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Conference Proceedings

**Nemzetközi tudományos konferencia  
a Magyar Tudomány Ünnepe alkalmából**

International Scientific Conference  
on the Occasion of the Hungarian Science Festival

**Sopron, 2024. november 7.**

7 November 2024, Sopron

**FENNTARTHATÓSÁGI ÁTMENET – INNOVÁCIÓS  
ÖKOSZISZTÉMÁK – DIGITÁLIS MEGOLDÁSOK**

SUSTAINABILITY TRANSITIONS – INNOVATION ECOSYSTEMS – DIGITAL SOLUTIONS

Szerkesztők / Editors:

RESPERGER Richárd, SZÉLES Zsuzsanna, TÓTH Balázs István

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# Harnessing Digital Tools for Sustainable Heritage Tourism: Comparative Analysis of Natural and Cultural Sites in China

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## **Abstract:**

As global tourism grows, World Heritage Sites (WHS) face increasing challenges in balancing tourism development with the preservation of cultural and natural heritage. This study explores the role of digital transformation in promoting sustainable tourism by employing technologies such as augmented reality (AR), virtual reality (VR), and digital guides. Focusing on Mount Tai and Kaiping Diaolou, the research examines how digital tools address environmental, cultural, and economic sustainability challenges. The study aims to assess the effectiveness of digital tools in mitigating environmental impacts at natural sites like Mount Tai and enhancing cultural preservation at cultural sites like Kaiping Diaolou, while also analyzing regional differences in the adoption and outcomes of these technologies between Shandong and Guangdong. Findings indicate that digital tools significantly reduce environmental impacts at natural sites and enhance cultural engagement at heritage locations. Regional differences in the adoption of digital tools, particularly between Shandong and Guangdong, shape the effectiveness of these technologies in achieving sustainability. The study also highlights the role of user experience in influencing visitor satisfaction and the balance between cultural preservation and economic growth. This research provides critical insights into how digital tools can be effectively applied to support long-term sustainability at heritage sites.

**Keywords:** digital tools; visitor engagement; regional differences; user experience; economic-cultural balance

**JEL Codes:** O33, L83, R11, M31, Z32

## **1. Introduction**

Tourism has become a vital force driving global economic development and cultural exchange (Cárdenas-García et al., 2024). Yet, as visitor numbers rise, especially at World Heritage Sites (WHS), the tension between tourism growth and heritage conservation intensifies (Zhang et al., 2023). These heritage sites, while invaluable for their cultural and environmental significance,

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face mounting pressures from over-tourism, environmental degradation, and the threat of cultural erosion (Zhang et al., 2023). The challenge of balancing visitor engagement with sustainable management practices has become a focal point for researchers and policymakers alike.

Digital transformation offers a promising avenue for addressing these challenges by integrating technologies such as augmented reality (AR), virtual reality (VR), and digital guides to enhance the visitor experience while minimizing physical impacts on heritage sites (Tan et al., 2022). Digital tools enable more immersive, educational, and sustainable forms of engagement, potentially reducing the ecological strain of physical tourism while promoting cultural preservation. However, the extent to which these technologies contribute to long-term sustainability outcomes, particularly in different regional and heritage contexts, remains underexplored.

China, with its vast array of natural and cultural heritage sites and its rapidly growing tourism sector, presents a unique case for investigating the role of digital transformation in sustainable heritage tourism (Zhang et al., 2024). The distinct regional characteristics of China's World Heritage Sites offer a diverse landscape for studying how different areas and site types adopt and benefit from digital tools (Zheng et al., 2022). In particular, natural sites such as Mount Tai face challenges related to environmental conservation, while cultural sites like Kaiping Diaolou are more concerned with maintaining historical authenticity amidst commercial tourism pressures.

Despite the growing adoption of digital technologies in tourism, current research primarily focuses on enhancing visitor experiences, with less attention paid to how these tools contribute to broader sustainability goals (Xiao et al., 2024). The gap between technological integration and its impact on both environmental and cultural sustainability in different regional contexts remains largely unexplored. Understanding the role of digital transformation in addressing site-specific sustainability challenges is critical for developing effective management strategies that balance tourism development with conservation efforts.

This study addresses this research gap by examining the impacts of digital tools on sustainable tourism at two contrasting World Heritage Sites in China: Mount Tai, representing natural heritage, and Kaiping Diaolou, a cultural site. By conducting a comparative analysis of these two sites, this research investigates how digital technologies influence sustainability outcomes, focusing on environmental, cultural, and economic dimensions. The study also explores how regional differences shape the implementation and effectiveness of digital tools in promoting sustainability at heritage sites.

The primary objectives of this study are to assess the role of digital transformation in mitigating environmental impacts at natural sites, enhancing cultural preservation at heritage sites, and supporting regional sustainability strategies. By analyzing visitor perceptions and regional data, the study provides critical insights into how digital tools can be leveraged to achieve long-term sustainability in diverse heritage contexts.

## **2. Research Overview**

Tourism has long been a driving force for economic development, cultural exchange, and global connectivity. However, with the increasing flow of tourists to World Heritage Sites, the delicate balance between preservation and development has become a pressing concern. While these sites offer significant cultural and natural value, they also face mounting pressures due to over-tourism, environmental degradation, and the challenge of maintaining cultural authenticity.

In response to these challenges, the advent of digital transformation provides new opportunities to foster sustainable tourism. By integrating technologies such as Augmented Reality (AR), Virtual Reality (VR), and digital guides, heritage sites can enhance the visitor experience while simultaneously reducing physical impacts on the sites. This study focuses on how digital tools can support the long-term sustainability of heritage sites, with a particular emphasis on natural and cultural heritage within China. The comparison between Mount Tai in Shandong

and the Kaiping Diaolou in Guangdong offers a valuable perspective on how different regions and heritage types leverage digital technologies to achieve sustainable development goals.

## 2.1. Research Background

Globally, World Heritage Sites face increasing pressure to balance tourism development with the preservation of cultural and natural heritage” (Zhang et al., 2023). With the growing number of tourists, many sites have turned to digital technologies (such as AR, VR, and digital guides) to enhance visitor experiences while minimizing physical damage. These tools provide opportunities to foster sustainable tourism by improving visitor engagement and reducing the strain on heritage sites (Tan et al., 2022; Jiang et al., 2023).

In China, the challenge of managing World Heritage Sites is particularly acute due to the country’s vast number of heritage locations and high visitor volumes” (Zhang et al., 2024). The adoption of digital transformation has gained momentum, but research primarily focuses on enhancing the visitor experience, with less attention on sustainability outcomes, especially across different regions and heritage types (Zeng et al., 2022). The regional context in China offers diverse challenges for both natural and cultural heritage conservation, creating a need for more comprehensive studies.

This study focuses on Mount Tai in Shandong and the Kaiping Diaolou in Guangdong, which represent natural and cultural heritage (figure 1). Mount Tai is a natural site with profound cultural and religious significance, attracting large numbers of tourists seeking both spiritual and scenic experiences. Managing environmental sustainability at such a popular site presents significant challenges. In contrast, Kaiping Diaolou, a cultural site in economically advanced Guangdong, is known for its unique blend of Chinese and Western architecture. Here, the focus is on using digital tools to preserve and transmit the site’s historical and cultural values.



