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## THE IMPACT OF SMART TECHNOLOGIES ON PRESERVING CULTURAL HERITAGE

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**Abstract:** Using smart technology to preserve cultural heritage has become a revolutionary way to protect and promote historical locations, artifacts, and customs. This article examines a number of contemporary smart technologies, such as artificial intelligence (AI), the Internet of Things (IoT), virtual reality (VR), and augmented reality (AR). It assesses how well they improve visitor experiences, maximize conservation strategies, and involve local people. The article also discusses the difficulties and moral dilemmas related to its application. The report offers a thorough analysis of the benefits and drawbacks of modern technologies in protecting cultural assets through case studies and expert interviews. A survey was conducted to assess public awareness of smart technologies and their role in heritage protection. The findings indicated that these technologies are widely used for heritage preservation in Bukhara, with growing interest in their application across Uzbekistan.

**Keywords:** smart technologies, virtual reality, augmented reality, artificial intelligence, Internet of Things.

### Introduction

The protection of cultural heritage is a crucial undertaking that ensures the preservation of historical narratives, artistic expressions, and societal values for future generations. With global challenges like climate change, urban expansion, and socio-political conflicts posing growing threats to cultural sites and traditions, the incorporation of smart technologies has become a transformative force in heritage conservation. Smart technologies include a wide range of tools such as digital documentation, augmented reality (AR), virtual reality (VR), artificial intelligence (AI), and the Internet of Things (IoT). These innovations not only improve preservation techniques but also enhance accessibility and engagement with cultural heritage.

The use of smart technologies in cultural heritage offers unparalleled opportunities for documenting, analyzing, and protecting cultural assets. For example, 3D scanning and modeling allow for precise digital representations of artifacts and sites, which can be vital for restoration or for creating virtual exhibitions. Additionally, AR and VR technologies provide immersive experiences that can transport users to historical settings, deepening their understanding and appreciation of cultural heritage.

Nevertheless, there are several difficulties in implementing smart technologies in this industry. To make sure that technology advancements do not diminish the inherent worth of cultural activities and objects, issues with authenticity, data security, and fair access must be

addressed. Since not all groups have equal access to technical resources, the digital divide also presents inclusion challenges.

Investigating the various effects of smart technology on the preservation of cultural assets is the goal of this paper. Case studies of successful implementations will be reviewed, the difficulties institutions have had implementing these technologies will be examined, and potential future trends that could impact the cultural preservation profession will be discussed. By considering both the benefits and limitations of smart technologies, stakeholders can develop more effective strategies for protecting our shared cultural heritage in a digital age.

### Literature Review

The integration of smart technologies in cultural heritage preservation has become a focal point of interest in recent years. Researchers and professionals have started to explore how technologies like augmented reality (AR), virtual reality (VR), artificial intelligence (AI), and the Internet of Things (IoT) can improve the preservation, documentation, and accessibility of cultural assets. This literature review summarizes key insights from various studies, focusing on the advantages and challenges of adopting these technologies.

Buonincontri P., Marasco, and others (2017) highlight that the advancement of smart technologies has created remarkable opportunities to enhance tourists' experiences at historical sites, which holds significant marketing potential for cultural tourism destinations. Smart technologies are being applied to cultural assets to improve both preservation and visitor engagement (Khalaf M., et al., 2019).

AI has proven to be a valuable tool for analyzing and managing cultural heritage data. When combined with smart sensors and data mining techniques, AI can help preserve and enhance cultural assets by replacing their old layers (Talamo, Valentini et al., 2020; Gonzalez et al., 2020). For example, AI can assist in classifying artifacts, predicting their degradation, and even suggesting restoration techniques based on historical data (Gonzalez et al., 2020). However, the use of AI also raises ethical concerns related to data privacy and the potential biases in algorithm-driven decisions.

AR and VR technologies offer immersive ways to engage the public with cultural heritage. Whelan et al. (2018) note that AR applications can superimpose historical information onto the real world, allowing users to interact with their environment in more meaningful ways. Likewise, VR can transport users into historical settings, promoting a deeper understanding of cultural histories (Falk & Dierking, 2016). These technologies not only enrich learning experiences but also create emotional connections between users and cultural heritage.

