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Smart Heritage Cities: Challenges and Opportunities for Sustainab
Cultural Tourism and Urban Development

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ABSTRACT

This study investigates the challenges and opportunities associated with smart heritage cities as an emerging paradigm at the nexus of digital innovation and cultural sustainability. The research underscores the importance of exploring how smart heritage strategies can be leveraged to foster sustainable cultural urbanism in heritage-rich cities. A qualitative methodology was employed, utilizing semi-structured interviews to generate in-depth insights from experts and practitioners across diverse professional fields, including cultural heritage specialists, archaeologists, urban planners, university professors, tour guides, and tourism experts. In total, twenty-seven interviews were conducted, both online and on-site, ensuring a comprehensive representation of perspectives. The findings highlight significant opportunities, including the application of augmented reality, artificial intelligence, and big data analytics to advance heritage conservation, enhance visitor engagement, and support sustainable tourism development. However, persistent challenges were identified, such as funding constraints, infrastructural limitations, and the inherent tension between technological innovation and the preservation of authenticity. The study provides valuable managerial and policy implications for heritage governance while also opening new avenues for research on digital transformation within heritage contexts. By addressing these challenges, heritage-rich cities can effectively harness smart heritage strategies to safeguard cultural assets, reinforce cultural identity, and promote sustainable urban development.

KEYWORDS

Smart Heritage, Cultural Sustainability, Digital Transformation, Urban Governance, Sustainable Tourism, Heritage Management.

المدن التراثية الذكية:
التحديات والفرص لتنمية سياحية ثقافية وعمرانية مستدامة

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الملخص

تتناول هذه الدراسة التحديات والفرص المرتبطة بمدن التراث الذكية باعتبارها نموذجًا ناشئًا يقع عند تقاطع الابتكار الرقمي والاستدامة الثقافية. وتؤكد أهمية استكشاف كيفية توظيف استراتيجيات التراث الذكي لتعزيز العمران الثقافي المستدام في المدن الغنية بالتراث. اعتمد البحث على منهجية كيفية باستخدام المقابلات شبه المهيكلة لتوليد رؤى معمقة من خبراء وممارسين ينتمون إلى مجالات مهنية متنوعة، من بينها المتخصصون في التراث الثقافي، وعلماء الآثار، والمخططون العمرانيون، وأساتذة الجامعات، والمرشدون السياحيون، وخبراء السياحة. وقد أُجريت سبعٌ وعشرون مقابلة عبر الإنترنت وميدانيًا، بما يضمن تمثيلًا شاملاً لمختلف وجهات النظر. أبرزت النتائج فرصًا مهمة، منها تطبيق تقنيات الواقع المعزز، والذكاء الاصطناعي، وتحليلات البيانات الضخمة في تعزيز صون التراث، وتطوير تفاعل الزوار، ودعم التنمية السياحية المستدامة. ومع ذلك، كشفت الدراسة عن تحديات مستمرة مثل قيود التمويل، وضعف البنية التحتية، والتوتر القائم بين الابتكار التكنولوجي والحفاظ على الأصالة. وتقدم الدراسة دلالات إدارية وسياساتية مهمة لحوكمة التراث، كما تفتح آفاقًا جديدة للبحث حول التحول الرقمي في السياقات التراثية. ومن خلال مواجهة هذه التحديات، يمكن للمدن الغنية بالتراث أن توظف استراتيجيات التراث الذكي بفاعلية لحماية الأصول الثقافية، وتعزيز الهوية الثقافية، ودعم التنمية الحضرية المستدامة.

الكلمات الدالة

التراث الذكي، الاستدامة الثقافية، التحول الرقمي، الحوكمة الحضرية، السياحة المستدامة، إدارة التراث.

1. Introduction

Over the past two decades, the concept of the smart city has emerged as a dominant framework in urban studies and policy, emphasizing the use of digital technologies to enhance governance, efficiency, and sustainability (Buhalis & Amaranggana, 2015; Meijer & Bolívar, 2016). At the same time, the preservation of cultural heritage has gained global prominence as cities increasingly recognize heritage not only as a repository of identity and memory but also as a driver of economic development and cultural tourism (Zhang et al., 2018; UNESCO, 2019). The intersection of these two paradigms has given rise to the emerging concept of the smart heritage city, which seeks to integrate technological innovation with heritage conservation and sustainable cultural urbanism (Lombardi et al., 2012; Angelidou et al., 2017).

smart heritage cities employ tools such as augmented reality (AR), artificial intelligence (AI), big data analytics, and Internet of Things (IoT) applications to improve heritage interpretation, enhance visitor experiences, and ensure the long-term sustainability of cultural assets (Borda & Bowen, 2017; Egusquiza & Gavalda, 2020; Yin et al., 2020). For instance, immersive technologies like AR and VR have been shown to enrich public engagement with cultural heritage while reducing the physical strain on fragile sites (Rahaman et al., 2019). Similarly, AI-driven heritage data management enables predictive conservation and authenticity preservation, while smart monitoring systems support sustainable tourism by managing visitor flows and mitigating overcrowding (Selim et al., 2022; Nofal et al., 2022).