**Figure 1: Mount Tai and Kaiping Diaolou location map**

Source: Own representation

These two provinces were selected due to their economic importance, tourism prominence, and contrasting heritage types. Shandong and Guangdong represent key regions in

China's eastern and southern coastal areas, each with distinct approaches to tourism development and heritage preservation. Studying these two sites provides valuable insights into how digital transformation can contribute to environmental, cultural, and economic sustainability in different regional contexts.

This study's innovation lies in comparing the effects of digital transformation on sustainability in natural versus cultural heritage. This addresses the gap in research on regional and heritage type-specific outcomes in China. This comparison will contribute to a broader understanding of how digital tools can support sustainable tourism and heritage management globally.

## **2.2. Research Objectives**

The primary objective of this study is to explore how digital transformation can contribute to sustainable tourism at World Heritage Sites in China, with a focus on comparing the impacts on natural and cultural heritage. By examining Mount Tai in Shandong and the Kaiping Diaolou in Guangdong, the study aims to uncover how digital tools can address the specific challenges faced by these heritage sites in promoting environmental, cultural, and economic sustainability.

*Key objectives include:*

1. Assess the effectiveness of digital tools in supporting sustainable tourism at natural and cultural heritage sites, particularly in mitigating environmental impacts at natural sites like Mount Tai and enhancing cultural transmission at cultural sites like the Kaiping Diaolou.
2. Analyze regional differences in the implementation and outcomes of digital technologies, investigating how the distinct economic, cultural, and environmental contexts of Shandong and Guangdong shape the role of digital transformation in sustainable tourism.
3. Identify site-specific challenges and propose tailored strategies for integrating digital tools into heritage site management, focusing on how these technologies can be more effectively aligned with long-term sustainability goals, such as balancing tourist engagement with conservation needs.

This study aims to provide a deeper understanding of how regional contexts and heritage types influence the sustainability outcomes of digital transformation, offering insights that can inform more targeted and effective heritage management strategies. The comparative analysis will not only highlight best practices but also reveal potential gaps, contributing to the broader discourse on how digital innovation can be harnessed to achieve sustainable development in heritage tourism, both in China and globally.

## **2.3. Research Focus**

This study explores how digital tools shape visitor perceptions of sustainability at both natural and cultural heritage sites. The application of technologies such as AR, VR, and digital guides plays a critical role in influencing visitors' understanding of sustainability practices. For instance, these tools can enhance awareness of environmental conservation efforts at Mount Tai and promote the preservation of cultural heritage at the Kaiping Diaolou.

Additionally, this research investigates the differences in the implementation and effectiveness of digital technologies between Shandong and Guangdong, with attention to how these regions' distinct economic, cultural, and tourism contexts shape the success of digital transformation. The regional disparities reflect unique challenges and opportunities for promoting environmental, cultural, and economic sustainability through technology.

Furthermore, the study identifies specific challenges faced by natural and cultural heritage sites in integrating digital tools for sustainability. In Mount Tai, the primary concern is balancing high visitor engagement with the preservation of natural landscapes, while in Kaiping Diaolou, the focus is on maintaining cultural authenticity while enriching visitor experiences

through digital means. Addressing these challenges requires tailored strategies that align technological solutions with long-term sustainability goals.

### **3. Literature Review**

As sustainable tourism continues to gain global significance, the integration of digital technologies in the management of World Heritage Sites (WHS) represents a dynamic and evolving area of research. These technologies not only enhance visitor experiences but also hold the potential to mitigate the negative impacts of tourism on fragile cultural and natural heritage environments. The next sections delve into the core aspects of sustainable tourism, the role of digital transformation in promoting sustainability, and the importance of considering regional differences in the adoption of these technologies. This exploration will provide a comprehensive framework for understanding how digital tools can contribute to the long-term preservation and sustainable management of WHS.

#### **3.1. Concept of Sustainable Tourism**

Sustainable tourism has evolved significantly in recent years, emphasizing the balance between tourism growth and the conservation of cultural and natural resources. Sustainable tourism not only seeks to minimize the environmental impact of tourism activities but also aims to promote cultural preservation and ensure economic benefits for local communities (Job et al., 2020). The concept has been applied broadly to World Heritage Sites (WHS), where it is critical to balance the rising influx of tourists with the need to conserve fragile ecosystems and historical sites (Mousazadeh et al., 2023).

However, existing research often focuses heavily on the environmental dimension of sustainability and has yet to explore the interplay between cultural and economic sustainability in heritage tourism (Streimikiene et al., 2021). This is particularly evident in the dichotomy between natural and cultural heritage sites, where the application of digital technologies has received inadequate attention, especially regarding its role in enhancing visitor engagement and promoting sustainable behaviors (Rasoolimanesh et al., 2023).

Cultural heritage sites face distinct challenges in maintaining historical authenticity while accommodating tourism growth. Over-tourism has led to the degradation of cultural significance in many WHS, with a lack of effective digital solutions to manage these pressures (Dai et al., 2021). Although the application of digital tools such as augmented reality (AR) and virtual reality (VR) has shown potential to enhance visitor experiences, current literature needs a comprehensive understanding of how these technologies can directly contribute to cultural sustainability (Caciora et al., 2021).

On the other hand, natural heritage sites primarily contend with environmental degradation. While substantial research exists on visitor behavior management and ecotourism practices, more attention should be given to how digitalization can help reduce physical strain on these ecosystems (Mousazadeh et al., 2023). Existing studies mainly emphasize physical interventions such as limiting visitor numbers or establishing conservation areas but fall short in exploring digital strategies that can foster sustainable tourism development (Chaudhary et al., 2022).

Despite increasing recognition of the role of digital transformation in tourism, its application in sustainable tourism still needs to be researched, particularly in the context of World Heritage Sites (Teshome et al., 2023). Scholars have highlighted that while digital technologies can mitigate issues like overcrowding and resource depletion, few empirical studies have addressed their long-term impact on sustainability goals (El Archi et al., 2023). Additionally, there needs to be more research on the regional variation in how digital tools are applied across natural and cultural sites, particularly in non-Western contexts (Tasnim et al., 2023).

### 3.2. Digital Transformation and Sustainability

Digital tools such as Augmented Reality (AR), Virtual Reality (VR), and digital guides have significantly reshaped the way tourists experience World Heritage Sites (WHS), offering new opportunities for promoting sustainable tourism. These technologies not only enhance the visitor experience but also contribute to reducing the physical strain on heritage sites, addressing a core challenge in sustainable tourism development. By simulating interactive experiences or providing virtual access to heritage sites, digital transformation has emerged as a critical component in fostering sustainable visitor behaviors and heritage preservation.

