



# Digital Innovation and Destination Competitiveness: Leveraging Mining Heritage for Virtual Tourism Experiences

Aditi Nag<sup>1\*</sup>, and Anurag Singh Rathore<sup>2</sup>

1. School of Architecture and Design, Faculty of Design, Manipal University Jaipur, Jaipur, Rajasthan, India

2. Department of Tourism Studies, Indira Gandhi National Open University, New Delhi, India

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## Abstract

The tourism industry is experiencing a profound transformation driven by digital innovations such as virtual reality (VR), augmented reality (AR), and interactive platforms. This paper explores how these technologies are reshaping destination competitiveness, with a specific focus on the mining heritage sites (MHSs). By leveraging VR and AR, heritage sites can offer immersive and interactive experiences that enhance visitor engagement, and broaden their reach. Through a case-study analysis, this work examines successful implementations of digital tourism initiatives at various MHSs including the Big Pit National Coal Museum, the Mining Museum of Slovenia, the Mining Museum of the West, the Erzgebirge Mining Region, and the Mesabi Iron Ore Mines. The findings reveal that digital tools significantly improve accessibility, educational value, and global appeal of these sites. However, challenges such as the technical and financial constraints remain. The paper concludes with recommendations for practitioners on integrating digital technologies effectively and suggestions for future research to explore long-term impacts and emerging trends. This work underscores the transformative potential of digital innovation in enhancing the competitiveness and sustainability of tourism destinations.

## 1. Introduction

The tourism industry is increasingly shaped by the rapid advancement of digital technologies, which are revolutionizing how destinations engage with their audiences and present their cultural and historical assets [1-2]. Virtual Reality (VR), Augmented Reality (AR), and interactive digital platforms are at the forefront of this transformation, offering innovative ways to experience and explore destinations that were once limited by physical constraints. Mining Heritage Sites (MHSs), with their rich historical and industrial significance, present a unique opportunity for the application of these digital tools [2-4]. Despite their potential, many of these sites struggle to attract a broad audience due to the geographical limitations and the niche nature of their content [5, 6]. This paper investigates how digital innovation can address

these challenges by enhancing visitor experiences and expanding the reach of Mining Heritage Tourism (MHT). Through a detailed analysis of the case studies including the Big Pit National Coal Museum, the Mining Museum of Slovenia, the Mining Museum of the West, the Erzgebirge Mining Region, and the Mesabi Iron Ore Mines, the study highlights the effectiveness of VR and AR in revitalizing MHSs. It explores the benefits and limitations of these technologies, offering practical recommendations for practitioners and setting the stage for future research in this evolving field.

✉ Corresponding author: [ar.aditi204@gmail.com](mailto:ar.aditi204@gmail.com) (A. Nag)

## 1.1. Background

Presently, the tourism industry is going through a seismic transformation that is based on the fast-changing digital technology [6]. Some of these developments include VR, AR, and interactive digital platforms, which have reshaped how destinations communicate and interact with their audience [6, 8]. These technologies have changed the visitor experience in a way that allows new ways of immersing into cultural and historic places thus changing the face of traditional tourism landscape [7]. VR involves drawing the users into either real-life or fabricated settings through computer generated experiences [6, 9, 10]. This notion enables the individuals to feel present at certain locations, which they would not be able to access due to financial, geographical, or logistical barriers among others. For instance, VR can be used to take people back in time with regards to the ancient historical sites, as well as simulations of past events and detailed reconstructions of abandoned industrial complexes [10]. Contrarily, AR enhances the physical world by superimposing digital information on top one's sight of the surroundings. The historical data can be easily shared using the AR applications; besides, it allows for 3D reconstructions, thereby giving visitors broader insights about their physicality [11-13]. The technology fuses digital improvements with physical surroundings, hence enhancing the educational and interpretative aspects of heritage sites. Interactive digital platforms include a variety of tools like mobile applications, websites, and virtual tours that provides interactive and engaging content [10, 13]. Often such platforms involve elements such as gamification, where the users can take part in interactive challenges or quests based on the site's history; multi-media presentations, which provide dynamic and captivating storytelling. These also facilitate remote accessibility, thereby enabling the individuals from all corners of the globe explore these sites virtually, thus expanding cultural historical tourism reach and influence [14-18].

The integration of these digital technologies is not only improving the way traditional tourist destinations are presented but also generating new opportunities for niche markets like MHT [3, 4, 19, 20]. MHSs are made up of the former mining towns, industrial complexes, and extraction sites,

all of which have a significant historical, cultural, and industrial significance [3, 19]. These places act as a gateway into our past, revealing how mining developed over time, what was the daily life of miners like, and the economic ramification that this industry brought about [21-23]. Nonetheless, attracting visitors to MHSs is often a huge battle. Physical barriers such as remoteness or decayed state of numerous locations can limit accessibility, while others can be geographically restricted [24]. Furthermore, mining heritage having specialized nature may not be interesting to many and conventional ways they present them like physical tours or static displays often consume much resource without giving full account for the dynamic history involved in the mining activities [19, 24]. Digital technologies offer unique ways out by providing true experiences that surpass physical limitations. VR makes it possible to recreate a great many historical mining processes, enabling the users to virtually go back in time, and see the place as it was in the past [14, 17]. The use of AR systems in the museum settings helps merge the gap between physical exhibits' experience and interactive displays by embedding digital information for context and learning enhancement [13, 25, 26]. Interactive platforms are able to provide dynamic content that is captivating enough to draw the visitors' attention such as virtual tours, gamified content, or multimodal presentations [26, 27]. Consequently, MHSs can use these digital innovations to offer compelling virtual experiences that surpass their local or regional boundaries. In doing so, these technological advancements help not only enhance the visitor experience but also extend MHSs' market reach, making them available worldwide for all people, thus enhancing their attraction [19, 24, 27]. Eventually, this is why digital innovations are central to the revitalization of MHT and its expansion into a competitive tourism market.

## 1.2. Research Problem

Despite the potential benefits of the digital technologies, there remains a gap in understanding how these innovations specifically impact the competitiveness of the mining heritage destinations. Although, the recent years multiple publications [10-27] are devoted to digital tourism and its impact in general to improve the destination competitiveness, there is not enough literature

related to the use of such technologies in connection with the tourism development of mining heritage. This gap has pointed the need for a targeted investigation on how 'digitalisation' solutions can improve the attractiveness and marketing of the mining heritage attractions. The current issues of the mining heritage destinations are not only the problem of attracting the tourist attention but also the problem of tourist engagement, and appeals for the explanation of the cultural values. The following are some of the challenges that the digital technologies avail solution in relation to these destinations; the digital technologies make it easier to access sites, and enhance the visitors' experiences in a way that captures more markets [24-27]. Nonetheless, the role and impact of these technologies in enhancing the competitiveness of a destination and enriching the visitors' experience has not been studied thoroughly [1, 4, 28].

### 1.3. Objectives of work

This work aims to address the identified gap by examining the impact of digital innovations on the competitiveness of mining heritage destinations through virtual tourism experiences. The specific objectives are:

#### 1. Primary Objective:

- To analyze the role of VR, AR, and interactive platforms in enhancing the competitiveness of MHSs.

#### 2. Secondary Objectives:

- To evaluate the effectiveness of these digital technologies in improving the visitor engagement and educational outcomes.
- To assess the potential for increased market reach and destination, appeal through the implementation of digital innovations.

### 1.4. Research question

To achieve the objectives, this work seeks to answer the following research questions:

#### 1. Main question:

- How do VR, AR, and interactive platforms influence the competitiveness of mining heritage destinations?

### 2. Sub-questions

- What specific digital technologies have been most effective in enhancing the visitor experience at MHSs?
- What are the challenges and opportunities associated with implementing these digital technologies in the context of MHT?
- How can the insights gained from digital innovations inform the strategic planning and future developments in MHT?

By addressing these questions, the work aims to provide valuable insights into the ways the digital technologies can be leveraged to improve the competitiveness of MHSs, and contribute to their sustainable development as tourist destinations.

## 2. Literature review

### 2.1. Digital innovation in Tourism

Currently, an advanced technology has introduced a paradigm shift in the different segments, and particularly in tourism [1-5]. Due to the advancement in technology, facilities like VR, AR, and interactive applications are novel ways of presenting and experiencing the destinations [22-27]. They have revolutionised the conventional approaches of interacting with the tourists to a completely different ways of form interacting with sites of culture and history [29]. Over the last decade or so, the incorporation of these media tools has complemented the conventional tourism activities, and at the same time, given rise to other forms of specialized tourism like MHT [4, 5, 30, 31]. Though having the historical and industrial importance, MHSs have some unfavorable factors such as physically limited access and geared content to the specific subject matter [1-7]. New form of challenges is presented by the digital technologies by creating appealing and sociable platform that keep people interested, and improves the competitiveness of the destination [15-22].