In Egypt, academic and applied initiatives reflect this integration of digital innovation and heritage preservation. The Luxor Living Lab demonstrates the role of digital mapping and participatory storytelling in safeguarding both tangible and intangible heritage (Luxor Living Lab, 2023). Similarly, studies on El Montazah Gardens in Alexandria highlight the potential of VR, AR, and IoT tools to enhance heritage tourism and sustainable site management (El-Sayed & Khalil, 2022). Moreover, research on smart architecture and heritage buildings emphasizes the importance of digital transformation in preserving Egypt's cultural identity while promoting sustainable urban development (Abdelrahman & El-Gohary, 2021).

Despite these opportunities, the adoption of smart heritage city strategies remains constrained by numerous challenges, particularly in developing countries. Financial limitations, gaps in digital infrastructure, inadequate technical expertise, and governance complexities continue to hinder implementation (Angelidou et al., 2017; Egusquiza & Gavalda, 2020). Furthermore, the tension between technological innovation and cultural authenticity raises critical questions about how digital tools can be harnessed without undermining the intangible values embedded in heritage (Zhang et al., 2018).

Despite the growing interest in integrating digital technologies within heritage cities, there remains a significant research gap in understanding how smart city frameworks can be effectively aligned with the conservation of cultural identity, inclusive governance, and long-term sustainability. Existing studies often examine either technological innovation or heritage conservation in isolation, without addressing the complex interdependence between smart infrastructure, community engagement, and cultural tourism. Moreover, limited empirical evidence is available—particularly in

developing country contexts—on how smart heritage strategies can mitigate risks such as commodification, eco-gentrification, and vulnerability while ensuring equitable benefits for local communities.

This study seeks to fill this gap by exploring holistic, context-sensitive approaches that balance innovation with authenticity in the development of smart heritage cities. Against this backdrop, the research examines the challenges and opportunities for adopting smart heritage city strategies in the context of sustainable cultural urbanism, with a particular focus on Egypt. **A qualitative methodology** was adopted due to its exploratory nature and suitability for understanding the complex social and cultural phenomena associated with implementing smart city concepts in heritage contexts—especially in relation to sustainable cultural tourism and urban development. This approach allows for an in-depth exploration of the experiences, perceptions, and attitudes of diverse stakeholders—including local residents, tourists, practitioners, and urban planners—toward digital transformation in historic cities.

By employing semi-structured interviews, the study generates fresh insights into how heritage-rich cities—particularly in Egypt—can leverage smart technologies to strengthen conservation practices, reinforce cultural identity, and advance sustainable urban development. The findings aim to contribute to both scholarly discourse and policy-making, offering practical recommendations for integrating digital innovation with heritage management while safeguarding cultural authenticity.

Accordingly, this paper seeks to critically analyze the opportunities and challenges associated with implementing smart city tools in heritage-rich urban environments. It addresses the following research questions:

1. What opportunities are available for Egyptian heritage sites to adopt smart heritage city strategies?

2. What challenges do Egyptian heritage sites face in implementing smart heritage city applications?

3. What strategies are proposed to enhance the implementation of smart heritage city applications in Egyptian heritage sites?

2. Literature Review

The convergence of smart city paradigms and heritage conservation has emerged as a significant theme in urban studies over the past decade. The term Smart Heritage Cities encapsulates efforts to integrate digital technologies into the governance, preservation, and interpretation of cultural heritage in urban environments (Della Corte et al., 2017). This literature reflects interdisciplinary intersections—spanning urban planning, heritage studies, information technology, and participatory governance.

2.1: Smart Cities and Digital Infrastructure

The smart city concept has become a central paradigm in urban development over the past two decades, emphasizing the integration of information and communication technologies (ICTs), big data, and interconnected infrastructure to optimize urban operations, improve sustainability, and foster citizen engagement (Caragliu, 2011; Komninos, 2013). Core elements of smart cities include digital governance, e-services, smart mobility, energy efficiency, and participatory platforms that enhance urban resilience and livability (Nam & Pardo, 2011; Hollands, 2015).

In recent years, this framework has been expanded to embrace culture and heritage as strategic assets in urban innovation. Organizations such as UNESCO (2016) emphasize that cultural heritage plays a pivotal role in sustainable development, providing identity, continuity, and economic opportunity through creative industries and tourism. Similarly, Bandarin & van Oers (2012) argue that heritage, when integrated into smart city planning, contributes to place identity and social cohesion, aligning with sustainable cultural urbanism.

Scholars increasingly view smart cities not only as technological systems but also as socio-technical ecosystems, where cultural heritage is a key resource for inclusive and sustainable futures (Lombardi et al., 2012; Angelidou et al., 2017). This shift reflects the recognition that urban innovation must be culturally grounded, balancing digital transformation with the preservation of historical continuity.

In Egypt, initiatives such as the Luxor Living Lab (2023), research on the El Montazah Gardens in Alexandria (El-Sayed & Khalil, 2022), and studies on smart architecture and heritage buildings (Abdelrahman & El-Gohary, 2021) demonstrate how digital technologies are being integrated into heritage management, enhancing cultural tourism, safeguarding identity, and supporting sustainable urban development. These examples illustrate how the global paradigm of smart cities is being contextualized within Egypt's heritage-rich urban environments, bridging technological innovation with cultural continuity.