#### 3.2.1. Enhancing Visitor Experience through Digital Tools

The integration of AR and VR technologies into tourism has led to more immersive and informative visitor experiences at heritage sites. These tools enable tourists to engage deeply with historical and cultural narratives without necessarily being in direct physical contact with the artifacts or structures (Trunfio et al., 2022). AR applications, for instance, allow visitors to visualize historical reconstructions of sites or artifacts using their smartphones, enhancing their understanding and appreciation of the site's significance (Khalil et al., 2024). Such immersive experiences not only improve the quality of the visit but also reduce the need for physical exploration, which can contribute to the conservation of fragile heritage structures (Cuomo et al., 2021).

Similarly, VR provides a fully immersive experience where visitors can “explore” heritage sites remotely or interact with virtual representations of cultural artifacts (Choi & Nam, 2024). This approach is particularly valuable in natural heritage sites, where tourist activities often lead to environmental degradation. By offering virtual tours or access to restricted areas, VR minimizes visitors' environmental impact, ensuring the protection of vulnerable ecosystems (Guo et al., 2023).

#### 3.2.2. Reducing Physical Strain on Heritage Sites

One of the most critical challenges for World Heritage Sites is the degradation caused by tourists' physical presence. Digital tools can mitigate this impact by diverting the focus from physical exploration to virtual engagement (Jiang et al., 2023). For instance, digital guides and interactive apps provide detailed information about a site's history, cultural relevance, and ecological importance, allowing visitors to gain a comprehensive understanding without the need for direct physical interaction with fragile artifacts or environments (Zuo et al., 2023).

These tools not only reduce wear and tear on heritage sites but also offer a more structured and controlled visitor experience. For instance, smart tourism applications can monitor visitor flows, ensuring that overcrowding is avoided in sensitive areas (Bec et al., 2021). Furthermore, drone-based virtual tours or remote sensing technologies offer tourists an aerial perspective of vast landscapes or restricted areas, providing access to natural sites without risking environmental damage (de Oliveira et al., 2024).

#### 3.2.3. Digital Tools and Sustainable Visitor Behavior

The use of digital technologies in tourism extends beyond merely enhancing experiences and reducing physical damage; it also plays a significant role in shaping visitor behaviors toward sustainability. AR, VR, and digital guides have been shown to increase visitors' awareness of environmental conservation and cultural preservation (Li et al., 2024). By providing visitors with real-time information about the environmental and cultural importance of a site, digital tools foster a sense of responsibility and encourage behaviors that align with sustainable tourism practices (Zhang & Szabó, 2024).

For example, interactive apps can include reminders about conservation practices, such as minimizing waste or respecting wildlife, which help visitors adopt more eco-friendly behaviors (Alghizzawi et al., 2024). Moreover, virtual educational platforms incorporated into tourism apps can enhance visitors' understanding of the ecological or cultural sensitivities of the sites they visit, further promoting responsible behaviors during and after their visit (Su et al., 2023).

Additionally, research shows that visitors who engage with digital tools tend to spend more time learning about the site's significance, leading to a deeper cultural appreciation and a stronger connection with heritage conservation efforts (Alghizzawi et al., 2024). These technologies also offer opportunities for personalized recommendations that guide tourists toward sustainable choices, such as eco-friendly accommodations or transportation options (Chamboko-Mpotaringa et al., 2023).

### **4.3. Regional Differences and Sustainability**

Sustainable tourism in World Heritage Sites (WHS) is shaped not only by digital tools and visitor behaviors but also by the regional context in which these sites are located. Regional cultural characteristics, environmental conditions, and economic development levels all play a critical role in the adoption and effectiveness of sustainability policies. A key aspect of this study is to examine how these regional variations—particularly between eastern and southern China—influence the implementation of sustainable tourism practices and digital transformation.

#### *4.3.1. Differences in Tourism Development Models*

The eastern and southern regions of China have seen different paths in their tourism development. Eastern China, exemplified by provinces like Shandong, has historically focused on cultural and historical tourism, driven by its rich history and significant cultural heritage sites, such as Mount Tai. These regions tend to emphasize cultural preservation while integrating modern tourism infrastructures to accommodate large visitor numbers (Chuang, 2023). In contrast, southern China, represented by provinces like Guangdong, is known for its economic dynamism and more commercialized tourism model, where sites like the Kaiping Diaolou combine cultural tourism with economic development goals (Madeira et al., 2023).

This contrast extends to the adoption of digital technologies. In more economically developed southern provinces, there is greater infrastructure for smart tourism systems and innovative digital tools such as VR, AR, and big data analytics. These technologies are more widely implemented to both enhance visitor experiences and monitor environmental impacts, reflecting a more technologically integrated approach to sustainable tourism (Ivars-Baidal et al., 2023). On the other hand, the eastern provinces, while advancing in digital transformation, still emphasize traditional tourism methods with less reliance on cutting-edge technology, focusing instead on visitor engagement through cultural narratives (Kusumastuti et al., 2024).

#### *4.3.2. Regional Cultural and Natural Differences*

Cultural diversity plays a significant role in shaping how sustainability policies are implemented in these regions. For instance, Shandong, with its emphasis on Confucian culture and historical significance, adopts sustainability policies that prioritize cultural preservation and education-oriented tourism. In this context, digital tools like augmented reality (AR) are used to provide rich cultural narratives without compromising the integrity of the historical structures (Li et al., 2024). The goal is to maintain the authenticity of the experience while offering digital solutions to manage increasing visitor numbers and reduce physical strain on the site (Wen et al., 2023).

In contrast, Guangdong – with its history of commercial development and the unique fusion of Chinese and Western architectural styles in the Kaiping Diaolou – approaches sustainability with a greater emphasis on economic sustainability. Digital technologies are implemented not only to preserve cultural heritage but also to promote commercial tourism, integrating economic benefits with sustainability goals (Rodrigues et al., 2023). These technologies help manage both visitor flows and economic opportunities, using tools like big data to optimize resource use and tourism promotion strategies (Ivars-Baidal et al., 2023).

In addition to cultural differences, natural conditions also influence the sustainability strategies adopted in these regions. Shandong's natural sites, such as Mount Tai, are mountainous and ecologically sensitive, requiring environmental protection measures that are compatible with large-scale tourism (Li et al., 2023). Here, the focus is on limiting visitor access to fragile areas while employing digital technologies to provide virtual tours and remote experiences. Conversely, Guangdong's tourism model, with its more urbanized and commercialized nature, prioritizes sustainable urban development and infrastructure that supports tourism while minimizing its environmental footprint (Balsalobre-Lorente et al., 2023).

#### *4.3.3. Influence on Sustainability Policy Implementation*

The varying levels of technological adoption and economic development in eastern and southern regions create differing sustainability policy frameworks. In Shandong, policies are more conservation-oriented, focusing on limiting visitors' physical impact and using digital technologies to enhance cultural education (Shafiee et al., 2023). The region's sustainability efforts often revolve around maintaining the integrity of its natural and cultural landscapes, promoting educational tourism and preserving cultural heritage (Filipiak et al., 2023).

On the other hand, Guangdong's policies focus on integrating digital transformation into commercial tourism models, aiming to achieve economic sustainability alongside environmental conservation (Chon et al., 2024). Here, the use of smart tourism technologies to monitor environmental impacts and optimize visitor management is a crucial component of sustainability policy, reflecting the region's focus on economic growth in conjunction with sustainability (Lee et al., 2024).