This literature review is intended to review the historical development of the digital technologies in tourism with specific interests in the VR, AR, and interactive digital platforms. It looks at the recent developments and emerging issues in digital tourism, illustrating how developments are changing visitors' experiences and presenting new possibilities for tourist destinations, especially in association with MHT. Thus analysing the available publications of various authors, the

purpose of the work aims at examining the effects of these technologies on the destination engagement and competitiveness, as well as discovering the future trends of the development of digital tourism.

### **2.1.1. Overview: Evolution of Digital Tools in Tourism**

Technological innovation remains pertinent in reshaping the tourism industry; technological innovation in the digital platform has to a great extent enhanced the communication channel of the tourism destination [32-34]. The common technologies in travel and tourism include VR, AR, and interactive applications that have together changed the way people experience a place [24-27, 33].

The VR technology can be asserted to have originated at the beginning of the 1990s, being at the time a specialized technology applicable in very few areas of tourism and traveling [17, 26, 27]. Though, enhancements in the technology of both the hard and the softwares have broadened the scope of the VR's use, and now it provides the necessary of three-dimensional graphics that provide the feel of a real place, or a place that is completely realizable [32, 33]. Initial explorers in the use of VR in the tourism sphere employed this method to provide the previews and virtual tours. When applied today, VR has become an effective mean to maximize the level of visitors' engagement due to the possibility to give them an opportunity to interact with different historical sites, natural landmarks, and even with imagined worlds [34-37]. The research work has also revealed that the presence and emotions could be boosted by the VR to the extent that it can be an appealing medium not only for the pre-visit preparation but also for virtual tourism.

AR has a relatively less background compared to VR, but is currently on the rise in the tourism sector chiefly due to the provision of digital information on top of the physical environments [34-37]. The AR technology originally started receiving attention with the help of smart phones and tablets that enable the users to interact with digital content in real-time via their devices [38-40]. In tourism, AR is applied to supplement the real physical sightseeing with the historical and

other data, 3D objects, and other multi-media. This technology assists in overcoming the division between the material and the virtual world, with using materials that may be presented to the visitor, and making them more interesting due to the additional features, which can be combined with basic materials in order to explain them or to make the general perception deep [34-38].

Mobile applications and websites also hold a significant importance in the digital transformation of tourism, being part of the interactive digital platforms [41-43]. It is also important to note that such platforms range from the simple functionalities such as virtual tours, game-based experiences, multi-media guide, and social media sharing [41]. They help the destinations to become globally famous, and offer the visitors an opportunity to get familiar with different information and enjoy booking services and other kinds of content [43]. Due to the widespread use of internet as a tool for marketing and sale of services, today's digital tourism management strategies could not be complete without including; Instant/user responsive interfaces – This is mainly because of the integration of 'the user-generated content' and most prominently, the integration of social media [41].

### **2.1.2. Technological Trends: Current Trends and Future Directions in Digital Tourism**

As digital tools continue to evolve, several key trends and future directions are shaping the landscape of digital tourism (refer to Table 1).

In conclusion, the evolution of digital tools in tourism has brought about significant changes in how destinations engage with tourists. VR, AR, and interactive platforms have transformed the visitor experience, offering immersive and interactive ways to explore and engage with destinations. The current trends and future directions in digital tourism are shaping the industry's future, with a focus on personalization, advanced technologies, sustainability, and social interaction. As these technologies continue to evolve, they will play a crucial role in shaping the competitive landscape of the tourism industry and enhancing the appeal of diverse destinations including MHSs.

**Table 1. Emerging trends in digital tourism technologies (Source: Author's compilation).**

Trend	Description	References
<b>Personalization and AI Integration</b>	Personalization is becoming a significant trend in digital tourism, driven by advancements in Artificial Intelligence (AI) and machine learning. The AI algorithms analyse the user data to offer tailored recommendations, customized itineraries, and personalized content. This trend is expected to grow, with AI playing a crucial role in enhancing the user experiences by predicting preferences and delivering relevant information and services.	[6, 14, 17, 25, 26, 40-43]
<b>Immersive Experiences with Advanced VR and AR</b>	The capabilities of VR and AR are continually advancing, with developments such as higher-resolution displays, improved motion tracking, and more realistic simulations. Future trends include the integration of VR and AR with other technologies such as haptic feedback and spatial computing to create even more immersive and interactive experiences. These advancements are likely to enhance the realism and engagement of virtual and augmented tourism experiences.	[6, 14, 17, 25-26, 42, 44-49]
<b>Integration of Blockchain and Smart Contracts</b>	The blockchain technology and smart contracts are emerging trends in digital tourism, offering potential benefits such as secure transactions, transparent booking processes, and streamlined verification systems. The blockchain can enhance the reliability and security of digital platforms, while smart contracts can automate, and simplify various aspects of the booking and payment processes.	[26, 46-48]
<b>Sustainable and Eco-Friendly Technologies</b>	As the tourism industry becomes increasingly aware of its environmental impact, there is a growing emphasis on sustainable and eco-friendly digital technologies. This includes the development of energy-efficient systems, the use of renewable resources, and the promotion of virtual tourism as a means to reduce the carbon footprint associated with travel.	[1, 21, 26, 42, 50-51]
<b>Enhanced Social Interaction and Virtual Communities</b>	The role of social interaction in digital tourism is expanding, with platforms facilitating the virtual communities and social sharing. Future trends may include the development of virtual travel experiences that enable the users to interact with others in real-time, share experiences, and participate in the collaborative activities. This trend reflects a growing desire for social connectivity and community engagement within the digital tourism experiences.	[10, 25, 30, 34, 51-54]
<b>Data-Driven Insights and Analytics</b>	The use of data analytics to gain insights into the visitor behaviour, and the preferences is becoming increasingly important. Digital tools are generating vast amounts of data, which can be analyzed to optimize the marketing strategies, improve the user experiences, and inform the destination management decisions. Future developments are likely to focus on harnessing the data to drive innovation, and enhance the effectiveness of the digital tourism initiatives.	[10, 11, 55, 59]

## 2.2. Virtual Tourism and Destination Competitiveness

As the digital technology advances, virtual tourism has emerged as a significant trend with the potential to revolutionize how destinations attract and engage the visitors. Virtual tourism, enabled by technologies such as VR and AR, allows the users to explore destinations remotely, offering a simulated experience of physical locations through digital means [6, 14, 17, 25-27, 48, 49, 59-61]. This innovation is reshaping the tourism industry by providing new ways for destinations to compete in a crowded market, enhance their appeal, and engage with a global audience [25-27, 49, 59, 60].

### 2.2.1. Impact of Virtual Tourism on Destination Competitiveness

Virtual tourism has the potential to significantly enhance the destination competitiveness by addressing several key factors that influence a destination's attractiveness and marketability (refer to Table 2).

### 2.2.2. Competitiveness: Effects of Digital Innovation on Destination Appeal

Digital innovation including virtual tourism plays a crucial role in enhancing the appeal of destinations by transforming how they are experienced and perceived by the potential visitors [9, 10, 12-14, 16-18, 27, 42, 49, 51-55, 58, 62, 64-68]. The effects of digital innovation on destination appeal can be observed in several ways (refer to Table 3).

In conclusion, virtual tourism and digital innovations have a profound impact on destination competitiveness by enhancing reach, engagement, and appeal. By leveraging these technologies, the destinations can overcome the traditional limitations, offer immersive experiences, and stand out in a competitive market. As digital tools continue to evolve, they will play an increasingly important role in shaping the future of tourism, and influencing how the destinations attract and engage the visitors.

**Table 2. Key Advantages of virtual tourism (Source: Author's compilation).**

Trend	Description	References
<b>Broadened Reach and Accessibility</b>	Virtual tourism breaks down the geographical barriers, enabling the destinations to reach the potential visitors who may not be able to travel due to distance, cost, or physical limitations. By providing a virtual experience of a destination, the tourism stakeholders can attract a wider audience, including those who may not have considered visiting in person. This expanded reach can lead to increased awareness and interest, ultimately enhancing the destination's competitiveness on a global scale.	[6, 17, 25]
<b>Enhanced Visitor Engagement</b>	The immersive nature of VR and AR creates engaging and interactive experiences that can captivate the users and foster a deeper connection with the destination. Virtual tours can simulate historical events, showcase cultural heritage, and provide interactive elements that enhance the learning experience. This level of engagement can lead to a greater visitor satisfaction and positive word-of-mouth, contributing to the destination's overall appeal and reputation.	[2, 10, 15, 17, 25-27, 49, 62]
<b>Pre-visit Experience and Decision-Making</b>	Virtual tourism allows the potential visitors to explore a destination before making a decision to travel. By offering a preview of what they can expect, the destinations can influence visitor decision-making and encourage bookings. This pre-visit experience can help manage the visitor expectations, and enhance the likelihood of a positive experience, which is crucial for maintaining a competitive edge in the tourism market.	[24, 27, 59-62]
<b>Marketing and Promotion</b>	Virtual tourism provides new opportunities for marketing and promotional strategies. High-quality virtual tours and interactive experiences can be shared on digital platforms, social media, and travel websites, attracting attention and generating interest. Effective use of digital content can enhance a destination's visibility and attractiveness, positioning it favorably in comparison to competing destinations.	[29, 35, 44, 47, 58, 63]
<b>Sustainable Tourism Practices</b>	Virtual tourism can contribute to sustainability by reducing the environmental impact associated with travel. By offering virtual experiences, the destinations can mitigate the carbon footprint of tourism, and promote sustainable travel practices. This alignment with sustainability goals can enhance the destination's appeal to the environmentally conscious travellers, and improve its competitive positioning.	[1, 21, 26, 42, 50, 51, 59-62]