2.2: Heritage and Digital Transformation

The emergence of the "smart heritage" paradigm signifies a new era in heritage management, where digital tools are deployed to support documentation, conservation, and interpretation (Qiu et al., 2015; Selim et al., 2022). Technologies such as 3D laser scanning, GIS mapping, digital twins, and immersive applications (AR/VR) are now widely adopted in archaeology, museum curation, and cultural tourism (Al-Qawasmi et al., 2021). These tools safeguard fragile artifacts and sites while simultaneously creating interactive, engaging experiences that broaden audience participation (Champion, 2016).

High-profile projects such as Rome Reborn and the digital reconstruction of Palmyra demonstrate the growing role of virtual heritage in visualizing lost or endangered sites, allowing global audiences to experience cultural heritage beyond geographical and political constraints (Forte, 2014; Vincent, 2016). Furthermore, big data and (AI) have been increasingly applied to predictive conservation and automated analysis, offering opportunities for proactive heritage management (Yin et al., 2020).

However, scholars emphasize that these digital transformations must be contextually grounded and ethically designed. As Lepkowska-White and Parsons (2019) caution, while digital platforms can democratize access to heritage and foster public engagement, they also risk oversimplifying cultural narratives, commodifying heritage, or privileging technologically advanced audiences at the expense of inclusivity. Similarly, Giaccardi & Fogli (2020) note that heritage digitization should not reduce cultural sites to mere data but must respect authenticity, pluralism, and local values.

Thus, the literature underscores a dual narrative: smart heritage technologies present significant opportunities for preservation and interpretation, yet they also pose ethical,

social, and epistemological challenges that must be carefully navigated to ensure sustainability and inclusivity.

2.3: Opportunities in Smart Heritage Cities

The integration of smart technologies with cultural heritage preservation offers a unique opportunity to reshape the relationship between urban development and historical identity. Technologies such as Geographic Information Systems (GIS), 3D scanning, and remote sensing allow for high-precision documentation of heritage sites, supporting risk assessment and informed decision-making in conservation and urban planning (Luo et al., 2018; Abdullah et al., 2019). Real-time monitoring systems can enhance the management of archaeological zones, while comprehensive digital databases contribute to long-term site sustainability (Qiu et al., 2015).

Furthermore, immersive tools like (AR) and (VR) offer new dimensions for heritage interpretation, enabling visitors to explore cultural assets without physically burdening fragile sites (Champion, 2016; Della Corte et al., 2017). These technologies enhance inclusivity by expanding access for individuals with disabilities and those geographically distant from heritage locations. Digital platforms also foster participatory heritage practices, enabling local communities to contribute narratives and content that reflect their cultural memory, thereby reinforcing a sense of ownership and identity (Pereira Roders & Hudson, 2011; Giaccardi, 2012).

Economically, Smart Heritage Cities have the potential to stimulate the local creative economy by supporting cultural entrepreneurship and promoting traditional crafts through digital marketplaces (UNESCO, 2019). Smart infrastructure enables integrated urban policies where heritage conservation aligns with transportation, energy efficiency, and visitor management. This convergence contributes to sustainable development while preserving the authenticity and integrity of heritage landscapes (Bandarin & van Oers, 2012).

2.4: Challenges in Smart Heritage Cities

Despite their transformative potential, Smart Heritage Cities face several interrelated challenges—technical, institutional, and socio-cultural. Technologically, many historic cities, particularly in developing regions, lack the foundational digital infrastructure necessary for implementing smart systems. Limited funding, fragmented data ecosystems, and a shortage of skilled personnel further constrain the successful deployment of smart heritage solutions (Bibri & Krogstie, 2020). Additionally, concerns about data privacy, cybersecurity, and the long-term maintenance of digital systems introduce further operational risks (UNESCO, 2019).

Institutionally, fragmented governance structures and overlapping responsibilities between cultural, municipal, and technological bodies often hinder coherent planning and policy implementation (Yung & Chan, 2011). The absence of integrated legal frameworks for regulating digital interventions in heritage sites can result in conflicting priorities between development and preservation, weakening conservation outcomes. Moreover, the lack of standardized methodologies and evaluation tools limits the scalability and replication of successful smart heritage practices (Abdullah et al., 2019).

From a socio-cultural perspective, challenges include the risk of commodifying heritage through over-digitalization, where commercialized narratives—driven by

tourism or private tech stakeholders—overshadow local voices and authenticity (Tsai et al., 2021). When smart technologies prioritize tourist experiences over community needs, heritage can be reduced to a consumable product rather than a living cultural legacy. Furthermore, digital exclusion presents a major barrier; marginalized groups often lack access to the devices, connectivity, or digital literacy required to engage with or benefit from smart heritage initiatives (Hollands, 2008). If unaddressed, this digital divide can deepen existing socio-economic inequalities and erode community participation in heritage governance (Tsai et al., 2021).

Lastly, the success of smart heritage strategies depends on balancing technological innovation with sustainability and ethical engagement. Without inclusive, context-sensitive approaches, the application of smart technologies may inadvertently contribute to the degradation of cultural values or the displacement of traditional practices (Ardito et al., 2019).

2.5: Towards Sustainable Cultural Urbanism

The literature converges on the view that smart heritage cities represent a transformative yet fragile paradigm, requiring careful integration of technology, governance, and cultural values. While digital innovations such as augmented reality, artificial intelligence, and big data analytics offer powerful tools for conservation and engagement, their effectiveness depends on the establishment of robust policy and management frameworks. These frameworks must safeguard the authenticity of heritage assets, promote inclusive participation from local communities, and align with the principles of long-term sustainability (Bandarin & van Oers, 2012; UNESCO, 2016; Selim et al., 2022).