### Methodology

The Bukhara region was taken as the object of research, and a systematic and complex approach, functional approach, analysis and synthesis, monographic analysis, scientific abstraction, grouping of statistical data, comparative analysis, selective observation, conducting a survey, preliminary data methods such as data collection were used.

### Findings and Discussion

The Bukhara region, rich in cultural heritage and historical significance, has seen the integration of smart technologies aimed at preserving its unique artifacts and sites. Here are some notable implementations and their impacts.

Digital Documentation and 3D Scanning	
<b>Application</b>	Many cultural heritage sites and artifacts in Bukhara, such as the Ark Fortress and the Bolo Haouz Mosque, have been digitally documented using 3D scanning and photogrammetry.

<b>Impact</b>	This technology allows for detailed digital records that can be used for restoration purposes and virtual tours, making these treasures accessible to a global audience.
<b>Augmented Reality (AR) Experiences</b>	
<b>Application</b>	AR applications have been developed to enhance visitor experiences at sites like the historic trading domes (Toki) in Bukhara.
<b>Impact</b>	Visitors can use their smartphones or AR glasses to view historical reconstructions and learn about the significance of various sites, bridging the gap between past and present.
<b>Environmental Monitoring with IoT</b>	
<b>Application</b>	The use of IoT sensors to monitor environmental conditions in museums and at outdoor heritage sites.
<b>Impact</b>	These sensors track humidity, temperature, and light levels, helping conservators take proactive measures to protect artifacts from deterioration.
<b>Digital Twin Technology</b>	
<b>Application</b>	Digital Twin Technology has been installed in the Ismail Somoni mausoleum based on Korean experience.
<b>Impact</b>	The digital twin can simulate different restoration approaches, helping conservators visualize potential outcomes before actual work begins.

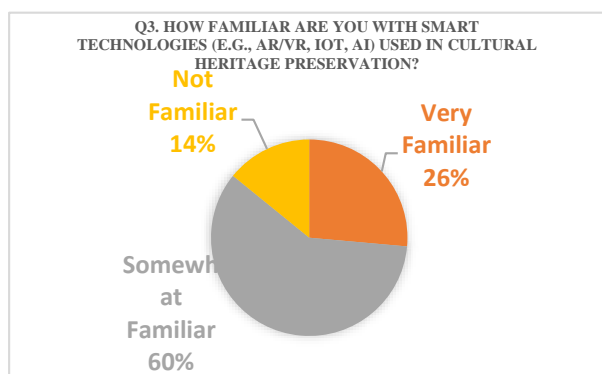
To supplement the document analysis, semi-structured interviews were conducted with local residents and foreign tourists, students visiting Bukhara.

<b>Section 1. Demographic information</b>			
<b>Q1 Age</b>	<b>Under 18</b>	<b>1</b>	<b>0,9</b>
	<b>18-24</b>	<b>64</b>	<b>60.4</b>
	<b>25-34</b>	<b>20</b>	<b>18,9</b>
	<b>35-44</b>	<b>14</b>	<b>13,2</b>
	<b>44 and over</b>	<b>7</b>	<b>6,6</b>
	<b>Total</b>	<b>106</b>	<b>100</b>
<b>Q2 Education</b>	<b>High school</b>	<b>1</b>	<b>0,9</b>
	<b>Bachelor</b>	<b>73</b>	<b>68,9</b>
	<b>Masters</b>	<b>20</b>	<b>18,9</b>
	<b>Phd</b>	<b>12</b>	<b>11,3</b>
	<b>Total</b>	<b>106</b>	<b>100</b>

### **Section 1: Demographic Information (Table 2)**

The interviews aimed to gather awareness and usage of smart technologies, perception of impact, Future perspectives to the success of tourism strategies.

Based on the research findings, the following key conclusions can be drawn:

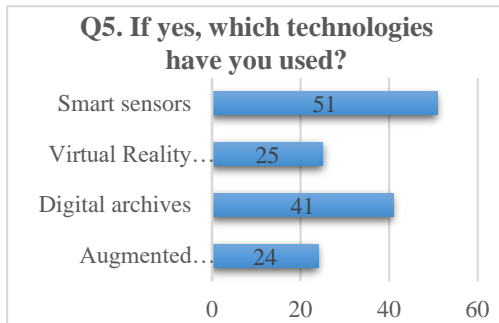


**Q1:** The age distribution of the survey respondents reveals that the majority are between 18-24 years old (60.4%), followed by those aged 25-34 (18.9%), 35-44 (13.2%), and 44 or older (6.6%). Only a small percentage (0.9%) are under 18.