**Table 3. Advantages of embracing digital innovation in tourism (Source: Author's compilation).**

Trend	Description	References
<b>Innovative Experiences</b>	Digital innovations introduce novel and interactive ways to experience destinations. By leveraging the VR and AR technologies; destinations can offer unique and immersive experiences that stand out in the competitive tourism market. These innovations can differentiate a destination from its competitors, and attract the visitors seeking new and engaging experiences.	[9-10, 12-14, 27, 42, 49, 55, 58, 62, 64-67]
<b>Enhanced Story-telling and Interpretation</b>	Digital tools enable destinations to tell compelling stories, and present information in dynamic ways. Through virtual tours, interactive exhibits, and the multi-media content, destinations can provide rich, contextual information that enhances the visitors' understanding and appreciation of the site. Effective story-telling and interpretation contribute to a destination's appeal by creating memorable and meaningful experiences.	[16-18, 68]
<b>Personalization and Customization</b>	Digital technologies allow for the personalized and customized experiences tailored to the individual preferences. By utilizing the data analytics and AI, the destinations can offer personalized recommendations, customized itineraries, and interactive content that aligns with the visitors' interests. Personalization enhances the visitor experience, and increases satisfaction, making the destination more attractive and competitive.	[16-18, 27, 42, 49, 55]
<b>Social Sharing and Engagement</b>	Digital innovations facilitate social sharing and engagement, allowing the visitors to share their virtual experiences on social media and other platforms. This user-generated content can serve as authentic endorsements, and contribute to the destination's reputation and appeal. Positive social media engagement can amplify the destination's visibility and attractiveness, attracting new visitors and enhancing competitiveness.	[10, 25, 30, 34, 51-54, 61]
<b>Adaptability and Innovation</b>	Embracing digital innovation demonstrates a destination's commitment to staying current and adapting to changing trends. By incorporating cutting-edge technologies and offering innovative experiences, destinations can position themselves as forward-thinking and progressive. This adaptability can enhance the destination's appeal to tech-savvy travelers and those seeking modern and dynamic experiences.	[2, 17, 42, 66]

### 2.3. Mining Heritage and Tourism

MHSs, encompassing former mining towns, industrial complexes, and extraction sites represent a unique and often underexplored facet of cultural and historical tourism [3, 4, 20]. These sites offer a window into the past, reflecting the technological,

social, and economic transformations that have shaped the industrial history [3, 4, 8, 16, 18-24, 27, 31, 68-77]. Despite their inherent value, MHSs often face challenges in attracting and engaging the visitors [3, 4, 24]. This section explores the significance of MHSs, and reviews the current

practices in MHT, highlighting the opportunities and challenges associated with these sites.

### 2.3.1. Significance: Cultural and Historical Value of MHSs

MHSs hold a substantial cultural and historical significance due to their role in shaping the industrial development and societal change (refer to Table 4).

### 2.3.2. Current Practices: Review of Existing MHT Practices

The practice of MHT involves various strategies and approaches to present and interpret

the mining sites for the visitors [50-58, 60, 71-78]. Table 5 examines the current practices, and highlights the challenges and successes associated with MHT.

In conclusion, MHSs hold a significant cultural, historical, and economic value, offering insights into the past and preserving the memory of mining communities. The current practices in MHT include preservation efforts, interpretive programs, museums, and events, each contributing to the presentation and interpretation of these sites. However, challenges remain, and the integration of digital innovations presents opportunities to enhance MHT and broaden its appeal.

**Table 4. Significance and value of the mining heritage sites (Source: Author's compilation).**

Aspect	Description	References
<b>Historical Insights</b>	MHSs provide valuable insights into the history of mining practices, technological advancements, and the socio-economic impact of the mining industries. These sites often feature remnants of mining equipment, infrastructure, and industrial processes, offering a tangible connection to the past. They serve as educational resources that illustrate the evolution of the mining techniques and the historical context of mining communities.	[4, 8, 16, 18-24, 27]
<b>Cultural Heritage</b>	The cultural significance of MHSs extends to the lives and experiences of the miners and their communities. These sites often include preserved buildings, arti-facts, and personal stories that reflect the daily lives, struggles, and achievements of those involved in the mining industry. By showcasing the cultural heritage of the mining communities, these sites contribute to the preservation of local traditions and collective memory.	[9, 10, 14, 25, 49, 60, 65-68, 78]
<b>Economic Impact</b>	MHSs also highlight the economic impact of the mining industries on the regions and nations. They demonstrate how mining contributed to the industrial growth, urbanization, and regional development. Understanding this economic context provides insight into the broader implications of mining on historical and contemporary economies.	[1, 8, 22, 25, 31, 36-40, 45, 54, 79]
<b>Architectural and Technological Value</b>	Many MHSs feature significant architectural and technological achievements including historic mining infrastructure, machinery, and industrial buildings. These sites offer examples of engineering prowess and architectural design specific to the mining industry, adding to their historical and educational value.	[7, 9-12, 26, 39-45, 53, 60, 66]

### 2.4. Case Study Literature

Examining successful case studies of digital tourism implementations provides valuable insights into how the digital tools and innovations can enhance the visitor engagement and destination competitiveness. These case studies illustrate how VR, AR, and interactive digital platforms have been effectively utilized in various tourism contexts. Understanding these examples can offer critical lessons for applying similar strategies to MHSs, enabling the development of immersive and engaging virtual tourism experiences (refer to Table 6).

In conclusion, the examination of successful case studies in digital tourism offers valuable insights into how VR, AR, and interactive platforms can enhance visitor engagement and destination competitiveness. By applying these

lessons to MHSs, stakeholders can develop innovative digital tourism strategies that address challenges, expand reach, and create compelling and immersive experiences.

### 3. Methodology

The objective of this work is to evaluate the effect of the digital tourism technologies on destination competitiveness in relation to MHSs. The work employs a case-based paradigm to demonstrate how VR, AR, and interactive digital environments are employed in the tourism context and the potential outcomes for the improvement of destinations attractiveness. The concept of the methodology is to give a detailed description of the successful cases of implementing digital tourism using the analysis of the corresponding literature and case-study materials. The research work

focuses in terms of design entails use of proper case selections that would demonstrate a proper adoption of the digital technologies in the tourism context. The research process involves data collection by means of literature review, with no attempt to ascertain the primary data. The obtained data is processed using thematic and comparative analysis in order to compare the findings, determine trends, and identify the key success factors of the digital tourism initiatives. Another characteristic of the evaluation criteria is to examine the efficiency of the digital tools, the

competence of the measures impacted by the digital tools for destination competitiveness, the advancement of technological measures, and the utility of the educational process. The work-flow of the research process is presented in Figure 1 that indicates the methodology of the study including research design, data collection, analysis, and evaluation. This figure highlights the various activities that are encompassed in the work, and the relationships between these methodological activities.

**Table 5. Key approaches and challenges in mining heritage tourism (Source: Author's compilation).**

Aspect	Description	References
<b>Preservation and Restoration</b>	Many MHSs have undergone preservation and restoration efforts to maintain their historical integrity and appeal. These efforts often involve the conservation of physical structures, machinery, and arti-facts, as well as the reconstruction of historical environments. Successful preservation projects can create immersive experiences that transport the visitors back in time, enhancing their understanding of the mining history.	[66, 71-78]
<b>Interpretive Programs and Tours</b>	Interpretive programs and guided tours are common practices in MHT. These programs aim to educate the visitors about the history, technology, and cultural aspects of mining through storytelling, demonstrations, and interactive exhibits. Effective interpretive programs can engage the visitors, and provide a deeper appreciation of the site's significance.	[10, 25, 30, 34, 51-54]
<b>Museums and Visitor Centers</b>	Many MHSs feature the museums and visitor centers that showcase exhibits related to the mining history, technology, and culture. These facilities often include the multi-media presentations, interactive displays, and educational resources. Museums and visitor centers play a crucial role in providing the context, and enriching the visitor experience.	[49, 77, 80, 81]
<b>Events and Re-enactments</b>	Some MHSs host the events and re-enactments to bring mining history to life. These events may include historical re-enactments, demonstrations of traditional mining techniques, and cultural festivals that celebrate the heritage of the mining communities. Events can attract the visitors, and create memorable experiences that highlight the site's historical significance.	[66, 76]
<b>Challenges and Limitations</b>	MHT faces several challenges including the physical condition of sites, geographical constraints, and the specialized nature of mining history. Many sites may be located in remote areas or face issues related to deterioration and maintenance. Additionally, the niche nature of mining heritage may limit its appeal to broader audiences.	[9, 10, 14, 25, 49, 51-54, 60, 65-68, 78-81]
<b>Digital Innovations and Future Directions</b>	The integration of digital technologies such as VR and AR is emerging as a promising approach to enhance MHT. Digital innovations can address some of the challenges associated with physical limitations by providing the virtual experiences that simulate the historical mining operations and interactive elements that engage the visitors. Future directions in MHT may involve a greater use of the digital tools to expand reach, enhance engagement, and attract a diverse audience.	[9-10, 12-14, 27, 42, 49, 55, 58, 62, 64-67, 81-85]