Scholars highlight that cultural urbanism in the digital age must extend beyond technological efficiency to embrace heritage-led urban regeneration and community empowerment (Bullen & Love, 2011). The emphasis on participatory governance reflects a growing recognition that heritage is not only a cultural resource but also a living dimension of urban identity and resilience (Meijer & Bolívar, 2016; Angelidou et al., 2017). Thus, adopting smart heritage strategies requires cities to balance innovation with cultural continuity, ensuring that technological applications do not commodify heritage but instead reinforce its role as a driver of social cohesion and cultural diversity (Lepkowska-White & Parsons, 2019).

For heritage-rich regions such as Egypt, where sites like Luxor and Cairo's historic quarters hold both global and local significance, this balance between innovation and preservation is particularly critical. The adoption of smart heritage strategies offers the potential to enhance visitor management, strengthen cultural identity, and promote sustainable tourism. At the same time, it requires alignment with the broader global movement toward sustainable cultural urbanism, which advocates integrating cultural heritage into the core of urban planning and sustainability agendas (UNESCO, 2016; Della Corte et al., 2017; Egusquiza & Gavalda, 2020).

2.6: Technologies Enabling Smart Heritage

The development of smart heritage cities is underpinned by a set of emerging technologies that support the documentation, conservation, management, and dissemination of cultural heritage. These technologies not only provide innovative

means for preserving heritage assets but also redefine the relationship between heritage, citizens, and urban sustainability.

- **Foundational Documentation Technologies**

1) **Geographic Information Systems (GIS) and Remote Sensing:** GIS and satellite-based remote sensing allow for spatial analysis and monitoring of archaeological landscapes, supporting urban heritage planning and risk management. These tools are critical in managing urban encroachment, climate-related threats, and tourism pressures on heritage sites (Agapiou et al., 2015; Myers et al., 2016).

2) **Digital Documentation and 3D Technologies:** 3D laser scanning, photogrammetry, and digital twins have revolutionized the way heritage sites are recorded and analyzed. These methods enable precise documentation of monuments and artifacts, creating digital replicas for conservation, research, and education (Remondino & Rizzi, 2010; Fassi et al., 2013). Digital twins generate dynamic models that replicate real-world conditions, enabling predictive maintenance and proactive risk assessment (Volk et al., 2014).

- **Interactive and Experiential Technologies**

1) **Augmented Reality (AR) and Virtual Reality (VR):** AR and VR applications enhance interpretation by reconstructing lost heritage and offering immersive visitor experiences. By overlaying digital reconstructions onto physical sites, AR enriches engagement without altering fragile monuments (Borda & Bowen, 2017; Bekele et al., 2018). These technologies have been successfully applied in projects such as *Rome Reborn* and the virtual reconstruction of *Palmyra* (Forte, 2014).

2) **Artificial Intelligence (AI) and Big Data Analytics:** AI-driven algorithms support automated analysis of heritage datasets, from classifying artifacts to detecting deterioration patterns. Combined with big data analytics, AI enables predictive conservation and facilitates interpretation of large-scale cultural datasets (Yin et al., 2020; Selim et al., 2022). Deep learning also transforms the analysis of ancient inscriptions, with tools like *Pythia* and *Ithaca* achieving high accuracy in reconstructing incomplete Greek and Roman texts (Assael et al., 2019; Assael et al., 2022).

- **Emerging Monitoring and Security Technologies**

1) **Internet of Things (IoT) and Smart Sensors:** IoT-enabled devices provide real-time monitoring of environmental conditions such as humidity, temperature, and visitor density. These data streams inform conservation strategies and enable adaptive visitor management systems, ensuring both site preservation and enhanced tourist experiences (Chianese & Piccialli, 2014; Zhu et al., 2015).

2) **Blockchain and Digital Heritage Security:** Blockchain can safeguard the authenticity and provenance of digital heritage records by providing transparent, immutable documentation systems (Ahmed & Abbas, 2023). This ensures long-term trust in digital archives while preventing unauthorized alterations.

Collectively, these technologies demonstrate that smart heritage is not simply about digitization but about creating integrated ecosystems that balance innovation with conservation. Their implementation, however, requires careful adaptation to local contexts and governance frameworks to avoid risks of commodification, inequity, or technological obsolescence.

3. Methodology

Given the novelty of this research area, the study adopts an exploratory design, which permits the identification of emerging themes, deepens understanding, and highlights topics that require further scholarly attention (Cranmer et al., 2016). The qualitative approach was selected as it enables the researcher to gain deeper insights into participants' perceptions and experiences. Unlike quantitative methods that impose predefined frameworks, qualitative inquiry allows respondents to express their views in their own words and introduce concepts of significance from their perspective (Altinay & Paraskevas, 2008).

To collect primary data, the study employed semi-structured interviews, a technique particularly effective for uncovering what is happening, generating new insights, identifying general patterns, and exploring relationships between variables (Altinay & Paraskevas, 2008). This method offered flexibility in probing while ensuring alignment with the research objectives, thus enabling a comprehensive examination of the challenges and opportunities facing Egyptian heritage sites in adopting smart heritage city applications.

