Exploring the Role of Digital Technologies in Safeguarding Taxila's Archaeological Heritage: A Qualitative Study

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Abstract
The advancement in digital technologies provides ways of protecting the heritage however, integration of those technologies in the preservation of heritage is limited in developing countries such as Pakistan. This paper focuses on the use of digital technologies in conservation and management of Taxila's archaeological sites and uses data collected through observation and interviews together with secondary sources to inform the study. Studies show that there is a significant capacity to expand the application of tools such as GIS mapping, 3D scanning, remote sensing, and virtual reality (VR) in documentation, monitoring, and public involvement; however, the practical application is limited by cost, lack of skills and institutionalization. It was noted during the research that in Taxila most of the conservation methods applied are traditional approaches with little or no incorporation of live monitoring technologies. An examination of the documentation noted that there are low levels of coherent policy development and intersectoral liaison between the heritage sector and technological specialists, which would negatively affect digitization. Based on the survey, it is suggested that a national digital heritage database should be created with funding for capacity, programs, AI monitoring systems should be setup, citizens' engagement increase and policy level digital integration should be advanced. In the following ways, it is possible for Pakistan to promote and preserve Taxila and its great heritage through systematic digital conservation.

Keywords: Digital Heritage, Archaeological Conservation, GIS Mapping, 3D Scanning, and Remote Sensing,

Introduction
Human civilization depends on archaeological heritage to expose the ways of life and cultural accomplishments of societies which existed in the past. All historical development knowledge and cultural identity surveillance depends on the numerous ancient cities monuments temples and artifacts that exist across the world. Recent threats to archaeological heritage sites continue to grow in number because of natural disasters together with climate change and urban expansion and vandalism and illegal excavations (Tahseen rt al., 2024). Historical preservation techniques which include physical restoration alongside site management prove inadequate for meeting the current conservation challenges properly This has brought the integration of digital technologies into heritage

preservation as a transformative approach of which innovative solutions of documentation, analysis, monitoring, and education have resulted (Ziyatbay, 2024).

Among all the positive impacts presumed by the digital technology in the case of heritage, documentation has been benefited immensely. Modern tools like 3D laser scanning, photogrammetry, GIS hardware and software gives the researchers the possibility to make digital reproductions of the site. These records do not only assist the restoration and reconstruction processes but also decrease the chances of deterioration in addition to centralized control. Third, digital archives make it possible for scholars and conservationists to virtually access and analyze the sites that are located in other parts of the world and promote global collaboration in the preservation of heritage (Prayogi & Nasrullah, 2024).

There is also the issue of real-time monitoring and analysis of different processes, which also plays an important role in the use of digital technologies in archaeology. Satellite imagery and surveillance through drones give up-to-date data about the site and surrounding areas to help authorities to prevent and address any issues like unauthorized digging or vandalism of resources. Another feature of AI technology and machine learning is emphasizing and focusing on patterns of deterioration and risk and making suggestions for conservation in advance. They assist the heritage managers in coming up with the necessary decisions in order to preserve such important archaeological features (Alt et al., 2022).

Apart from conservation, digital technologies help in the engagement of people and raising awareness. In terms of culture, virtual and augmented reality systems allow an individual to get a feel of experiencing cultural heritage sites without physically moving from their respective locations (Frieman, 2021). Having many issues related to the presentations of ancient civilizations in museums and art galleries in mind, one can but notice that methods which are currently actively used in historical and archaeological studies allow exposing communities to history in rather unique and engaging ways. Moreover, social media and online databases create access to people, researchers, educators, and cultural heritage contents and enthusiasts from across the world. In this connection, the application of these technologies ensures that heritage sites not only obtain a wider visibility but also act as promoters of cultural tourism as well as platform for sustainable conservation (Meskell, 2002).

However, there are some challenges that requires to be meet while implementing the digital preservation strategies (Sachs, 1990). The utilization of these solutions is a capital-intensive process that necessitates adequate finance, technology, and infrastructure, which may be quite costs in the case of developing regions. Other essential issues that may result in abuse of technology include; ownership of data, opening up of data and commercialization of the heritage. In order to address these challenges, proper cooperation between archaeologists, technologists, policymakers and local population is needed. By developing collaboration and dissemination of knowledge, digital heritage can be even and enhanced (Kintigh et al., 2024).