### 3.1. Research Design

This research work uses the case-study method on how the technologies such as VR, AR, and interactive platforms are anchored, and their impact on the competitiveness of the tourist destination. This approach is selected because it allows to give a more detailed description of particular cases when these technologies are applied. Researching authentic cases, it reveals the relationships with the technology, content, and visitors and as a result, it offers a vital knowledge on the advanced experiences, issues, and the real-world implementations. Concerning the mediums, it is important to state that the range of cases is limited to positive experiences in employing the

digital tourism technologies in different settings. From this analysis, the key case studies are chosen purposively because of their association with digital tourism, and proven effectiveness in boosting the level of participation, and suitability in the context of MHSs. The geographical coverage selected also covers both the international and local cases to get a rich view on the innovations in digital tourism [15-22]. The research academia [25-47] stipulates that the case studies should be recent, specifically not older than the last five to ten years. The said focus encompasses a wide array of the digital technologies, which enables one to develop a holistic picture of various strategies and their efficiency.



**Table 6. Notable case studies for successful digital tourism implementations and lessons learnt through key insights from application to the mining heritage sites (Source: Author’s compilation).**

		<b>Previous case studies of digital tourism implementations</b>	<b>References</b>
<b>Successful Examples</b>	<b>Vatican Museums VR Experience (Rome, Italy)</b>	The Vatican Museums have implemented the VR technology to offer virtual tours of their extensive art collections and historic spaces. This initiative allows the users to explore the museums' exhibits and architectural features from remote locations, providing a highly immersive experience that complements the physical visits. The success of this project demonstrates the potential of VR to enhance cultural tourism by offering accessible and engaging content.	[86-88]
	<b>The Anne Frank House AR App (Amsterdam, Netherlands)</b>	The Anne Frank House has utilized an AR app to provide the visitors with a deeper understanding of Anne Frank’s life and experiences. The app overlays historical content and personal stories onto the physical space of the museum, enriching the visitor’s experience with interactive elements and multi-media content. This approach highlights how AR can enhance the historical interpretation and engagement.	[89-92]
	<b>The Smithsonian Institution’s Digitization Projects (Washington, D.C., USA)</b>	The Smithsonian Institution has undertaken numerous digitization projects to make its collections accessible online. Virtual exhibits, interactive features, and digital archives allow the users to explore arti-facts, documents, and historical information from their own devices. These projects exemplify how digital tools can expand reach, enhance educational content, and engage a global audience.	[93-97]
	<b>Hiroshima Peace Memorial Museum VR (Hiroshima, Japan)</b>	The Hiroshima Peace Memorial Museum has integrated the VR technology to recreate the city’s landscape before and after the atomic bombing. This immersive experience provides the visitors with a poignant and educational view of the historical impact of the bombing. The success of this VR implementation demonstrates how the digital technology can convey complex historical events, and foster a deeper understanding of the significant events.	[98-102]
	<b>The Tower of LONDON Virtual Tours (London, UK)</b>	The Tower of London offers virtual tours that allow the users to explore its historic rooms, exhibitions, and the Crown Jewels. This digital initiative provides an engaging way to experience the site’s history and arti-facts from a distance. The Tower of London’s virtual tours highlight the potential of digital tools to make heritage sites accessible and appealing to a broader audience.	[103-106]
		<b>Key Insights and Lessons Applicable to MHSs</b>	<b>References</b>
<b>Lessons Learned</b>	<b>Enhancing Accessibility</b>	Successful digital tourism implementations demonstrate that the VR and AR technologies can significantly enhance accessibility by providing remote access to the cultural and historical sites. For MHSs, this means creating virtual experiences that allow the users to explore mining operations, machinery, and historical contexts from anywhere in the world. Ensuring that digital content is user-friendly and accessible can broaden the reach of MHT.	[6, 17, 25]
	<b>Immersive and Interactive Experiences</b>	The use of immersive technologies such as VR and AR has proven effective in engaging the visitors, and providing a deeper understanding of the cultural and historical contexts. MHSs can benefit from similar approaches by creating interactive simulations of the mining processes, historical reenactments, and virtual tours that capture the essence of the mining heritage. Engaging content can enhance the visitor satisfaction and interest.	[9, 10, 12-14, 27, 42, 49, 55, 58, 62, 64-67]
	<b>Rich Contextual Content</b>	Case studies highlight the importance of providing the rich, contextual content that enhances the visitor experience. Digital tools that offer detailed information, personal stories, and historical context can make virtual experiences more meaningful. MHSs should incorporate comprehensive and engaging content that reflects the historical, cultural, and technological aspects of mining.	[9, 10, 14, 25, 49, 60, 65-68, 78]
	<b>Integration with Physical Visits</b>	Digital tourism initiatives often complement physical visits by offering additional layers of information and engagement. MHSs can use digital tools to enhance in-person visits such as through the AR applications that provide interactive elements and contextual information at key locations. This integration can enrich the overall visitor experience, and create a more comprehensive understanding of the site.	[10, 25, 30, 34, 51-54]
	<b>Expanding Market Reach</b>	The successful case studies demonstrate that digital tourism can expand market reach, and attract a global audience. MHSs can leverage the digital tools to reach potential visitors who may not be able to travel to the site physically. Effective marketing and promotion of virtual experiences can increase visibility, and attract diverse audiences.	[29, 35, 44, 47, 58, 63]
	<b>Educational Value</b>	Digital implementations often have strong educational components that contribute to the visitor learning and engagement. MHSs can incorporate educational elements into their digital experiences such as interactive lessons on mining history, technology, and environmental impact. Providing educational value can enhance the appeal of MHT and attract the visitors with a strong interest in learning.	[10, 25, 30, 34, 51-54, 61]

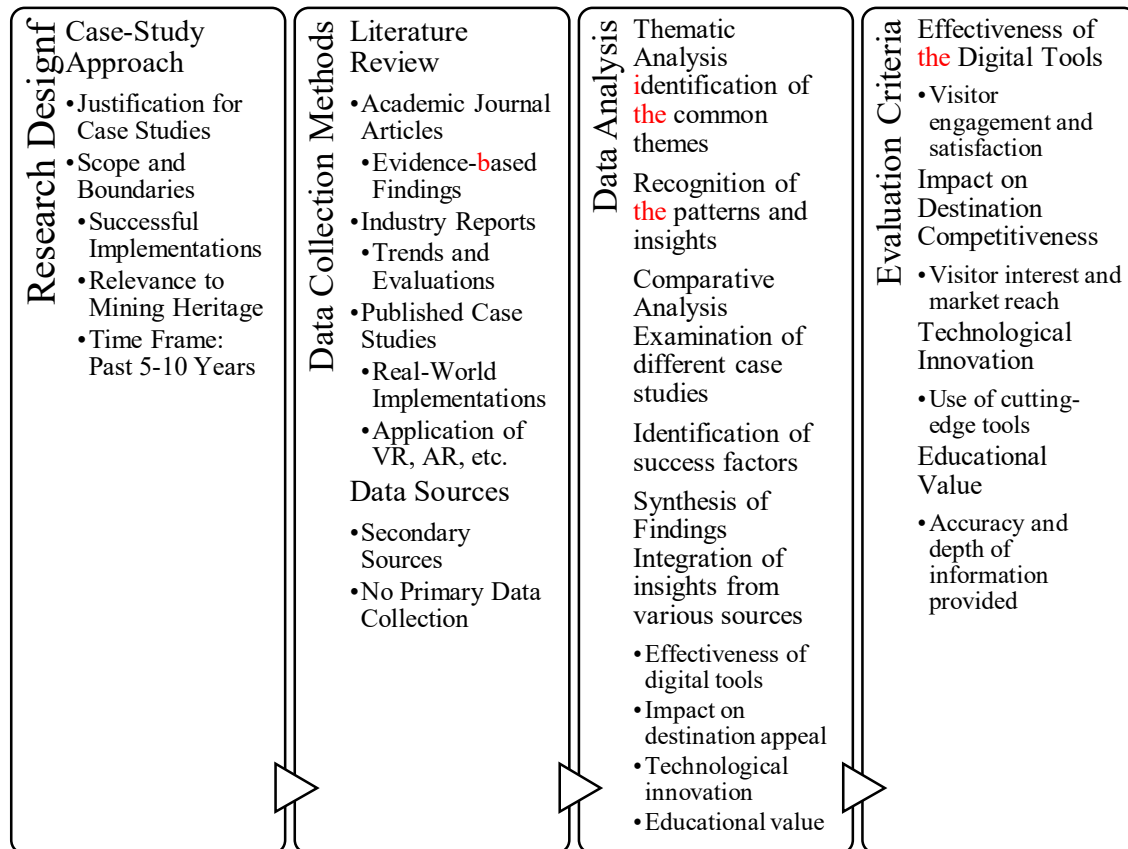


Figure 1. Research workflow diagram illustrating the methodology of the work including research design, data collection, analysis, and evaluation of processes (Source: Author).