Participants were selected through purposive sampling, which is appropriate when the aim is to describe a phenomenon about which little is known and when expert insights are required (Kumar, 2014, p. 244). Eligible respondents were recruited from diverse professional backgrounds, including cultural heritage specialists, urban planners, university professors, tour guides, and tourism experts. This ensured representation from key stakeholders involved in Egypt's heritage management. Purposive sampling was guided by the researcher's judgment regarding which individuals could provide the most relevant and reliable data to address the study's objectives (Kumar, 2014).

A total of 31 potential interviewees were contacted, of which 27 interviews were successfully conducted—both face-to-face and online. The selected participants were recognized as experts in their respective fields, possessing the knowledge and experience necessary to contribute meaningful insights into the research questions. Interviews took place between February 2025 and April 2025. A detailed overview of the sample is presented in Table 1.

Table (1): List of Participants

Participant ID	Domain	Male		Female		Avg. years of experience	Total	
		No.	%	No.	%		No.	%
P1-P6	Archaeologists & Cultural Heritage Specialists	4		2		21	6	22%
P7-P11	Technical Experts	4		1		19	5	19%
P12-P15	Tour guides	2		2		18	4	14.5

							%
P16-P19	Tourism Experts	3		1		21	4	14.5 %
P20-P24	University Professors	3		2		23	5	19 %
P25-P27	Urban Planners	2		1		22	3	11 %
Total		**18**	**66 %**	**9**	**34%**	**20.6**	**27**	**100 %**

The researchers took field notes in Arabic during the interviews, and the original transcripts were categorized before being translated into English. This process ensured that cultural and linguistic nuances were preserved. Subsequently, a qualitative content analysis was conducted to identify recurring themes and emerging patterns. To support systematic coding and transcription analysis, the researchers employed the web-based software **Delve**, which facilitates the organization and categorization of qualitative data. The software's functionality allowed for efficient identification of recurrent concepts and the extraction of central themes, particularly those relating to cultural tourism sustainability, community participation, and the role of technology in preserving cultural identity. In addition, Delve's user-friendly interface enhanced the transparency of the analytical process and reduced subjective bias by enabling visual data organization and code comparison.

To address the research questions, a set of open-ended interview questions was designed and informed by existing literature (e.g., Della Corte et al., 2017; Angelidou et al., 2017; Abed, 2021; Al-Qawasmi et al., 2021; Selim et al., 2022). Specifically, eight sub-questions were developed to explore the first research question, five for the second, and eight for the third (see Table 2).

Table (2): Interview Questions

Research Question	Interview Sub-Questions
Research Question 1: What opportunities are available for Egyptian heritage sites to adopt smart heritage city strategies?	1. What are the main opportunities you see for implementing smart heritage city technologies in Egyptian heritage sites? 2. How can smart technologies improve the visitor experience at heritage sites? 3. Which current smart applications or initiatives do you believe could be further developed? 4. How can smart heritage cities contribute to preserving cultural identity? 5. What role can technology play in promoting sustainable tourism? 6. How can smart heritage cities improve visitor management? 7. What partnerships or collaborations could enhance smart heritage city strategies? 8. What factors contribute to the successful implementation of such initiatives in Egypt?
Research Question 2: What challenges do Egyptian heritage sites face in	1. What are the main technical challenges hindering the implementation of smart heritage cities? 2. What financial or funding challenges exist?

implementing smart heritage city applications?	3. How available are the required human skills and expertise? 4. How do legal and regulatory frameworks impact the implementation of smart heritage cities? 5. What social or cultural barriers could limit the application
Research Question 3: What strategies are proposed to enhance the implementation of smart heritage city applications in Egyptian heritage sites?	1. What strategies or plans do you suggest to accelerate the transition towards smart heritage cities? 2. How can collaboration between government and private sectors be strengthened? 3. What measures should be taken to develop the technical infrastructure? 4. How can community awareness of smart heritage cities be enhanced? 5. What policies could support this transformation? 6. What is the role of training and capacity-building in the success of these projects? 7. How can successful international experiences be leveraged? 8. What performance indicators can be used to measure the success of these initiatives

4. Data Analysis

The researchers employed the six-phase thematic analysis approach proposed by Braun & Clarke (2006) to analyze the data. The phases included :1) Familiarizing with the data by carefully reviewing the transcripts and identifying potential themes or patterns. 2) Generating initial codes that capture key concepts or ideas, whether latent or semantic, within the data. 3) Collating all relevant coded extracts into preliminary themes formed by grouping the initial codes. 4) Reviewing the themes to ensure each is distinct and supported by coherent, meaningful data. 5) Defining and naming the themes by organizing data extracts logically and adding narrative descriptions to highlight unique aspects of each theme. 6) Producing the final report with an analytic narrative that compellingly represents the data, incorporates vivid quotations, and addresses the research questions through well-reasoned arguments (Tuckett, 2005).

To ensure the credibility and trustworthiness of the findings, the study followed the trustworthiness framework suggested by Nowell et al. (2018). This involved: Employing thick description to move beyond simple reporting, providing interpretive insights and supporting arguments.Utilizing peer debriefing, whereby two independent researchers reviewed and evaluated the study's findings and procedures. Applying triangulation of sources by selecting participants from various professional fields related to culture heritage and technology, ensuring a diverse range of perspectives.