**Q2:** A significant portion of the respondents (approximately 70%) holds a Bachelor's degree, making it the most common level of education among them. A smaller, but notable, group (18.9%) has obtained a Master's

degree, indicating a highly educated demographic. A small number of respondents have a PhD (11.3%) or a High School education (0.9%), suggesting that the majority of the respondents are well-educated, with most having at least a Bachelor's degree.

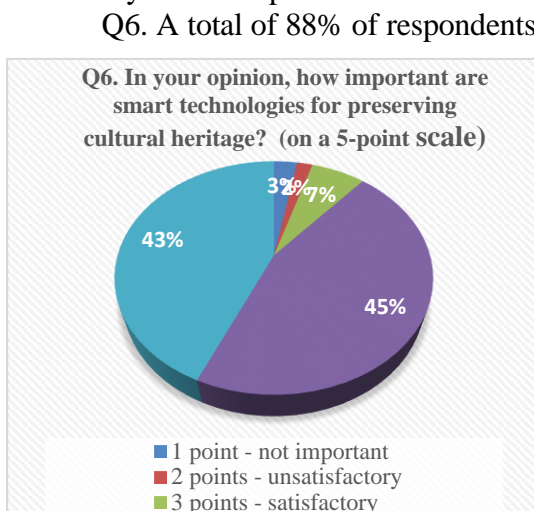
Q3: "How familiar are you with smart technologies (e.g., AR/VR, IoT, AI) used in cultural heritage preservation?" The survey results reveal that a large majority (86%) of respondents have some level of familiarity with smart technologies in cultural heritage preservation. Only 14% of the respondents are completely unfamiliar with these technologies, indicating that there is already a solid foundation of knowledge or awareness among the participants.



Q5. The highest number of respondents (51) indicated that they have used smart sensors. This suggests that smart sensor technology is the most commonly utilized among the listed options.

A significant portion of respondents (41) reported using digital archives, highlighting that this technology is also widely adopted in cultural heritage preservation. About half of the number for smart sensors, 25

respondents have used virtual reality (VR) experiences, indicating a moderate usage level. Similar to VR, 24 respondents reported using augmented reality (AR) apps, suggesting that AR is less commonly used compared to smart sensors and digital archives.



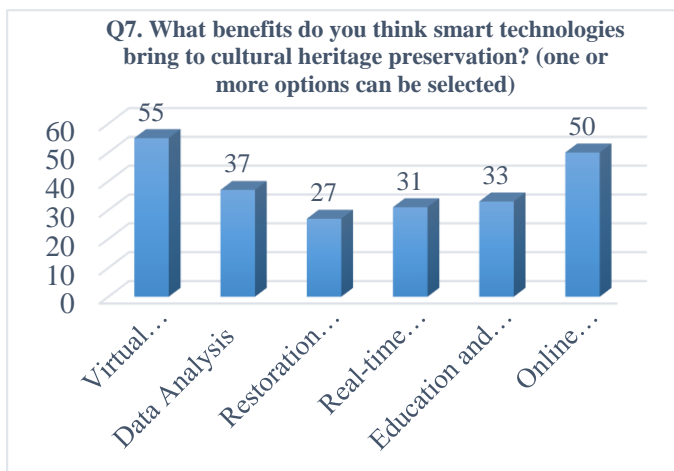
Q6. A total of 88% of respondents (combining 4 and 5 points) view smart technologies as "Good" or "Excellent" for preserving cultural heritage, indicating a strong agreement on their value. Conversely, only 5% of respondents (combining 1 and 2 points) believe these technologies have little to no importance in this area, showing minimal opposition to their use. This data highlights widespread acceptance and acknowledgment of the crucial role smart technologies play in cultural heritage preservation, with a clear preference for their further integration into the field.

Q7. Virtual Accessibility (55%) and Online Resources (50%) are seen as the most impactful contributions of smart technologies, allowing broader

and easier access to cultural heritage.

Restoration Techniques (27%) and Real-time Monitoring (31%) are regarded as more

specific technical applications but are less frequently cited compared to access and resource benefits.