These regional differences demonstrate how cultural values, economic priorities, and natural conditions influence the application of digital technologies in promoting sustainable tourism. The contrast between Shandong's emphasis on cultural preservation and Guangdong's focus on economic sustainability underscores the need for region-specific approaches to sustainability policy.

#### **4.4. Research Gaps and Contributions**

Despite significant advances in the scholarship surrounding sustainable tourism and the integration of digital technologies at World Heritage Sites (WHS), several critical gaps in knowledge persist. These gaps underscore the necessity for more nuanced inquiry into how digital transformation can effectively support sustainability goals, especially in diverse cultural and natural heritage contexts.

One area for improvement in the current literature is the limited exploration of how digital technologies such as augmented reality (AR), virtual reality (VR), and smart tourism platforms can simultaneously facilitate both cultural preservation and economic sustainability. Existing research tends to disproportionately emphasize the environmental dimensions of sustainability, particularly within natural heritage sites. However, the potential of digital tools to contribute to cultural sustainability—by maintaining the authenticity of heritage sites while also boosting their economic viability—has been insufficiently addressed. This gap is particularly pronounced in regions where heritage tourism plays a pivotal role in the local economy yet faces

challenges related to over-tourism and the delicate balance between commercialization and cultural integrity.

Moreover, the literature needs to be more empirical studies that assess the concrete impact of digital tools on visitor behaviors in the context of sustainability. While theoretical frameworks have acknowledged the potential of technologies such as AR and VR to enhance visitor engagement, few studies have quantitatively examined how these tools influence sustainable behaviors. In particular, there is scant evidence on how digital interventions may encourage visitors to adopt environmentally responsible practices, such as reducing physical strain on fragile heritage sites or increasing awareness of conservation efforts. The need for robust empirical data leaves a gap in understanding the long-term behavioral shifts that digital technologies might inspire among tourists.

Additionally, there needs to be more comparative research on how regional differences affect the implementation and effectiveness of sustainability policies supported by digital transformation. While some studies have explored variations in tourism development models across different economic regions, few have investigated how cultural values, natural conditions, and regional economic priorities shape the adoption of digital tools for sustainability. This deficiency is particularly significant in non-Western contexts, where cultural heritage and economic growth intersect in complex ways. The Shandong and Guangdong regions in China, with their distinct cultural and economic landscapes, present a compelling opportunity for examining how local factors influence the success of sustainability initiatives through digital transformation. In addressing these gaps, the present study offers several innovative contributions to the literature:

1. **Investigating the Role of Digital Technologies in Cultural and Economic Sustainability:** This research will examine how digital tools not only mitigate environmental impacts but also enhance cultural preservation and economic sustainability at World Heritage Sites. Focusing on Mount Tai and the Kaiping Diaolou, this study will provide insights into how AR and VR technologies can simultaneously support visitor engagement and heritage conservation while promoting sustainable economic development.
2. **Providing Empirical Evidence on the Influence of Digital Tools on Visitor Behaviors:** By analyzing how tourists interact with digital guides, virtual tours, and other digital tools, this study will offer much-needed empirical data on how these technologies influence sustainable visitor practices. This will include exploring how digital interventions can reduce the physical impact of tourism on heritage sites and foster greater environmental awareness. The study's empirical focus will help fill the gap in understanding the practical effects of digital transformation on sustainability outcomes at both natural and cultural heritage sites.
3. **Exploring Regional Variations in Digital Technology Adoption:** The research will conduct a comparative analysis of Shandong and Guangdong, examining how regional differences in cultural heritage, economic structures, and technological infrastructure influence the adoption of digital tools for sustainability. By investigating the unique challenges and opportunities presented by these two regions, the study will contribute to a more nuanced understanding of how local contexts shape the effectiveness of sustainability initiatives. This regional comparison will offer new perspectives on the role of digital transformation in diverse heritage settings.

In summary, this research addresses several key gaps in the current body of knowledge by offering a comparative analysis of how digital technologies can support sustainability at World Heritage Sites within different regional contexts. By providing empirical insights into how digital tools shape visitor behaviors and contribute to both cultural and economic sustainability, the study will advance the understanding of how heritage management can leverage digital transformation to achieve long-term sustainability goals. Its emphasis on the regional specificity of these interventions further underscores the importance of tailoring digital strategies to the distinct cultural and economic conditions of each heritage site, offering significant practical implications for heritage managers and policymakers.

## 5. Data Results

The data results from a detailed analysis of visitor perceptions regarding the implementation of digital tools at two World Heritage Sites in China: Mount Tai and Kaiping Diaolou. The focus is on how digital technologies contribute to sustainable tourism in these different heritage settings. By analyzing quantitative survey data, the section examines visitors' use of digital services, their satisfaction with these tools, and their impact on sustainability awareness. Statistical methods, including T-tests and correlation analyses, are employed to explore differences in visitor experiences between natural and cultural heritage sites. The insights gained provide a deeper understanding of how regional variations affect the adoption and effectiveness of digital technologies in fostering sustainable tourism.

### 5.1. Data Sources Method

The data for this study is derived from a larger research project focused on visitor perceptions of digital transformation at World Heritage Sites (WHS) in eastern and southern China" (Zhang et al., 2023). For the purposes of this analysis, the study focuses on data collected from visitors to Mount Tai in Shandong and the Kaiping Diaolou in Guangdong. These two sites were selected to provide a comparative framework that captures differences between natural and cultural heritage settings, offering a unique perspective on how digital tools influence sustainable tourism in diverse regional contexts (Zuo et al., 2023).

The survey was conducted between December 2023 and May 2024 through the wjx.cn platform, targeting visitors who had been to one of the selected sites within the past year. To ensure the reliability of the data, screening questions were used to confirm that only eligible respondents participated, and IP address locking was implemented to prevent multiple submissions (Guo et al., 2023).

A total of 101 valid responses were collected, with 50 responses from Mount Tai and 51 responses from Kaiping Diaolou. A purposive sampling approach was employed to target visitors who had engaged with digital tools during their visit, ensuring relevance to the study objectives. The survey focused on capturing visitors' perceptions of digital tools, such as digital guides and interactive experiences, and their influence on sustainability awareness and overall tourism experience (Trunfio et al., 2022). To enhance the representativeness of responses, data collection was conducted at various times of the day and on both weekdays and weekends. The quantitative section utilized a five-point Likert scale to measure key variables, including the usability of digital services, environmental awareness, and visitor satisfaction with interactive experiences (Khalil et al., 2024).

To ensure that respondents had genuinely visited the target World Heritage Sites, screening questions were included at the beginning of the survey, asking participants to specify the date of their visit and describe key site-specific features or experiences. These details helped verify the authenticity of their responses (Zhang et al., 2024). The IP address monitoring was employed to prevent duplicate submissions, ensuring the validity of the collected data. Additionally, demographic information, including age, education, and income, was collected to assess how different visitor segments interacted with and evaluated the digital services offered at the sites (Jiang et al., 2023).