Problem of statement
The archaeological site of Taxila which is a world heritage site in Pakistan is one

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of the evidences of this heritage. However, it has been threatened by environmental degradation, urbanization, illegitimate digging, and lack of conservation. Current approaches of preservation in Pakistan rooted in the country's past may not be accompanied with the proper technologies required for accurate documenting, constant surveillance, and public involvement. The inference is that if there is no systematic digitization, Taxila can continue to deteriorate, and digital heritage can be lost for good. This paper shows that innovative technologies like 3D scanning, GIS mapping, remote sensing and VR could be instrumental in the protection of the site. However, these tools are not widely researched and adopted in the context of conservation of cultural heritage in Pakistan. The objective of this work is to investigate how digital technologies can be beneficial to be used for the preservation and documentation of Taxila and its accessibility for future generation.

Research Objectives
1. To assess the role of digital technologies in documenting and preserving archaeological heritage.
2. To evaluate the effectiveness of remote sensing and AI in monitoring and protecting heritage sites.
3. To examine the impact of virtual and augmented reality on public engagement in heritage conservation

Literature Review
There has been a remarkable interest from the scholars when it comes to applying new technologies towards the conveyance of archaeological heritage. Experts in history, archaeology, IT and other related fields have attempted to capture, observe, as well as preserve historical structures and other sites to make them more easily accessible and safe from various vandals and other hazardous forces of nature. This research aims at reviewing the various digital instruments used in the management of heritage conservation goals, and the impact they have, the difficulties that may arise in its implementation, and the possible developments it has in the future.

Digital Documentation and 3D Reconstruction
Among the most popular areas of research in the field of digital preservation of the heritage is the documentation of archeological sites with modern instruments. Although various authors have written about the usefulness of 3D laser scanning photogrammetry, and LIDAR in heritage, (Alt et al., 2022). specifically point that they provide detailed digital models of historical places. These techniques make it possible to have accurate measurements of the structures, meaning even if the site gets to degrade, there is a record to rebuild and for the academic use. Photogrammetry specifically is preferable for everyone because it is cheap and offers high accuracy from everyday photos (Kintigh et al., 2024).

Indeed, there are some works stressing the benefits of applying Building Information Modeling (BIM) and Geographic Information Systems (GIS) for the archaeological purposes and monuments preservation. GIS makes it easier for the researchers to understand the spatial setting of the archaeological sites and the setting changes over a particular period. It has been applied in architecture

and urban planning but today is adapted and used in heritage conservation in order to analyze the impact of the different vivid scenarios for restoration and the effects of climate change on the edifice in the future (Meskell, 2002). These digital tools give the heritage managers and archaeologists an opportunity to have accurate information that will enable them to plan on the conservation of the respective heritage sites.

Remote Sensing and Real-Time Monitoring

Digital technologies are also used in the assessment of archaeological sites so as to check on activities such as vandalism in this case. Other authors like Ziyatbay (2024). have explained how satellite imagery and drones can assist in identifying spoil, cracks, and alterations in utilization of space around cultural assets. Remote sensing is an advantage because it does not require physical contact and so is particularly useful in remote areas where it might not be easy to access the sites due to geographical or political implications.

Modern drones fitted with hi-tech lenses that include high definition cameras and laser-based thermal imaging cameras come in handy when carrying out archaeological surveys, drones offer a range of advantages when it comes to capturing aerial images better than other conventional methods. When applied jointly with artificial intelligence, these technologies allow detecting the early signs of wear and tear and subsequently addressing such issues without having to wait for a complete breakdown. Machine learning algorithms have

also, been applied for the evaluation of the patterns associated with erosion, weathering and material degradation for the purpose of the probable risks modeling (Tapete & Cigna, 2021).

Virtual and Augmented Reality in Heritage Conservation

With advance in technology, Virtual Reality (VR) and Augmented Reality (AR) have had a significant impact on the aspect of cultural heritage. This is in a way that the scholars propose that they close the gap between academic scholarship and outreach. Since using VR to recreate ancient sites depicts them as they were in the past, users are able to learn otherwise unknown aspects of cultural heritage. Presently, museum and heritage organizations purposefully employ AR applications to overlay more historical features onto the current remains and enhance the audience's learning (Bekele et al., 2018).

A study by Shim et al. (2024) highlights the benefits of digital storytelling and interactive simulations in heritage preservation. In the same way, they help in education and promotion of travel to historical sites for cultural experiences because these structures are made easily accessible to the international community. Nevertheless, it is worth noting that VR and AR applications have some drawbacks which include high costs, technical constraint, and the necessity to provide the accurate historical data for reconstruction of the environment.

Challenges and Ethical Considerations in Digital Heritage Conservation

Finally, there are some issues connected with using digital technologies in the sphere of the heritage preservation Generally, digital technologies have certain benefits in comparison with the traditional methods. First of which is the contingency of data accessibility or ownership. There are many instances where

the heritage site is at a politically sensitive location, which makes one wonder, who owns the digital records and how are these records disseminated. Hence, the management and enhancement of digital heritage projects need considerable monetary support and advanced technology, which might not be feasible in all areas (Brusaporci 2017).