5. Findings

The findings highlighted respondents' perceptions of the barriers hindering the adoption of smart heritage city applications within Egyptian heritage sites. Moreover, their insights shed light on related aspects, particularly the opportunities that could facilitate the implementation of smart heritage city strategies and the potential effects of such adoption on the overall quality and sustainability of these sites.

Thematic analysis of the collected data revealed the following key themes:

1) Current Uses of Smart Technologies in Egyptian Heritage Sites;
2) Prospects for Adopting Smart Heritage City Strategies;
3) Barriers to the Implementation of Smart Heritage City Applications;
4) Proposed Approaches to Facilitate the Adoption of Smart Heritage City Applications;
5) Efforts of the Egyptian Ministry of Tourism and Antiquities towards Adopting Smart Heritage City Strategies.

5.1 Current Uses of Smart Technologies in Egyptian Heritage Sites

The participants highlighted several ongoing applications of smart technologies within Egyptian heritage sites that aim to enhance preservation, visitor engagement, and management efficiency, including electronic ticketing systems that streamline visitor access and reduce overcrowding at popular locations such as the Pyramids and Luxor Temple. One expert remarked:

"Electronic ticketing has been a game changer in managing visitor flows and minimizing queues, which helps protect the sites from excessive human pressure." (P18)

Moreover, geographic information systems (GIS) and digital mapping are increasingly used for monitoring and documenting archaeological zones. A heritage specialist noted:

"GIS technology allows us to map and monitor the sites accurately, aiding both conservation and research." (P1)

One technical expert mentioned:

" Currently, some heritage sites have begun using GIS mapping and sensor technologies to monitor environmental conditions and detect potential threats to artifacts." (P3)

Another participant pointed out the adoption of digital platforms for visitor information and experience:

"Mobile applications and virtual tours are being developed to provide visitors with interactive and informative experiences, allowing remote access to heritage sites." (P14)

Augmented reality (AR) applications have also been introduced to enrich the visitor experience by providing interactive and immersive historical interpretations. According to a heritage manager:

"Visitors can now engage with the history through AR apps that bring ancient stories and structures to life, enhancing understanding without impacting the physical site." (P17)

Moreover, the use of data analytics for crowd management was also noted:

"Smart systems analyze visitor flow patterns to optimize site accessibility and minimize overcrowding, which is crucial for preserving fragile areas." (P16)

Despite these initiatives, several respondents emphasized that the implementation remains limited and fragmented, requiring broader coordination and investment to maximize the potential of smart heritage technologies.

Furthermore, digital databases are being developed to compile and preserve extensive cultural data, facilitating sustainable heritage management. A university professor explained:

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"Digital archives ensure that knowledge about our heritage is systematically recorded and accessible for future generations." (P22)

5.2 Prospects for Adopting Smart Heritage City Strategies

The data revealed that participants perceive multiple opportunities for leveraging smart heritage city technologies to enhance heritage conservation and improve visitor experience. One specialist stated:

"Augmented reality can reconstruct ancient sites in visitors' minds, thereby enhancing their understanding and encouraging respect for heritage." (P3)

They also emphasized the importance of integrating technology in supporting cultural identity, as one participant noted:

"Cultural identity requires modern means of documentation and interpretation, and artificial intelligence can contribute to analyzing heritage data while preserving its authenticity." (P10)

Furthermore, the role of smart technologies in achieving sustainable tourism through better visitor flow management was highlighted by a Tourism expert who said:

"Smart systems for monitoring and controlling visitor numbers can reduce pressure on fragile sites and preserve their integrity for future generations." (P18)

5.3 Barriers to the Implementation of Smart Heritage City Applications

Participants identified several technical, financial, and social challenges. One technical expert pointed to weak digital infrastructure, saying:

"Most heritage sites lack stable internet networks, which limits the implementation of advanced smart solutions." (P7)

Similarly, a participant drew attention to insufficient funding for modern technologies in heritage:

"Funding allocated to these projects is minimal compared to the need, making implementation slow and fragmented." (P1)

The limited availability of qualified skills was also raised, with a researcher stating:

"We lack technical cadres qualified in both heritage knowledge and modern technologies, which delays many initiatives." (P2)

Regarding the legal framework, a university professor explained:

" Current legislation does not keep pace with technological development and lacks the flexibility needed to support innovation in smart heritage." (P22)

Lastly, a participant addressed the social dimension:

" There is resistance from some local communities, fearing that their culture and traditions might be lost due to the introduction of technology." (P19)

5.4 Proposed Approaches to Facilitate the Adoption of Smart Heritage City Applications

Participants agreed on the importance of adopting clear strategic plans. An urban planning expert said:

"We need a comprehensive national vision for smart heritage that precisely defines goals and required resources." (P25)

The importance of strengthening public-private partnerships was also emphasized by heritage specialist:

"Partnerships with local and international tech companies are key to securing the necessary funding and expertise." (P1)

They stressed the development of technical infrastructure, as one participant explained:

"No smart initiative can succeed without updating networks and communication systems." (P9)

Community awareness was also highlighted, with a heritage specialist stating:

"Continuous awareness campaigns are necessary to explain the benefits of smart heritage so communities accept this change." (P2)

A university professor pointed out the role of training:

"Investing in capacity building is vital to ensure the sustainability of projects." (P20)

Finally, some participants stressed the value of learning from international experiences, with a researcher noting:

" Cities like Barcelona and London have achieved great success in integrating heritage with technology, and we should learn from these models." (P23)

5.5 Efforts of the Egyptian Ministry of Tourism and Antiquities towards Adopting Smart Heritage City Strategies

The participants highlighted that The Ministry of Tourism and Antiquities has been actively working to adopt digital strategies aimed at enhancing the management of heritage sites. One of the key initiatives includes the implementation of an electronic ticketing system across more than 110 archaeological sites. As one participant noted:

"The electronic ticketing system at the Pyramids and other museums has contributed to reducing overcrowding and improving the visitor experience." (P15)

In the realm of digital documentation, the Ministry launched a project to digitize historical documents. A participant stated:

"The digitization project aims to preserve documents and reinforce cultural identity through digital data preservation." (P2)

Furthermore, renewable energy applications have been introduced, with solar power plants installed at sites such as Karnak Temple to support sustainability efforts. Another official explained:

"The installation of solar energy stations at Karnak supports our sustainability initiatives." (P19)

To enhance digital skills, the Ministry launched the "EGTAP" e-training platform, which contributed to:

"Improving the competencies of tourism and antiquities personnel and enabling them to utilize modern technologies." (P8)

Finally, coordination with UNESCO and academic institutions is ongoing to develop conservation and restoration plans for heritage areas. As one participant highlighted:

"Collaboration with international and local bodies ensures the preservation of world heritage sites in Cairo and other locations." (P3)

6. Discussion

This study represents a significant contribution to understanding the current state of smart technology utilization in Egyptian heritage sites, through the application of thematic analysis methodology that revealed the practical realities, opportunities, and challenges associated with this usage. The study aimed to explore the nature of existing smart applications and their impact on improving heritage management and preservation, alongside the factors influencing the integration of these applications

within heritage sites. The study sought to answer three key questions. ***First***, what opportunities are available for Egyptian heritage sites to adopt smart heritage city strategies? The findings highlight significant opportunities for the adoption of smart heritage city strategies within Egyptian heritage sites, reflecting global discourses on the intersection of digital technology, cultural identity, and sustainable heritage management. The emphasis by participants on augmented reality (AR) resonates with scholarly arguments that immersive technologies can enrich visitor interpretation, enhance engagement, and foster deeper respect for cultural heritage. This is consistent with the study of Borda and Bowen (2017), who emphasized the potential of AR and virtual reality to deepen public engagement with heritage and promote cultural appreciation, as well as Egusquiza and Gavalda (2020), who underlined the role of immersive tools in supporting heritage education and accessibility. By virtually reconstructing lost or damaged elements, AR not only supports experiential learning but also minimizes the need for physical interventions that may threaten the integrity of fragile monuments.

In addition, the recognition of artificial intelligence (AI) as a tool for heritage documentation and analysis underscores a broader shift towards data-driven heritage conservation. This reflects the growing scholarly consensus that AI and big data analytics can enhance authenticity preservation, facilitate predictive maintenance, and enable more nuanced interpretations of cultural narratives. The participants' emphasis on safeguarding cultural identity through modern technological means highlights an awareness of the delicate balance between innovation and authenticity in heritage practices. These insights align with Yin et al. (2020), who demonstrated that AI-driven data analysis can support more effective conservation strategies while ensuring that the authenticity of heritage assets is preserved.

Furthermore, the role of smart technologies in sustainable tourism management was strongly emphasized, particularly in relation to visitor flow monitoring and site protection. Participants noted that smart systems for tracking and regulating visitor numbers can reduce pressure on fragile sites, thereby ensuring their long-term integrity. This perspective echoes Angelidou et al. (2017) and Rahaman et al. (2019), who argue that digital monitoring systems are vital for mitigating overcrowding, balancing visitor access, and preserving heritage for future generations. In this sense, technology is not merely an enhancement tool but a mechanism for achieving sustainability by reconciling conservation priorities with tourism development.

Taken together, these findings suggest that adopting smart heritage city strategies in Egypt is not only a technological advancement but also a cultural necessity. By integrating AR, AI, and smart management systems, Egyptian heritage sites have the potential to strengthen conservation practices, reinforce cultural identity, and promote sustainable tourism. This positions Egypt within the global movement toward smart and resilient heritage cities, where innovation and tradition are brought into productive balance.

Second, what challenges do Egyptian heritage sites face in implementing smart heritage city applications? Efforts to adopt smart technologies in heritage sites face a range of major challenges that hinder effective integration and sustainable infrastructure. Among the most prominent challenges is the weakness of technical

infrastructure, including limited availability of high-speed digital networks and the lack of integrated smart systems necessary for advanced heritage management.

In addition, the sector suffers from a shortage of qualified and specialized personnel capable of handling modern technologies and employing them optimally. This issue is closely linked to the limited funding allocated for digital transformation projects in the heritage field, highlighting the need for sustainable financial support to enhance research, development, and provision of necessary tools.

On the regulatory side, the absence of a clear and supportive regulatory framework presents an additional challenge, as current laws and policies do not adequately cover the requirements for introducing smart technology or fail to keep pace with modern technological changes, leading to slow adoption of digital solutions.

On the social and cultural level, the adoption of technology faces resistance from some stakeholders and local communities, due to concerns over losing the original character of the sites or lack of understanding of the potential benefits of technology.