The survey data provided a comprehensive evaluation of digital guide usability, the effectiveness of interactive experiences, and the role these tools play in enhancing visitors' environmental awareness and conservation behaviors (Choi & Nam, 2024). This dataset enabled an in-depth analysis of how digital technologies contribute to sustainable tourism at both natural and cultural heritage sites, while also highlighting differences in regional adoption and the effectiveness of digital transformation in promoting sustainability practices (Bec et al., 2021).

Through various statistical analyses, including T-tests and correlation analysis, the findings revealed general satisfaction with digital tools at both sites. However, distinct differences

in how visitors from each region perceived the role of digital services in sustainability and cultural preservation were also identified. These insights provide valuable implications for policymakers and heritage managers in optimizing digital strategies to support long-term sustainability at World Heritage Sites (Mousazadeh et al., 2023).

## 5.2. Results of Regional Variations in the Impact of Digital Tools on Visitor Experience and Historical Engagement

Digital tools significantly enhance visitor experiences in both Guangdong and Shandong by improving accessibility, historical understanding, and engagement. In both regions, there is a strong correlation between the availability of digital guides and their perceived quality (Guangdong:  $r = 0.53$ , Shandong:  $r = 0.61$ ; see Tables 1 and 2), as well as between guide availability and their impact on visitor experience (Guangdong:  $r = 0.63$ , Shandong:  $r = 0.62$ ). This underscores the importance of accessible digital tools in shaping positive visitor perceptions and satisfaction.

Shandong stands out for its stronger correlation between digital displays and the enhancement of historical understanding ( $r = 0.71$ ), compared to Guangdong ( $r = 0.27$ ), suggesting that Shandong's digital strategies are more effective in conveying historical content. Additionally, visitor interest is more strongly linked to digital tools in Shandong ( $r = 0.59$ ) than in Guangdong ( $r = 0.49$ ), indicating a more immersive experience.

Both regions show a robust relationship between the perceived value of digital experiences and service convenience ( $r = 0.63$  for both), highlighting that ease of use is critical to the success of digital platforms. However, Shandong exhibits a stronger connection between visitor interest and the perceived value of digital tools ( $r = 0.67$  vs. Guangdong:  $r = 0.55$ ), suggesting higher engagement.

These findings emphasize the importance of tailoring digital strategies to regional contexts. While accessibility is universally important, Shandong benefits more from immersive, educational content, highlighting the need for region-specific approaches to support sustainable tourism and enhance visitor satisfaction.

**Table 1: Impact of Digital Tools on Visitor Experience in Guangdong**

	Used Digital Guide	Guide Availability	Guide Quality	Enhanced Experience	Historical Understanding	Increased Interest	Digital Experience Value	Convenience
Used Digital Guide	1							
Guide Availability	0.1	1						
Guide Quality	0.3	0.53	1					
Enhanced Experience	-0.12	0.63	0.54	1				
Historical Understanding	-0.03	0.27	0.17	0.32	1			
Increased Interest	0.14	0.09	0.27	0.15	0.49	1		
Digital Experience Value	0	0.21	0.09	0.29	0.72	0.55	1	
Convenience	0.07	0.38	0.33	0.5	0.56	0.53	0.63	1

Source: Own representation

**Table 2: Impact of Digital Tools on Visitor Experience in Shandong**

	Used Digital Guide	Guide Availability	Guide Quality	Enhanced Experience	Historical Understanding	Increased Interest	Digital Experience Value	Convenience
Used Digital Guide	1							
Guide Availability	0.23	1						
Guide Quality	-0.1	0.61	1					
Enhanced Experience	0.15	0.62	0.49	1				
Historical Understanding	-0.19	0.23	0.27	0.27	1			
Increased Interest	-0.16	0.14	0.28	0.19	0.59	1		
Digital Experience Value	-0.25	0.19	0.3	0.12	0.71	0.67	1	
Convenience	-0.1	0.18	0.14	0.11	0.55	0.57	0.63	1

Source: Own representation

### 5.3. Results of Digital Service Impact on Visitor Experience and Regional Perceptions

The correlation analysis reveals that familiarity with cultural aspects has a weak relationship with both learning through online channels (Guangdong: 0.05, Shandong: 0.04) and satisfaction with digital services (Guangdong: -0.08, Shandong: -0.12), indicating that cultural familiarity does not significantly influence engagement with digital tools at World Heritage Sites. Additionally, prior online exposure to these sites shows a slight negative correlation with satisfaction (Guangdong: -0.09, Shandong: -0.12), suggesting that learning about a site online does not necessarily improve satisfaction. However, a modest positive correlation between online learning and recommending digital services (Guangdong: 0.14, Shandong: 0.09) suggests that those exposed online may be more inclined to endorse these services.

Satisfaction with digital services is strongly linked to the perception that these tools enhance the visitor experience (Guangdong: 0.43, Shandong: 0.44), highlighting the importance of high-quality digital tools in engaging visitors. Furthermore, satisfaction strongly correlates with the likelihood of recommending these services to others (Guangdong: 0.51, Shandong: 0.50). The relationship between experience enhancement and recommending digital services is particularly robust in both regions (Guangdong: 0.71, Shandong: 0.70), indicating that visitors who perceive improved experiences are highly likely to promote these services.

Demographic factors, such as age, occupation, and income, show only weak correlations with satisfaction. Age has minimal impact (Guangdong: 0.05, Shandong: 0.03), and occupation shows a slight negative effect (Guangdong: -0.07, Shandong: -0.06). Income, however, has a modest positive correlation with satisfaction (Guangdong: 0.16, Shandong: 0.15), suggesting that higher-income visitors may be more satisfied with digital tools, likely due to greater exposure or familiarity with similar technologies.

Overall, these findings suggest that while demographic factors play a limited role, the enhancement of visitor experience through digital services is key to driving satisfaction and recommendations. High-quality digital tools that enhance visitor engagement are essential for promoting positive word-of-mouth, regardless of demographic differences.

**Table 3: Impact of Digital Services on Visitor Satisfaction and Recommendations in Guangdong**

	Familiarity with cultural aspects	Learned through online channels	Satisfaction with digital services	Digital services enhanced experience	Recommend digital services	Biological sex	Age	Gender identity	Education level	Type of education	Occupation	Monthly income
Familiarity with cultural aspects	1											
Learned through online channels	0.33	1										
Satisfaction with digital services	0.13	-0.09	1									
Digital services enhanced experience	-0.01	0.05	0.51	1								
Recommend digital services	0.12	0.11	0.6	0.58	1							
Biological sex	-0.17	-0.28	0.14	-0.01	0.03	1						
Age	0.1	0.21	0.23	0.16	-0.01	0.2	1					
Gender identity	-0.09	-0.26	0.18	-0.01	0.06	0.96	0.15	1				
Education level	0.06	-0.1	-0.05	0.13	0.09	-0.18	-0.45	-0.17	1			
Type of education	0.02	-0.09	-0.01	-0.12	-0.06	0.04	0.14	0.1	-0.07	1		
Occupation	-0.07	0.17	0.18	0.18	0.09	0.14	0.39	0.17	-0.11	0.17	1	
Monthly income	0.13	-0.09	0.47	0.37	0.19	0.18	0.21	0.21	0.08	-0.06	0.26	1