### 3.2. Data Collection Methods

Information for this work is collected by means of analyzing the existing literature and case studies regarding the adoption of digital tourism solutions. This entails a methodology that includes the analysis of the secondary data such as scholarly articles, market research, and case studies available in the discipline. The emphasis of the research work is placed on identifying the information from prior studies that describe the effective use of VR, AR, and other interactive solutions in the context of tourism. The use of digital tools to increase the visitors' engagement, and the competitiveness of the destination is described in the academic journal articles that present research findings. Publications of industrial organizations as well as technology suppliers provide research data and information on best practices on the implementation of the digital technologies in tourism with regards to the case studies, tendencies, or assessments of the digital tourism strategies. The literature includes actual examples of the application of the concept in tourism: how digital tourism technologies are

applied, which of them are used, VR and AR technologies, and interactive platforms used in certain mining tourism projects.

### 3.3. Data Analysis

The process of analysing the collected literature aims to extract information through a number of methods. In turn, thematic analysis is applied to analyze and reveal similar threads, patterns, and findings based on the literature review, focusing on recognizing how the digital technologies are adopted in tourism, and the resultant effects on the visitor interaction and destination attractiveness. Comparative analysis compares various examples of companies' experience to define the factors that can cause positive effect on the digital tourism implementations, in general, and make conclusions regarding the effective practices and activities. The study is an integration of findings in an attempt to offer the best and extensive analysis of the effects of the digital tourism technologies. This involves a combination of the literature review and theoretical

analysis from the articles, business news, and case studies.

The criteria for measuring the outcomes of advanced digital tourism solutions include the usefulness of the digital tools being implemented, the contribution of the tools improving the competitiveness of the destinations, the level of technological integration, as well as the education value of the implemented tools. In as much as digital tools are efficient, their effectiveness is measured on the extent to which it will attract and engage the visitors. The changes in the competitiveness of the destination are assessed based on the interest, appeal, and coverage of the market. The technological advancement is measured with concerning to the extent to which the advanced technologies and the digital applications are applied to enrich the tourisms. Finally, the educational value is determined in terms of how accurate the information presented is, as well as how sophisticated the historical and cultural background information given is.

Overall, this methodology outlines a comprehensive approach to studying digital tourism through a review of the literature and case studies, aiming to provide valuable insights into how the digital tools enhance the visitor engagement and destination competitiveness.

#### 4. Case Studies

The case studies section analyses how the digital tourism technologies work in practice, and focuses, in particular, on the application of the technology in the context of MHSs. Thus the analysis of these case studies will help the research to reveal the efficiency and outcomes of the VR, AR, and interactive platforms in the context of the increased visitors' interest and destinations' competitiveness. At the same time, each case covers a specific subject area, and focuses on the digital technologies used in tourism; thus it demonstrates various strategies and effective solutions that can be applied, while working with these tools. Some of the cases reported are from the global environment, while others are from within the surrounding environment, and they embrace different technologies and impacts. The implementation of the offered ideas in the case of tourism experiences, thus makes them special as they illustrate the key strengths, weaknesses, and real-world considerations for the adoption of the

digital technologies. Therefore, while analyzing the information of these case studies, the research work aims at identifying the major success factors that influence the implementation of the digital tourism projects. The purpose is to present the findings and suggestions on how to increase the impact of digital solutions, to raise awareness and support of MHSs. This section not only showcases various best practices but also provides ways on how to address the issues that can hinder the use of digital innovations in the tourism industry, and the best ways on how to optimize its usage.

##### 4.1. Case Study 1: Virtual Mine Tour of Big Pit National Coal Museum, Wales

The Big Pit National Coal Museum, situated in Blaenavon, Wales, is a significant heritage site dedicated to preserving and showcasing the history of coal mining. Established in 1983, the museum operates within a former coal mine that was active from the early 19th century until its closure in 1980 [74]. The museum's main attraction is its extensive underground tour, which allows the visitors to descend into the old mining tunnels, and experience firsthand the working conditions of the miners. Above ground, the museum features an array of exhibits related to the mining history including machinery, tools, and personal stories of the miners and their families [76]. The museum's comprehensive approach to preserving and interpreting the mining heritage makes it a valuable educational resource, and a popular destination for those interested in the industrial history [77].

To address the limitations of physical access, and to enhance its educational reach, the Big Pit National Coal Museum has embraced the digital technology through the creation of a virtual mine tour. This virtual experience utilizes a 360-degree video technology to provide an immersive, panoramic view of the mine's underground and surface areas [80]. The users can virtually navigate through the mining tunnels, view the key historical sites, and explore detailed representations of the mining equipment and arti-facts. The virtual tour incorporates several interactive elements designed to engage the users, and enhance their learning experience [105]. The clickable hotspots within the video allow the users to access additional information, historical context, and the multi-media content related to the specific features of the mine. For instance, the users can click on a mining

helmet icon to learn about the equipment used by the miners or on a machinery icon to see a video demonstration of how it was operated [106]. These interactive features provide a richer understanding of the mining processes, and the daily lives of the miners. In addition to the 360-degree video, the virtual tour includes interactive overlays that offer the contextual information, photographs, and audio narrations [74]. This multi-media approach helps to bring the historical and technical aspects of mining to life, providing a more comprehensive and engaging experience for the users [77]. By integrating these digital tools, the museum not only enhances the virtual tour experience but also makes the site accessible to a global audience who may not have the opportunity to visit in person.

The implementation of the virtual mine tour has yielded several positive outcomes for the Big Pit National Coal Museum. One of the most notable results is the increased accessibility of the museum's content [106]. By offering a virtual tour, the museum has removed the geographical barriers, enabling the individuals from across the world to explore the site, and engage with its heritage. This expanded reach has led to a significant rise in an online engagement, as users from diverse locations can now experience the museum's offerings remotely. The virtual tour has also contributed to the heightened visitor engagement. The immersive and interactive nature of the digital experience has enhanced the users' understanding and appreciation of the mining heritage. Feedback from the users indicates that the virtual tour provides an engaging and informative experience that complements the museum's physical exhibits [107-109].

Furthermore, the digital initiative has positively impacted the museum's overall visibility and outreach. By leveraging a modern technology, the Big Pit National Coal Museum has successfully extended its educational mission and cultural impact beyond the confines of its physical location. This digital expansion has not only supported the museum's sustainability but also demonstrated the potential for other heritage sites to utilize the digital tools to enhance their appeal and educational value.

#### **4.2. Case Study 2: Virtual reality experience at Mining Museum of Slovenia**

The Mining Museum of Slovenia, located in the town of Idrija, is a notable institution dedicated to preserving the rich history of mining in Slovenia.

Established in 1952, the museum is situated in the historic Idrija mercury mine, which was one of the world's largest mercury mines from the 15th century until its closure in 1994. The museum offers a comprehensive exploration of the mining processes, equipment, and the lives of the miners through its well-preserved mine tunnels, extensive collections of mining arti-facts, and educational exhibits [78]. The site is also recognized as a UNESCO World Heritage Site for its historical significance and well-preserved mining infrastructure [110].

To enhance the visitor experience, and broaden the reach of its educational offerings, the Mining Museum of Slovenia has integrated advanced digital technologies including an AR app and a VR simulation [78, 111]. The AR app enriches the on-site experience by overlaying digital information and interactive elements onto physical exhibits. The visitors can use their smartphones or AR glasses to view additional details about the mining tools, historical events, and operational processes, as they explore the museum [112]. For example, pointing a device at a mining drill might reveal a 3D model of the tool in action, or provide historical anecdotes about its use. In addition to the AR app, the museum has developed a VR simulation that allows the users to experience the mining environment virtually. The VR simulation immerses the users in a detailed, 3D reconstruction of the mine, providing a realistic portrayal of what it was like to work in the Idrija mercury mine [111-113]. The users can navigate through the mine's tunnels, operate mining machinery, and interact with the virtual representations of the miners. This simulation offers an engaging and educational experience that brings the historical and technical aspects of mining to life, allowing the users to gain a deeper understanding of the site's significance [114].

