role these tools play in enhancing visitor satisfaction.

The study's findings support the research hypotheses, demonstrating the significant influence of demographic characteristics on the usability and satisfaction with digital tools (H1, H2, H3). Visitors with higher educational backgrounds, particularly in STEM fields, younger visitors (ages 25–34), and those with higher incomes (over 12,000 CNY) expressed the highest satisfaction levels, pointing to the need for advanced, personalized features to cater to their preferences. Conversely, older and lower-income visitors showed lower engagement with these services, emphasizing the importance of simpler, more accessible digital tools for these groups. These results suggest that a one-size-fits-all approach is insufficient, and heritage site managers must develop differentiated digital strategies tailored to distinct demographic groups to optimize visitor satisfaction.

This research contributes significantly to addressing key gaps related to non-Western contexts and the intersection of digital technologies and cultural heritage management. While much of the existing literature focuses on Western heritage sites, this study provides the first in-depth analysis of digital service satisfaction in China's rapidly evolving coastal cities, offering a fresh perspective on how cultural and technological expectations vary across regions. By applying the Technology Acceptance Model (TAM) and Expectation-Confirmation Theory (ECT) in a non-Western setting, the research extends these theoretical models and demonstrates their relevance in diverse cultural contexts.

The theoretical implications of this study advance our understanding of how demographic factors shape visitor perceptions of digital services in heritage tourism. Practically, the findings provide actionable recommendations for WHS managers to design and implement digital strategies that cater to a range of demographic profiles, ensuring that technological innovation enhances, rather than detracts from, the cultural heritage experience. The research underscores the importance of ensuring that digital tools are both accessible and engaging across diverse visitor groups to promote sustainable tourism and preserve cultural authenticity.

This study not only fills critical gaps in the literature but also provides a robust framework for improving digital services at heritage sites, particularly in non-Western regions. By integrating demographic insights into digital strategy development, heritage site managers can enhance visitor satisfaction and engagement while fostering a deeper appreciation for cultural heritage. The findings serve as a blueprint for other regions facing similar challenges, ensuring that the benefits of digital transformation are fully realized while preserving the authenticity and integrity of World Heritage Sites.

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