Source: Own representation

**Table 4: Impact of Digital Services on Visitor Satisfaction and Recommendations in Shandong**

	Familiarity with cultural aspects	Learned through online channels	Satisfaction with digital services	Digital services enhanced experience	Recommend digital services	Biological sex	Age	Gender identity	Education level	Type of education	Occupation	Monthly income
Familiarity with cultural aspects	1											
Learned through online channels	0.05	1										
Satisfaction with digital services	-0.08	-0.09	1									
Digital services enhanced experience	-0.05	0.11	0.43	1								
Recommend digital services	-0.02	0.14	0.51	0.71	1							
Biological sex	-0.05	0.13	-0.16	0.1	0.18	1						
Age	0.08	0.01	0.05	-0.06	0.11	0.21	1					
Gender identity	-0.1	0.11	-0.14	0.05	0.13	0.96	0.18	1				
Education level	-0.11	0	0.07	-0.06	-0.05	-0.06	-0.15	-0.01	1			
Type of education	0.15	-0.19	0.02	0.2	0.09	-0.08	0.07	-0.09	0	1		
Occupation	-0.35	-0.05	-0.07	-0.15	-0.11	-0.25	0.06	-0.19	0.22	0.06	1	
Monthly income	-0.17	-0.02	0.16	0.13	0.09	-0.1	0.23	-0.13	0.13	-0.1	0.06	1

Source: Own representation

#### 5.4. Results of Enhancing Visitor Engagement through Usability and Convenience of Digital Tools

In Guangdong, the correlation between the availability of digital guides and their usability is moderate ( $r = 0.23$ ), while the link between usability and quality is notably stronger ( $r = 0.61$ ). This suggests that improving usability directly enhances the perceived quality of digital tools. In Shandong, similar trends are observed with an even stronger relationship between usability and quality ( $r = 0.61$ ), highlighting that user-friendly tools are crucial for positive visitor experiences in both regions.

When examining the convenience of digital services, both regions exhibit a strong positive correlation with visitor satisfaction in recommending the site based on digital services (Guangdong:  $r = 0.47$ , Shandong:  $r = 0.42$ ). This underscores the importance of convenience in driving visitors' willingness to endorse these services.

In terms of AR/VR appreciation, correlations with digital services' convenience are also strong in both regions (Guangdong:  $r = 0.42$ , Shandong:  $r = 0.42$ ), indicating that visitors who value convenience also tend to appreciate immersive technologies like AR/VR.

Finally, the willingness to revisit if more digital elements are added shows a positive correlation with digital service quality (Guangdong:  $r = 0.29$ , Shandong:  $r = 0.29$ ). This highlights the potential for future investment in digital tools to increase repeat visits and further engage visitors.

These findings emphasize that focusing on the usability and convenience of digital tools is key to enhancing visitor satisfaction and increasing recommendations for heritage sites.

**Table 5: Impact of Usability and Convenience of Digital Tools on Visitor Engagement in Guangdong**

	Used Digital Guide	Type of Digital Guide	Digital Guide Usability	Digital Guide Quality	Digital Services Convenience	Appreciation of AR/VR	More Digital Elements to Future Visits	Digital Transformation to Long-term Appeal	Recommend Site Based on Digital Services
Used Digital Guide	1								
Type of Digital Guide	-0.14	1							
Digital Guide Usability	0.1	0.17	1						
Digital Guide Quality	0.3	-0.15	0.53	1					
Digital Services Convenience	0.07	-0.18	0.38	0.33	1				
Appreciation of AR/VR	0.2	-0.04	0.28	0.34	0.17	1			
More Digital Elements to Future Visits	0.01	-0.02	0.23	0.38	0.25	0.28	1		
Digital Transformation to Long-term Appeal	-0.15	0.06	0.19	0.29	0.26	0.19	0.75	1	
Recommend Site Based on Digital Services	-0.11	0.14	0.28	0.32	0.09	0.26	0.57	0.6	1

Source: Own representation

**Table 6: Impact of Usability and Convenience of Digital Tools on Visitor Engagement in Shandong**

	Used Digital Guide	Type of Digital Guide	Digital Guide Usability	Digital Guide Quality	Digital Services Convenience	Appreciation of AR/VR	More Digital Elements to Future Visits	Digital Transformation to Long-term Appeal	Recommend Site Based on Digital Services
Used Digital Guide	1								
Type of Digital Guide	0.01	1							
Digital Guide Usability	0.23	-0.22	1						
Digital Guide Quality	-0.1	-0.03	0.61	1					
Digital Services Convenience	-0.1	-0.1	0.18	0.14	1				
Appreciation of AR/VR	0.03	-0.14	0.23	0.35	0.42	1			
More Digital Elements to Future Visits	-0.07	-0.2	0.17	0.29	0.41	0.12	1		
Digital Transformation to Long-term Appeal	0.06	-0.11	0.25	0.3	0.41	0.08	0.6	1	
Recommend Site Based on Digital Services	-0.08	-0.24	0.06	0.19	0.47	0.17	0.68	0.64	1

Source: Own representation

## 6. Discussion

Digital technologies are increasingly central to achieving sustainability goals at heritage sites, both natural and cultural. The following section will explore how these tools, such as augmented and virtual reality (AR/VR), interactive digital guides, and smart tourism systems, have been employed to enhance visitor experiences while promoting conservation. By analyzing regional differences and specific site characteristics, we can assess the dual impact of these technologies on both environmental sustainability and cultural preservation. This analysis will reveal how digital tools offer tailored solutions to the unique challenges faced by natural sites like Mount Tai and cultural sites like Kaiping Diaolou, providing insight into their long-term sustainability potential.

### 6.1. Impact of Digital Tools on Sustainability in Natural and Cultural Heritage Sites

The integration of digital tools into heritage site management represents a pivotal shift in how sustainability can be achieved, particularly by addressing the distinct needs of natural and cultural sites. At natural sites such as Mount Tai, the primary challenge has always been mitigating the environmental impacts of heavy tourist activity. Digital tools, particularly AR and VR, offer a solution by providing visitors with the ability to engage in immersive experiences without physically interacting with the fragile natural environment. This not only helps reduce environmental wear but also enables the site to accommodate more visitors without increasing its ecological footprint (Zhang et al., 2023; Jiang et al., 2023). Furthermore, these technologies can simulate restricted or remote areas, allowing visitors to “access” places that are otherwise off-limits, thus enhancing the overall visitor experience while prioritizing conservation (Tan et al., 2022).

For cultural heritage sites like Kaiping Diaolou, the challenge is different. Here, the focus is on the transmission of historical narratives and the preservation of cultural authenticity. While digital tools can enhance visitor engagement by reconstructing historical events or showcasing architectural details, they must be carefully balanced with the need to preserve the site’s original cultural fabric. Over-reliance on technology risks shifting the visitor’s focus from the site itself to the digital medium. Therefore, the successful integration of these tools depends on ensuring they complement the physical heritage rather than replacing it. In the long term, the use of digital tools in cultural heritage should emphasize enhancing the understanding of cultural significance, ensuring visitors leave with a deeper appreciation for both the physical and intangible aspects of heritage (Bec et al., 2021; Mousazadeh et al., 2023).