The implementation of the AR and VR technologies at the Mining Museum of Slovenia has led to several positive outcomes. The AR app has significantly enhanced the visitors' understanding of the exhibits by providing interactive and contextual information that complements the physical displays [110-112]. This added layer of engagement helps the visitors better grasp the historical and technical details of the mining operations, and the museum's arti-facts. The VR simulation has proven to be particularly

effective in delivering an immersive historical experience [114, 115]. By recreating the mining environment in a virtual space, the simulation allows the users to experience the mine as if they were actually there. This immersive approach has been praised for its ability to transport the users back in time, and provide a tangible sense of the conditions faced by the miners. The VR experience has been especially valuable in communicating the scale and complexity of the mining operations to the audiences who may not have a background in the mining history [111].

Overall, these digital innovations have enhanced the educational value of the Mining Museum of Slovenia, and attracted a wider audience. The ability to engage with the site through the cutting-edge technology has positioned the museum as a leading example of how the digital tools can enrich heritage tourism. The success of these implementations demonstrates the potential for other MHSs to adopt similar technologies to improve the visitor engagement and educational outcomes.

### **4.3. Case Study 3: Interactive mining heritage experience at Mining Museum of the West, USA**

The Mining Museum of the West, located in the heart of the American West, is dedicated to celebrating the history and impact of mining in this region. The museum, established to preserve the rich heritage of the mining activities, features an array of exhibits that showcase the mining equipment, historical arti-facts, and the stories of the individuals who shaped the mining industry [73]. Its collection includes vintage machinery, photographs, and personal accounts from the miners, providing a comprehensive overview of the mining processes, and their effects on the local communities. The museum's location in a historically significant mining region adds to its importance, making it a key destination for both the educational and heritage tourism [116]. The museum's mission is to provide an engaging and informative experience that highlights the technological advancements in mining, and the social history of the industry [117].

To modernize its offerings and enhance the visitor engagement, the Mining Museum of the West has integrated interactive exhibits and the VR simulations into its displays. The interactive exhibits include touch screens, multi-media

presentations, and digital touchpoints that allow the visitors to delve deeper into the various aspects of the mining history [116]. These exhibits offer interactive elements such as quizzes, detailed infographics, and virtual reconstructions of the mining operations, which help to make complex historical and technical information more accessible and engaging. The museum has also developed several VR simulations that provide an immersive experience of the historical mining environments [61, 118]. These simulations recreate specific mining sites and scenarios, allowing users to virtually experience the challenges and working conditions faced by the miners. The VR experiences are designed to be highly interactive, enabling the users to operate the mining equipment, navigate through tunnels, and interact with the virtual representations of historical figures [119, 120]. This approach provides a compelling way for the visitors to understand the mining process and the historical context of the arti-facts on display.

The introduction of interactive exhibits and VR simulations at the Mining Museum of the West has resulted in significant enhancements to its educational offerings and visitor engagement. The interactive exhibits have improved the visitors' understanding of mining technology and history by providing dynamic and hands on learning experiences [116, 121]. These exhibits cater to diverse learning styles, and make the museum's content more engaging and memorable. The VR simulations have been particularly effective in offering an immersive experience that brings the historical mining environments to life [115]. The visitors can gain a firsthand perspective on the mining process, and the daily life of the miners, which enhances their overall understanding of the industry's historical impact [120, 121]. The immersive nature of the VR simulations has received positive feedback from the visitors, who appreciate the opportunity to explore the mining history in a more interactive and experiential manner.

Overall, these digital innovations have elevated the museum's ability to educate and engage its audience. By incorporating the cutting-edge technologies, the Mining Museum of the West has successfully modernized its approach to heritage tourism, making its educational content more accessible and engaging. The positive outcomes of these digital implementations underscore the

potential for other heritage sites to leverage similar technologies to enhance their visitor experiences and educational impact.

#### **4.4. Case Study 4: Digital Story-telling and virtual tours at Erzgebirge Mining Region, Germany**

The Erzgebirge Mining Region, located in southeastern Germany along the border with the Czech Republic, is renowned for its rich mining heritage. This historic region, also known as the Ore Mountains, has been a significant site for silver, tin, and other mineral extraction since the middle ages [60]. The Erzgebirge Mining Region is recognized for its well-preserved mining infrastructure including old mining tunnels, processing facilities, and historical mining towns. Its historical and cultural importance is underscored by its designation as a UNESCO World Heritage Site, which highlights its contribution to the development of mining techniques and its role in the industrial history of Europe [121]. The region's extensive network of the mining arti-facts, and historical sites offer a unique glimpse into the evolution of mining technology and the social impact of mining on local communities. The Erzgebirge Mining Region attracts the scholars, history enthusiasts, and tourists interested in exploring its historical and cultural landscape [122].

To enhance its global reach and appeal, the Erzgebirge Mining Region has employed digital story-telling and virtual tours as part of its tourism strategy. Digital story-telling involves the use of multimedia elements—such as videos, animations, and interactive narratives—to convey the region's rich mining history in an engaging and accessible manner [123]. Through the digital story-telling platforms, the visitors can explore the stories of the miners, the technological advancements in mining, and the socio-economic impacts of mining on the region. These digital narratives provide a personal and immersive experience, allowing the users to connect with the historical and cultural context of the mining activities [121]. In addition to digital story-telling, the region has developed virtual tours that offer a comprehensive exploration of its mining sites. These virtual tours use a 360-degree video, and the interactive maps to allow the users to virtually visit the key locations within the mining region. The users can navigate through historical

mines, view detailed reconstructions of the mining facilities, and access additional information through interactive elements embedded in the virtual tour [124]. The virtual tours are designed to replicate the experience of visiting the sites in person, providing the users with a sense of immersion and engagement.

The implementation of digital story-telling and virtual tours has significantly strengthened the global presence and appeal of the Erzgebirge Mining Region. By utilizing these digital tools, the region has been able to reach a wider audience, and attract the visitors who might not otherwise have had the opportunity to explore its mining heritage [121-124]. The digital story-telling approach has enhanced the visitors' understanding of the region's historical significance, and created a more engaging way to experience its cultural narratives. The virtual tours have proven particularly effective in offering an immersive experience that extends beyond the physical constraints of the region. The users can explore the mining sites from anywhere in the world, gaining insights into the mining operations and the historical context without needing to travel [123]. This expanded reach, has increased the visibility of the Erzgebirge Mining Region, and contributed to its reputation as a leading example of how digital innovation can enhance the heritage tourism.

Overall, the integration of digital story-telling and virtual tours has provided the Erzgebirge Mining Region with innovative tools to promote its heritage and engage a global audience. The success of these digital initiatives underscores the potential for other heritage sites to leverage similar strategies to enhance their appeal and educational impact.

#### **4.5. Case Study 5: Digital Reconstruction of Mesabi iron ore mines, India**

The Mesabi Iron Ore Mines, located in Jharkhand, India, hold a crucial place in the country's industrial heritage due to their significant contribution to steel production [24]. These mines, known for their high-grade hematite with iron content ranging between 65-70%, have played a vital role in the India's iron ore supply. Historically, the Mesabi Iron Ore Mines have employed various mining techniques including open-pit extraction and have been central to the development of the India's steel industry. Despite their importance, the site has faced challenges in preserving, and

effectively presenting its historical and industrial significance. To address these challenges, a comprehensive digital reconstruction project was undertaken [24]. The primary goals of this project were to preserve the historical and technological aspects of the Mesabi Iron Ore Mines, enhance the site's educational value, and broaden its global visibility. The digital reconstruction involved the use of advanced 3D modeling techniques to create detailed and interactive virtual representations of the mining site. This included reconstructions of mining equipment, extraction processes, and the overall layout of the operations [125]. Additionally, virtual reality (VR) and interactive digital platforms were developed to allow the remote users to explore the reconstructed mining site. This immersive experience enabled the users to navigate through the site, interact with various elements, and access contextual information about the mining operations. The digital models and virtual tours were created using high-resolution 3D rendering and VR technologies, aiming to replicate the on-site experience, and provide a detailed understanding of the mining operations and their historical context [126].

The impact of the digital reconstruction has been substantial. It has significantly enhanced the educational value of the Mesabi Iron Ore Mines by offering an engaging and informative presentation of the site's history and technology [24]. The 3D models and virtual tours provide a comprehensive view of the site's operations, which might be challenging to convey through the traditional exhibits alone. Moreover, the virtual site visits have expanded the global reach of the Mesabi Iron Ore Mines, making it possible for the users from around the world to explore the site, and appreciate its historical and technological significance [125]. The project has also addressed several preservation challenges. By offering a virtual experience, it has overcome the physical accessibility barriers, allowing the individuals who cannot visit the site in person to engage with its history. Furthermore, the digital models serve as a preservation tool, documenting the site's features and operations for future generations. Overall, the digital reconstruction of the Mesabi Iron Ore Mines represents a successful integration of technology into the heritage management and tourism [126]. It has revitalized interest in the site, provided valuable educational resources, and broadened its

appeal [24]. This case study highlights the potential of the digital tools to enhance the presentation and preservation of significant historical and industrial sites, bridging gaps in accessibility, and offering immersive educational experiences.