These challenges align with what Ardito et al. (2019) reported, emphasizing the importance of having a strong technical infrastructure alongside effective institutional support for successful technology adoption in heritage sites. UNESCO reports (2018) also indicate that the human aspect, especially training and capacity building represent some of the greatest obstacles facing smart heritage projects, stressing the need for investment in skill development and raising awareness among stakeholders about the importance of technology in heritage preservation.

Third, what strategies are proposed to enhance the implementation of smart heritage city applications in Egyptian heritage sites? The study's results revealed a clear deficiency in institutional awareness regarding the importance of adopting smart technologies in the management and preservation of heritage sites, alongside weak integrated strategic planning that connects the various stakeholders and ensures the sustainability of digital projects. This shortfall limits institutions' ability to effectively and sustainably realize the benefits of smart technology and hinders the development of coherent and practically applicable operational models. These findings align with Komninos (2020), who emphasized the necessity of having a comprehensive and clear national vision, supported by effective governmental policies, to promote and support smart heritage projects at organizational and financial levels. Angelidou (2018) also highlights that training and institutional capacity building is critical factors contributing to the successful adoption of smart technologies, enabling specialized teams to effectively address technical and organizational challenges.

Accordingly, achieving the desired integration in the use of smart technologies requires developing comprehensive strategies focused on unifying the vision, enhancing cooperation between different sectors, and emphasizing institutional capacity building and technical skills to ensure the sustainability of smart heritage projects.

Overall, these findings align with previous studies such as Selim et al. (2022) and Della Corte et al. (2017), which stressed the importance of institutional support, funding, infrastructure, and training for the success of smart heritage city initiatives. They also underscore the need for clear policies and effective partnerships between government entities and the private sector to enhance the adoption of smart

technologies. Therefore, it can be concluded that a systematic and integrated development of smart technology use in Egyptian heritage sites represents a significant opportunity to enhance heritage conservation and achieve sustainable development, while overcoming the technical, human, and regulatory obstacles that currently impede progress (Khan et al., 2021; Silva et al., 2020).

7 .Conclusion

The study's findings indicate that the application of smart technologies in Egyptian heritage sites is neither effectively nor cohesively utilized by the relevant authorities, with some components being used in a fragmented and isolated manner. This situation stems from a range of technical, organizational, and social barriers that require urgent intervention from decision-makers to activate these advanced technological tools for the sustainable preservation and development of heritage.

Institutional support and awareness of the importance of smart technology and its impact on enhancing management and conservation processes are fundamental factors for successful adoption. Therefore, an appropriate incentive structure and intensive training to build human capacities are essential conditions for the effective and sustainable integration of these technologies.

Moreover, there is a pressing need to reform regulatory frameworks to allow freer data exchange and improved accessibility within a robust system and integrated digital infrastructure. It is also recommended to redirect financial resources from reliance on temporary solutions to long-term investment in developing digital infrastructure and human capacity building.

This study calls for further research exploring the perspectives and readiness of multiple stakeholders—from government agencies and heritage and tourism institutions to local communities and visitors—to ensure the adoption of comprehensive and balanced strategies. Additionally, expanding the scope of studies to include experiences from other countries with similar economic and regulatory conditions would enhance the generalizability of findings and provide a solid framework for comparative analysis between developing and developed countries.

This study adopts a qualitative, exploratory approach to investigate the opportunities and challenges associated with the implementation of Smart Heritage City strategies. The research design is grounded in interpretivist epistemology, which acknowledges the socially constructed nature of heritage and emphasizes the centrality of human meaning-making in understanding urban and cultural. Within this framework, heritage is not merely a set of physical assets but a dynamic cultural process shaped by the perceptions, practices, and interactions of diverse stakeholders. Accordingly, the study privileges the voices of experts, practitioners, and policymakers, recognizing their perspectives as essential for evaluating the feasibility and sustainability of integrating smart technologies into heritage contexts. By employing this lens, the research moves beyond purely technical assessments to explore how social, cultural, and institutional dimensions influence the adoption of Smart Heritage City strategies.

8. Recommendations

1. Establish Integrated Governance Frameworks: Enhance cooperation between national heritage agencies, municipal authorities, technology providers, and

community actors to ensure cohesive decision-making and efficient implementation of digital heritage initiatives.

2. Invest in Digital Infrastructure and Human Capital: Upgrade internet connectivity and technical systems for real-time monitoring, visitor flow management, and content delivery, while also improving digital literacy among officials, professionals, and community members.

3. Safeguard Cultural Integrity through Ethical Digital Practices: Prevent over-commercialization by grounding initiatives in community values, protecting intellectual property, and ensuring culturally sensitive representation of heritage assets.

4. Implement Sustainable Tourism Strategies: Adopt smart platforms for dynamic visitor management, personalized itineraries, and real-time feedback to reduce congestion, improve visitor experiences, and preserve heritage sites.

5. Promote Participatory Digital Tools for Community Engagement: Use crowd-sourced storytelling, oral history archiving, and participatory mapping to foster local ownership, deepen public engagement, and strengthen social cohesion.

6. Develop Legal and Technical Standards for Digital Heritage: Adopt national policies aligned with UNESCO and ICOMOS standards, covering digital documentation, data sharing, and cybersecurity to ensure secure and ethical heritage management.

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