As these tools become more advanced, heritage sites have the opportunity to tailor digital experiences to different visitor segments (Aman et al., 2024). For instance, younger, tech-savvy tourists may engage more with AR/VR applications, while older generations might prefer digital guides with historical explanations (Kangai et al., 2024). The future of sustainability at these sites lies in offering customized digital experiences that cater to diverse visitor needs while still fulfilling conservation and cultural preservation goals. From a policy perspective, integrating digital tools into heritage management strategies requires a balanced approach that ensures technological innovation supports, rather than disrupts, heritage conservation efforts. Policy-makers should consider developing guidelines that standardize digital heritage applications while allowing flexibility for site-specific adaptations. Additionally, government and institutional support can facilitate investment in digital infrastructure, ensuring equitable access to these technologies across different heritage sites.

Future research could explore the long-term impacts of these tools on visitor behavior, assessing whether they foster lasting conservation attitudes (Alghizzawi et al., 2024). Moreover, investigating how policy frameworks can incentivize sustainable digital innovations—such as promoting eco-friendly digital applications or integrating digital engagement metrics into heritage site management—would provide valuable insights for both academic and practical

applications. While previous studies have focused primarily on visitor engagement, there is still a need for further research into how these digital tools contribute to both environmental and cultural sustainability across different heritage contexts (Trunfio et al., 2022; Jiang et al., 2023).

## **6.2. Visitor Behavior and Interaction with Digital Technologies**

Visitor behavior is a critical aspect of sustainability at heritage sites, and digital technologies have the power to influence this behavior in significant ways. At natural sites, the primary goal is often to manage large tourist volumes without damaging the environment. Digital tools not only facilitate this by offering alternative exploration options but also embed sustainability messages into the visitor experience. For example, interactive digital guides can provide real-time information on conservation efforts or the environmental impact of tourism, subtly educating visitors about their role in preserving the site. This has the potential to shift visitor behavior towards more sustainable practices, such as reducing waste, respecting wildlife, or staying within designated areas (Li et al., 2024; Trunfio et al., 2022; Mousazadeh et al., 2023). The key to success here is designing these technologies in a way that seamlessly integrates educational content into the overall experience, without appearing overly didactic or detached from the tourism aspect.

In cultural heritage contexts, digital technologies must engage visitors more deeply with the historical and cultural significance of the site. The challenge is not just in providing historical facts but in creating an emotional connection between the visitor and the cultural heritage. This requires digital tools to be immersive, interactive, and contextually rich, offering visitors a deeper understanding of the cultural narratives behind the site (Trunfio et al., 2022; Guo et al., 2023; Alghizzawi et al., 2024). However, these tools mustn't trivialize or oversimplify the cultural content. The goal is to foster a genuine interest in cultural preservation, encouraging visitors to not only learn about the site but to support its ongoing preservation efforts (Guo et al., 2023; Li et al., 2024; Khalil et al., 2024).

Looking ahead, digital technologies could be further enhanced by incorporating artificial intelligence to personalize the visitor experience (Kangai et al., 2024). AI-driven tools could tailor content based on visitor preferences or prior knowledge, providing a customized learning experience that maximizes both engagement and conservation outcomes. For example, AI-powered guides could offer different levels of historical detail depending on the visitor's interests, ensuring that each leaves with a nuanced understanding of the site (Aman et al., 2023).

From a policy perspective, the integration of AI in digital heritage management necessitates clear regulatory frameworks to ensure ethical data use, visitor privacy protection, and equitable access to AI-driven experiences. Policymakers should establish guidelines that balance technological innovation with heritage conservation priorities, preventing over-commercialization while enhancing visitor education. Additionally, incentives for heritage sites to adopt AI responsibly—such as government funding for sustainable AI applications or certification programs for ethical digital heritage practices—could encourage wider adoption of these technologies while maintaining cultural authenticity.

Future studies could investigate how digital tools influence visitor behavior over time, particularly whether they lead to more sustainable actions beyond the immediate visit (Guo et al., 2023; Su et al., 2023; Jiang et al., 2023). Moreover, research on how policy interventions—such as AI-driven visitor education programs or digital conservation initiatives—can shape long-term sustainability behaviors would provide valuable insights for both academia and heritage management practices.

### 6.3. Regional Differences in Digital Transformation and Heritage Site Management

Regional factors, including economic development, technological infrastructure, and cultural priorities, heavily influence the effectiveness of digital transformation at heritage sites. In economically advanced regions like Guangdong, digital tools are often deployed not just to enhance visitor experiences but also to generate economic benefits. Sites like Kaiping Diaolou are in regions with robust technological infrastructure, allowing for the integration of more sophisticated digital solutions such as smart tourism systems. These systems can monitor visitor flows, track environmental impact, and even adjust site operations in real-time to optimize both the visitor experience and sustainability outcomes. This dual focus on cultural preservation and economic growth is critical in regions where tourism plays a significant role in local economies (Ivars-Baidal et al., 2023; Guo et al., 2023; Zhang & Szabó, 2024).

In contrast, regions like Shandong, where Mount Tai is located, prioritize environmental sustainability over commercial tourism. The use of digital tools in these contexts focuses more on reducing the physical impact of tourism on natural environments. Here, the challenge is not just technological but cultural, as visitors must be educated on the importance of environmental conservation and encouraged to engage with the site in a way that minimizes their ecological footprint. This requires a different approach to digital transformation, one that emphasizes conservation over convenience or commercial appeal (Li et al., 2023; de Oliveira et al., 2024; Filipiak et al., 2023).

The regional context also affects the scalability of digital solutions. What works in a technologically advanced region may not be as effective in areas with limited resources or infrastructure. Future research could explore how digital tools can be adapted to different regional needs, ensuring that heritage sites in both economically developed and developing areas can benefit from technological innovations (Chamboko-Mpotaringa & Tichaawa, 2023).

From a policy standpoint, governments and heritage management authorities should consider strategies to bridge the digital divide, ensuring equitable access to digital tools across diverse regions. Policy measures such as subsidized digital infrastructure, public-private partnerships, and capacity-building programs for local heritage managers could facilitate the adoption of digital technologies in resource-limited settings. Additionally, regulatory frameworks should ensure that digital transformation does not disproportionately benefit well-funded sites while leaving smaller or less-developed heritage locations behind (Alghizzawi et al., 2024).

There is also potential to examine the long-term economic impacts of digital transformation on heritage sites, assessing whether investments in technology lead to increased revenue without compromising the site's cultural or environmental integrity (Choi & Nam, 2024). Further research could explore how policy incentives—such as tax benefits for sustainable digital investments or funding for community-led digital heritage initiatives—can maximize both economic viability and conservation outcomes in diverse heritage contexts.