## 5. Discussion

In the following discussion, this study delves into the implications and insights drawn from the case studies presented. The integration of digital technologies in MHT reveals significant advancements in how the heritage sites are experienced and perceived by global audiences. By examining the detailed implementations and outcomes of the digital tools such as VR, AR, and digital story-telling across various MHSs, this work aims to uncover the broader impacts of these innovations on destination competitiveness, and the visitor engagement. The case studies, which encompass diverse geographic locations and technological approaches, provide a comprehensive understanding of the current trends, and successes in digital tourism. This discussion explores how these digital implementations enhance the educational value, increase accessibility, and expand global reach for MHSs. The work assesses the effectiveness of various digital strategies in addressing the challenges faced by the traditional methods of heritage presentation, and considers the potential for these technologies to transform the landscape of heritage tourism. Additionally, the study examines the common themes and distinct differences among the case studies to identify the best practices and key lessons. This analysis highlights how digital innovations contribute to the preservation and promotion of the mining heritage, offering valuable insights for the future initiatives. By reflecting on the outcomes and experiences detailed in the case studies, the work draws conclusions about the evolving role of the digital technology in heritage tourism, and its implications for enhancing destination competitiveness and visitor engagement.

### 5.1. Impact of Digital Innovation

Digital innovations such as VR and AR significantly enhance visitor experiences at heritage sites. VR technology allows visitors to immerse themselves in realistic, 360-degree

recreations of historical environments, providing a sense of presence and engagement that traditional displays often cannot achieve [62, 64, 67, 127]. For example, visitors to MHSs can virtually explore underground tunnels, experience the working conditions of miners, and interact with reconstructed machinery, all from a safe and controlled environment. This immersive experience not only brings history to life but also caters to diverse audiences, including those who may be unable to visit the sites physically [9, 10, 12-14, 27, 42, 49, 55, 58, 62, 64-67, 128-131]. The AR technology, on the other hand, overlays digital information onto the physical world, enhancing the learning experience by providing contextual information and interactive elements directly in the visitor's view [55, 58, 62]. For instance, at MHSs, AR can be used to display the historical data, facts about mining techniques, or stories of the miners, enriching the visitor's understanding and appreciation of the site. These technologies transform static exhibits into dynamic, interactive experiences, making the history and heritage of mining sites more accessible and engaging.

The incorporation of digital innovations such as VR and AR significantly boosts the competitiveness of heritage destinations [9-15]. By offering unique and technologically advanced experiences, these sites can attract a broader audience, and stand out in the competitive tourism market. Digital tools can enhance the appeal of heritage sites to the tech-savvy tourists and younger generations who seek interactive and immersive experiences [10, 51-54]. Furthermore, digital innovations extend the reach of heritage sites beyond their physical locations. Virtual tours and online interactive experiences can attract global audiences, providing access to those who may not have the means or opportunity to visit in person [25, 30, 34]. This increased accessibility can lead to higher visitor numbers, greater visibility, and improved financial sustainability for the heritage sites. The implementation of digital technologies also allows for the collection of valuable visitor data through interactive platforms [48-66, 114, 119-121]. This data can provide insights into the visitor preferences and behaviors, enabling site managers to tailor their offerings, and marketing strategies more effectively [16-18, 27, 42, 49, 55]. As a result, heritage sites that embrace digital innovations can create more personalized

and engaging visitor experiences, enhancing their overall competitiveness in the tourism industry.

## 5.2. Challenges and limitations

Implementing digital innovations such as VR and AR in heritage tourism comes with significant technical and financial challenges. One of the primary technical challenges is the need for high-quality hardware and software to create and run immersive experiences [9-0, 14, 78-81]. VR and AR technologies require sophisticated equipment, including VR headsets, high-resolution cameras, and powerful computing systems [25, 49, 65-68]. Additionally, developing detailed and accurate virtual environments or AR content necessitates advanced technical expertise and can be time-consuming [51-54, 60]. From a financial perspective, the initial costs of acquiring the necessary technology and developing digital content can be prohibitive for many heritage sites, particularly those with limited budgets [29, 35, 63]. Funding for such projects often relies on external grants, sponsorships, or partnerships, which can be competitive and uncertain. Moreover, maintaining and updating digital systems to ensure they remain functional and relevant over time adds ongoing expenses [44, 47, 58].

Despite their potential, the current digital implementations and case studies reveal several limitations. One significant limitation is the accessibility of the digital tools for all visitors [132-135]. While the VR and AR technologies can enhance the experience for many, they may not be accessible to everyone. For example, the individuals with visual or hearing impairments, or those who are not comfortable with advanced technology, may find it challenging to engage with the VR and AR content [136]. Additionally, the immersive nature of VR can sometimes lead to motion sickness or discomfort for the users, potentially detracting from the visitor experience [10-17]. Another limitation is the dependency on stable and high-speed internet connections for some AR applications and interactive platforms, which may not always be available in the remote or underdeveloped areas [137-140]. Furthermore, the case studies highlight that while the digital tools can offer a simulated experience of heritage sites, they cannot fully replicate the sensory and emotional impact of physically visiting a location. The tactile and atmospheric qualities of a heritage



site such as the smell of old machinery or the echo of footsteps in an underground tunnel, are difficult to convey through digital means [55-68]. Lastly, the effectiveness of digital tourism initiatives largely depends on how well they are integrated into the broader visitor experience and narrative of the site [110-115]. Poorly designed or implemented digital content can appear gimmicky or distract from the historical and educational value of the site. Thus careful planning, user testing, and iterative improvements are essential to ensure that digital innovations genuinely enhance rather than detract from the heritage experience [131-140].

### **5.3. Implications for destination competitiveness**

The findings from this work have significant strategic implications for the tourism destinations, particularly those focused on heritage and cultural tourism. By integrating digital innovations such as VR and AR, the heritage sites can create more engaging and immersive visitor experiences that stand out in a competitive market. These technologies can help attract a broader audience including younger generations and tech-savvy tourists, thereby expanding the market reach of the heritage sites [1, 3, 28]. The tourism destinations can leverage digital tools to differentiate themselves and enhance their appeal. For instance, the implementation of interactive digital platforms can facilitate personalized experiences, catering to the individual visitor preferences and enhancing satisfaction [6, 14, 44-49]. Additionally, the ability to offer virtual tours and online experiences can extend the reach of heritage sites to a global audience, overcoming geographical and physical constraints [17, 25, 26, 42]. Moreover, the data collected through digital interactions can provide valuable insights into the visitor behavior and preferences. This information can inform strategic planning and decision-making, enabling the site managers to tailor their offerings and marketing strategies more effectively [10, 11, 55-59]. By understanding what visitors find most engaging and informative, the heritage sites can continuously refine their digital content, and improve the overall visitor experience [14-144].

Looking ahead, several potential future trends in digital tourism could further impact the competitiveness of MHSs. As technology continues to advance, we can expect to see even

more sophisticated VR and AR applications that provide richer and more immersive experiences. For example, the haptic feedback technology, which allows the users to feel virtual textures and objects, could enhance the sensory experience of the virtual tours. The integration of AI and machine learning could also play a significant role in the future of digital tourism. AI can be used to create more dynamic and interactive experiences such as virtual tour guides that respond to the visitor questions in real-time or personalized content recommendations based on the visitor interests. Furthermore, the rise of the Mixed Reality (MR) technology, which blends real and virtual worlds, could offer new ways to experience heritage sites. MR can overlay the digital content onto the physical environment in more seamless and interactive ways, creating a more immersive and engaging experience for the visitors. The Blockchain technology may also emerge as a tool for enhancing the transparency and trustworthiness of the heritage site operations. For example, blockchain could be used to create secure and verifiable digital records of the site preservation efforts, visitor donations, and other activities, providing a greater transparency and building trust with the visitors and stakeholders. For MHSs, these trends suggest the exciting opportunities to enhance their digital offerings, and attract a wider audience. By staying abreast of technological advancements and being willing to innovate, the heritage sites can continue to improve their competitiveness and relevance in the ever-evolving tourism landscape. These trends also underscore the importance of ongoing investment in the digital infrastructure and skill development to fully leverage the potential of digital tourism.