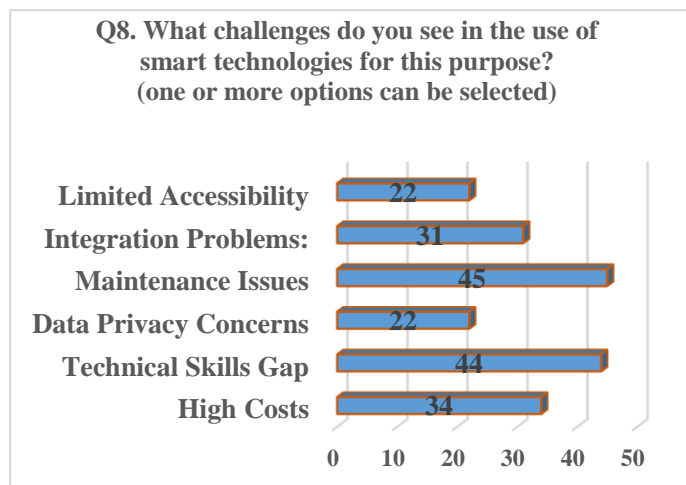


Education and Awareness (33%) and Data Analysis (37%) highlight the educational and analytical potential of technology in cultural heritage.

These results indicate that accessibility and educational resources are the primary perceived advantages of smart technologies in this field, suggesting a focus on how technology can democratize and enhance the understanding of cultural heritage.



Q8. The most frequently reported challenges in adopting smart technologies are Maintenance Issues (45%) and the Technical Skills Gap (44%). In contrast, Data Privacy Concerns and Limited Accessibility are less commonly cited, both at 22%.



and Limited Accessibility are less commonly cited, both at 22%. High Costs (34%) and Integration Problems (31%) are also notable barriers. This analysis indicates that the main obstacles to adopting smart technologies are more related to practical issues and skill gaps than to concerns about accessibility or privacy.

#### **Section 4: Case Studies and Examples**

Q9: Can you provide an example of a project or initiative where smart technology has positively impacted cultural heritage preservation? Respondents mentioned several examples, including Petra in Jordan, various museums, the Samanid Mausoleum in Bukhara, the Hermitage Museum in Russia, the online guide implemented at the Ark Museum in Bukhara, the "Visit Japan Web" program, and the Registan in Samarkand.

Q10: Which specific cultural heritage sites or practices could benefit from smart technology? Participants suggested several sites, including the Buddha statue in Afghanistan, the Ulugbek Observatory in Samarkand, the Bahoutdin Architectural Complex in Bukhara, George Town in Malaysia, the Louvre Museum in France, Topkapı Palace in Turkey, the Gaudí Museum in Spain, the Smithsonian Institute, Pompeii, Spain, and Barcelona.

#### **Section 5: Future Perspectives**

Q12: When asked about additional tools or technologies for preserving cultural heritage, respondents suggested various ideas, including protective measures, holograms for disappearing objects, security technologies, and the organization of devices and free Wi-Fi zones near cultural sites that provide information via QR codes. They also proposed the development of a program using new-generation statistical machines to calculate preliminary cost estimates for infrastructure repairs or demolition. Other suggestions included the application of 3D digital technology, excavation scanners, smart guides, and a dedicated virtual smart technology or app with an engineering and traffic map of the entire city. Additional ideas included virtual glasses and the creation of virtual models for museums and other historical works, signaling systems, and technologies for inclusive tourism.

#### **Conclusion**

This study highlights the considerable potential of smart technologies in preserving and promoting cultural heritage. The use of AR, VR, IoT, and AI not only enriches visitor engagement and experience but also supports conservation efforts and encourages community participation in heritage protection. Survey results from Bukhara show a strong awareness and interest among the local population in the role of these technologies in safeguarding cultural assets, reflecting a positive shift toward embracing innovation in heritage management.

Nevertheless, the adoption of smart technologies faces several challenges. Ethical issues, data privacy concerns, and the need for interdisciplinary collaboration must be addressed to ensure these advancements benefit all stakeholders. As Uzbekistan continues to explore and implement

smart technologies, it is vital to maintain a balance between technological progress and the preservation of cultural integrity.

In conclusion, while smart technologies offer exciting possibilities for improving cultural heritage preservation, continued dialogue, research, and policy development are essential to navigating the complexities of their use. This study adds to the expanding knowledge on the intersection of technology and cultural heritage, paving the way for future research and practical applications in this important field.

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