### 6.4. User Experience and Its Relationship to Sustainable Tourism

The usability of digital tools is a crucial determinant of their success in promoting sustainable tourism. Visitors are more likely to engage with digital guides, AR/VR experiences, and smart applications if these tools are user-friendly and enhance their overall experience. Poorly designed or difficult-to-navigate interfaces can frustrate visitors, leading to disengagement and, ultimately, a failure to achieve the sustainability goals of the site. On the other hand, well-designed tools that offer intuitive navigation and relevant content can significantly enhance the visitor experience, making it more informative and enjoyable while promoting sustainable behaviors (Chuang, 2023; de Oliveira et al., 2024; El Archi et al., 2023).

Digital tools also have the potential to provide a more structured and controlled visitor experience, which is critical for managing large tourist numbers at heritage sites. For instance,

digital guides can be used to direct visitors away from sensitive areas, ensuring that their interactions with the site are aligned with conservation goals. Moreover, digital tools can provide personalized recommendations, guiding visitors to eco-friendly options such as sustainable transportation or accommodations, thus extending the sustainability impact beyond the immediate site visit (Filipiak et al., 2023; Mousazadeh et al., 2023; Wen et al., 2023).

Looking forward, digital tools could incorporate more sophisticated analytics to track visitor behavior in real time, providing site managers with valuable data on how visitors interact with different parts of the site. This information could be used to optimize the design of future digital tools, ensuring they continuously improve in terms of usability and sustainability impact (Papp-Váry et al., 2023). Furthermore, partnerships with tech companies could lead to the development of new digital solutions specifically tailored to heritage site management, enhancing both the visitor experience and the sustainability outcomes (Rodrigues et al., 2023).

From a policy perspective, the implementation of real-time analytics in heritage sites requires clear regulations on data privacy, ethical data usage, and visitor consent. Policymakers should establish frameworks that balance technological advancement with visitor rights, ensuring transparency in data collection and usage. Additionally, government support for digital infrastructure—such as funding for smart tourism initiatives or incentives for heritage sites to adopt data-driven management practices—could accelerate the responsible integration of these technologies (Khalil et al., 2024).

Moreover, partnerships with tech companies could be guided by policy-driven collaboration models that prioritize cultural preservation and sustainability goals over purely commercial interests (Guo et al., 2023). Future research could examine how public-private partnerships and policy interventions shape the development and deployment of digital analytics tools, ensuring they serve both economic and conservation objectives without compromising cultural integrity.

## **6.5. Balancing Economic and Cultural Sustainability Through Digital Transformation**

Balancing economic growth with cultural preservation is a key challenge for many heritage sites, particularly in regions like Guangdong, where tourism plays a significant role in the local economy. Digital tools offer a solution by enabling sites to attract more visitors without compromising their cultural or environmental integrity. For example, smart tourism systems that provide real-time data on visitor flows can help manage overcrowding, improving both the visitor experience and the long-term sustainability of the site (Ivars-Baidal et al., 2023; Chon & Hao, 2024; Lee et al., 2024). Moreover, these technologies can be used to promote local economies by directing visitors to sustainable businesses, such as eco-friendly accommodations or locally sourced products (Streimikiene et al., 2021; Chamboko-Mpotaringa & Tichaawa, 2023). However, the commercialization of heritage sites through digital tools comes with risks. Over-commercialization can undermine a site's cultural authenticity, turning it into a mere tourist attraction rather than a place of historical and cultural significance. Therefore, it is essential that digital tools be designed to enhance, rather than commodify, the cultural heritage they are meant to protect (Dai et al., 2021; Rasoolimanesh et al., 2023). This requires a careful balance between economic sustainability and cultural preservation, ensuring that the economic benefits of tourism do not come at the expense of the site's cultural value.

Future efforts in digital transformation should focus on creating digital experiences that highlight the cultural importance of the site while still offering economic benefits (Aman et al., 2024). For instance, AR/VR experiences could be used to offer virtual tours that attract paying visitors without increasing the physical strain on the site (Trunfio et al., 2022; Wen et al., 2023). Moreover, digital tools could be used to promote cultural education, ensuring that visitors leave with a deeper understanding of the site's significance.

From a policy standpoint, heritage management authorities should develop regulatory frameworks that ensure digital innovations support both cultural preservation and economic sustainability (Szeberenyi et al., 2022). Policies could include guidelines on revenue-sharing

models between heritage sites and digital content providers, ensuring that financial benefits are reinvested into conservation efforts. Additionally, public funding or tax incentives for heritage sites implementing sustainable digital tourism solutions could encourage responsible digital transformation (Aman et al., 2022).

Research could also explore the long-term economic impacts of digital transformation on heritage sites, assessing whether these technologies contribute to sustainable economic growth without compromising cultural integrity (Su et al., 2023; Rodrigues et al., 2023). Further studies could examine how policy interventions—such as digital heritage certification programs or state-backed funding for non-commercial digital education initiatives—can ensure that digital tools enhance cultural engagement while maintaining economic viability.

## 7. Conclusion

This study has critically examined how digital transformation can contribute to sustainable tourism at World Heritage Sites, with a specific focus on the contrasting natural and cultural heritage sites of Mount Tai and Kaiping Diaolou in China. The findings demonstrate that digital tools, such as augmented reality (AR) and virtual reality (VR), play a crucial role in enhancing visitor experiences, reducing physical strain on heritage sites, and promoting sustainable behaviors among tourists.

At natural sites like Mount Tai, immersive digital experiences successfully mitigate the environmental impact of large visitor numbers, offering a sustainable solution to preserve fragile ecosystems. In contrast, at cultural heritage sites like Kaiping Diaolou, the primary challenge lies in using digital tools to maintain historical authenticity while enhancing visitor engagement. The study highlights the importance of carefully balancing technological integration with the preservation of cultural heritage to avoid over-commercialization.

The regional analysis of Shandong and Guangdong reveals significant variations in the implementation of digital technologies. Shandong's strategies are more focused on environmental sustainability, while Guangdong places a greater emphasis on economic sustainability through the integration of smart tourism systems. These regional differences underscore the necessity of tailoring digital transformation strategies to local contexts, considering both the specific sustainability challenges and the economic priorities of each region.

This research makes several key contributions to the discourse on sustainable tourism. It provides empirical evidence on how digital tools influence sustainable visitor behaviors, particularly in fostering environmental and cultural awareness. Additionally, it highlights regional disparities in digital adoption, emphasizing the need for tailored approaches to heritage management. The findings also expand the understanding of digital transformation's role in supporting not only environmental sustainability but also cultural and economic sustainability, particularly in non-Western contexts. These insights are valuable for both heritage site managers and policymakers, underscoring the importance of strategic digital integration and supportive regulatory frameworks that promote responsible innovation while ensuring equitable access and conservation priorities.

Future research should explore the long-term effects of digital tools on visitor behavior and site sustainability, particularly in the context of artificial intelligence and smart tourism systems. AI-driven personalization, real-time visitor analytics, and smart navigation tools could enhance both engagement and conservation efforts. Additionally, further investigation is needed into how digital heritage strategies can generate economic benefits without compromising cultural integrity. Examining policy-driven frameworks that balance conservation and commercialization will be essential in ensuring that digital transformation aligns with long-term sustainability goals. By continuously refining digital strategies and aligning them with effective policy measures, heritage sites can better preserve their cultural and natural significance for future generations.

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