## **6. Conclusions**

The work examines the role of digital innovation in enhancing the competitiveness of tourism destinations, with a particular focus on MHSs. Through an analysis of several case studies, key insights emerge that underscore the transformative potential of the technologies such as VR, AR, and interactive digital platforms. Firstly, the implementation of VR and AR significantly enhances the visitor experience by providing immersive, engaging, and educational interactions with the heritage sites. For instance, the Big Pit National Coal Museum in Wales uses a 360-degree

video and interactive elements to offer virtual tours that expand its global reach and improve accessibility for visitors who cannot physically visit the site. Similarly, the Mining Museum of Slovenia employs AR apps and VR simulations to create an immersive historical experience that deepens the visitor understanding and engagement. Secondly, digital innovations enhance the overall competitiveness of heritage destinations by attracting a broader and more diverse audience. The ability to offer virtual and augmented experiences makes these sites appealing to tech-savvy and younger demographics, who seek interactive and novel ways to engage with the history and culture. The Mining Museum of the West, for example, has successfully used interactive exhibits and VR simulations to boost the visitor engagement and educational offerings. Moreover, digital story-telling and virtual tours, as implemented at the Erzgebirge Mining Region in Germany, strengthen the global presence and appeal of the heritage sites. These digital tools enable the heritage sites to transcend geographical limitations, and reach international audiences, thereby enhancing their visibility and attractiveness. The digital reconstruction of the Mesabi Iron Ore Mines in India exemplifies how 3D modeling and virtual site visits can significantly enhance the educational value and global reach of MHSs.

However, the study also identifies several challenges and limitations associated with the implementation of digital technologies. Technical and financial constraints can hinder the adoption and maintenance of the VR and AR systems. Furthermore, while these technologies offer substantial benefits, they cannot fully replicate the sensory and emotional impact of physically visiting a heritage site. Overall, the findings highlight the critical role of digital innovation in modernizing heritage tourism and enhancing the destination competitiveness. By leveraging advanced technologies, MHSs can create more engaging and accessible experiences, attract a wider audience, and sustain their relevance in an increasingly digital world.

### 6.1. Recommendations

Based on the findings of this work, several recommendations are proposed to enhance the implementation of digital technologies in MHT,

and to guide future research. These recommendations aim to help the practitioners effectively integrate digital innovations into their heritage sites and to address the gaps identified in the current literature. For practitioners, the focus is on the practical strategies for leveraging VR, AR, and other digital tools to create engaging, accessible, and sustainable visitor experiences. Meanwhile, for future research, suggestions are offered to explore areas that can further our understanding of the digital tourism's impact, address existing challenges, and investigate the emerging technological trends. These recommendations (refer to Table 7) are designed to inform and support both the current practices and future advancements in the field of digital heritage tourism.

### 6.2. Final Thoughts

The role of continuous digital innovation in tourism cannot be overstated. As the industry evolves, embracing new technologies such as VR and AR becomes crucial for maintaining and enhancing the destination competitiveness. These innovations offer unprecedented opportunities to transform the visitor experiences, making the heritage sites more accessible and engaging. They not only enable immersive explorations of historical and cultural contexts but also help attract diverse audiences by providing novel and interactive ways to connect with the past. Looking to the future, the integration of the digital technologies holds immense potential for further enhancing the appeal and competitiveness of tourism destinations. Advances in VR, AR, and related fields are likely to offer even more sophisticated and immersive experiences, creating new avenues for story-telling and visitor engagement. The continued evolution of these technologies, along with the integration of emerging trends such as AI and blockchain, will further enrich the digital tourism landscape. As such, destinations that proactively adopt and innovate with these technologies will be well-positioned to stand out in an increasingly competitive global market.

In summary, the ongoing advancement of digital tools presents a dynamic and promising frontier for tourism. By continually exploring and implementing new digital innovations, the heritage sites can enhance their attractiveness, engage a

broader audience, and sustain their relevance in an ever-changing industry. The future of tourism will undoubtedly be shaped by the creative and strategic

use of digital technologies, making it essential for destinations to remain forward-thinking and adaptable.

**Table 7. Recommendations for practitioners and future research in digital mining heritage tourism (Source: Author).**

Category	Recommendation	Details
For practitioners	<b>Invest in high-quality digital tools</b>	Practitioners should prioritize investing in the high-quality VR and AR technologies to create immersive and engaging experiences. Ensuring that these tools are both user-friendly and accessible to a wide range of visitors is essential for maximizing their impact.
	<b>Develop comprehensive digital strategies</b>	A well-defined digital strategy that integrates VR and AR into the broader visitor experience can enhance engagement and satisfaction. This strategy should include regular updates and maintenance of the digital content to keep it relevant and exciting for returning the visitors.
	<b>Enhance accessibility</b>	Ensure that digital tools are accessible to all the visitors including those with disabilities. This can involve developing features such as audio descriptions for visually impaired users or alternative interaction methods for those who may not be comfortable with the traditional VR headsets.
	<b>Leverage data analytics</b>	Utilize data collected from digital interactions to gain insights into the visitor behavior and preferences. This data can inform strategic planning, helping practitioners tailor their offerings to better meet the needs and interests of their audience.
	<b>Seek funding and partnerships</b>	Explore funding opportunities and partnerships with technology companies, educational institutions, and cultural organizations to support the development and implementation of digital initiatives. Collaborative projects can bring additional expertise and resources.
	<b>Provide staff training</b>	Ensure that staff are adequately trained to manage and troubleshoot the digital tools. This includes both the technical training and an understanding of how to integrate digital experiences into the overall visitor engagement strategy.
For future research	<b>Explore Longitudinal impact studies</b>	Future research should focus on the longitudinal studies to assess the long-term impact of digital innovations on visitor engagement, educational outcomes, and site competitiveness. Understanding these long-term effects can guide sustainable digital strategy development.
	<b>Investigate accessibility and inclusion</b>	Further research is needed on how the digital tools can be made more accessible and inclusive for all visitor demographics. Studies could explore the effectiveness of various accessibility features, and the extent to which they enhance the visitor experience.
	<b>Evaluate cost-benefit analyses</b>	Conduct detailed cost-benefit analyses to evaluate the financial viability of implementing the advanced digital technologies. This research can help the heritage sites prioritize investments, and make informed decisions about resource allocation.
	<b>Examine cross-cultural applications</b>	Investigate how digital innovations in MHT can be adapted and applied in different cultural contexts. Comparative studies across various regions and heritage sites can provide valuable insights into best practices and potential challenges.
	<b>Integrate emerging technologies</b>	Future research should explore the integration of emerging technologies such as AI and blockchain in heritage tourism. Examining how these technologies can enhance the visitor experiences, improve operational efficiency, and increase transparency will be crucial for the next phase of digital innovation.
	<b>Assess visitor feedback</b>	Gathering and analyzing extensive visitor feedback on the digital experiences can provide insights into the user satisfaction and areas for improvement. Research focused on understanding the visitor perceptions and preferences can guide the development of more effective digital content and interactions.

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## نوآوری دیجیتال و رقابت مقصد: استفاده از میراث معدنی برای تجارب گردشگری مجازی

آدیتی ناگ<sup>۱\*</sup>، و آنوراگ سینگ راتور<sup>۲</sup>

۱- دانشکده معماری و طراحی، دانشکده طراحی، دانشگاه مانپال جیپور، جیپور، راجستان، هند

۲- گروه مطالعات گردشگری، دانشگاه آزاد ملی ایندیانا کاندی، دهلی نو، هند

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\* نویسنده مسئول مکاتبات: ar.aditi204@gmail.com

## چکیده:

صنعت گردشگری با نوآوری‌های دیجیتالی مانند واقعیت مجازی (VR)، واقعیت افزوده (AR) و پلتفرم‌های تعاملی، تحول عمیقی را تجربه می‌کند. این مقاله به بررسی این موضوع می‌پردازد که چگونه این فناوری‌ها رقابت‌پذیری مقصد را با تمرکز ویژه بر سایت‌های میراث معدنی (MHSs) تغییر شکل می‌دهند. با استفاده از واقعیت مجازی و واقعیت افزوده، سایت‌های میراث می‌توانند تجربیات تعاملی و هم‌جهانی‌ای را ارائه دهند که تعامل بازدیدکنندگان را افزایش می‌دهد و دامنه دسترسی آنها را افزایش می‌دهد. این کار از طریق تجزیه و تحلیل مورد مطالعه، اجرای موفق ابتکارات گردشگری دیجیتال را در MHSهای مختلف از جمله موزه ملی زغالسنگ بیگ پیت، موزه معدن اسلوونی، موزه معدن غرب، منطقه معدن Erzgebirge و سنگ آهن مسابی بررسی می‌کند. یافته‌ها نشان می‌دهد که ابزارهای دیجیتال به طور قابل توجهی دسترسی، ارزش آموزشی و جذابیت جهانی این سایت‌ها را بهبود می‌بخشد. با این حال، چالش‌هایی مانند محدودیت‌های فنی و مالی همچنان وجود دارد. این مقاله با توصیه‌هایی برای متخصصان در زمینه ادغام موثر فناوری‌های دیجیتال و پیشنهادهایی برای تحقیقات آتی به منظور بررسی اثرات بلندمدت و روندهای نوظهور به پایان می‌رسد. این کار بر پتانسیل تحول آفرین نوآوری دیجیتال در افزایش رقابت‌پذیری و پایداری مقاصد گردشگری تاکید می‌کند.

کلمات کلیدی: نوآوری دیجیتال، رقابت مقصد، واقعیت مجازی، واقعیت افزوده، گردشگری میراث معدنی MHT.