Another ethical problem that has come about is commodification of digital heritage. The problem is that this process might make the access to cultural knowledge restricted or paid due to private companies investing in such heritage digitization projects. Other scholars have also raised concerns with concerns to credibility and reliability of the digital reconstructions: for this reason, while constructing such models it's important to use archaeological data exclusively and only in such scenarios (Vilbig et al., 2020).

Future Directions in Digital Heritage Preservation
In their view, scholars concluded that in the future, more complexity of Artificial Intelligence (AI), expansion of the blockchain technology and advanced Robotics will be embraced within heritage conservation. New generation of artificial intelligent helps in classification and interpretation of archaeological data along with cutting down efforts for site documentation (Campiani, et al., 2022). Due to its feature of reliable data storage and anti-forgery, the application of blockchain technology has been considered to prevent interference and unauthorized modifications in the digital records.

Another up and coming trend is the application of crowdsourcing and citizen science in archaeological studies. Many are the open access databases, mobile applications where members of the public post photos and geographic location of such heritage assets (Besides supplementing the data gathering process, the approach empowers participants to play a part in the protection of cultural assets (Ronchi et al., 2023).

Methodology
This research used qualitative research method to determine the involvement of technology in the protection of Taxila archaeological site. The reason for the use of a qualitative research approach was due to the study's focus on exploring the role of particular digital tools and their applications in the domain of heritage preservation, tracking, and dissemination. Semi-structured interviews, observational research, and documentation review were used to gather data, which offered an adequate assessment of the study's research issue. A total of 10 semi-structured interviews were carried out with stakeholders including archaeologist, professional conservators and heritage managers, policymakers in cultural heritage, and digital technologist. These interviews were helpful in understanding the success, difficulties, and possibility of using technological solutions in cultural preservation. Some of the open-ended questions provided perfect opportunities for valuable qualitative data on real experience and outlooks on actual applications of 3D scanning, GIS mapping, remote sensing, and virtual reality. Site visits to the Taxila archaeological sites were conducted in order to observe the current status of preserve and also to understand the number of ways in which profession has adopted the use of technology. It was through observation that one was able to capture evident threats to the heritage structures and a live experience on the challenges of applying digital interference.

Document analysis included surveying that focused on material available in existing literature, reports and cases on the subject of digital heritage conservation in Pakistan as well as in the international domain. These were UNESCO documents, government documents and research papers related to the digital technology applied in archaeology. It was useful to compare the findings with other sources to place it in perspective, with regards to Taxila's conservation efforts. The collected data were analyzed with thematic analysis, whereby different patterns and themes would be given to the participation of digital technology in heritage management. It was therefore analyzed into four broad categories of documentation and monitoring, restoration, and public engagement. This allowed for a more qualitative focus on how such endeavors can improve the restoration of Taxila's archaeological sites and the difficulties experienced in the process.

Results and Discussion
This section encompasses a detailed discussion of the key themes extracted from the study, highlighting their significance and implications. It further provides an in-depth analysis of the findings in relation to existing literature and theoretical perspectives. Finally, the section concludes by summarizing the key insights, addressing the study's contributions, and suggesting potential directions for future research.

Emerging Themes from Data Analysis
As a result of the qualitative data collected from the interviews, the observation, and the analysis of the identified documents, it is possible to articulate four paramount themes in relation to the involvement of the digital technologies for preservation of Taxila's archaeological sites. These themes depict the prospects and issues of using technology in preservation of the history.

Digital Documentation and Preservation of Heritage Sites
The third major concern that arose was the role of History of Taxila Digital Image Project for the documentation of Taxila's archaeological sites and structures. From a review of the UNESCO reports and the various conservation policies enacted, knowledge of incrementing global use of advances such as 3D scanning, photogrammetry, GIS mapping to make accurate digital records of the heritage sites was gained. Nevertheless, it is important to note that as of now, Pakistan still relies on old school techniques for conservation.
One senior archaeologist, thus spoken word-souvenirs to this cliché:
"We continue using paper as a medium and photography as well but these are inadequate to our needs. If a structure collapses, other parts of it that may be of importance to architects and engineers are lost as well despite through photographs and other forms of technology, they can be reconstructed. It is therefore necessary that this Mapping applications and 3D scanning for mapping should form part of conservation measures taken normally."
These concerns were also found valid during the field observation at Taxila. Some of the sites had good documentation in terms of documentation but unfortunately others had records out of date and thus it was tricky to restore. As for one of the main challenges, the lack of professionals with proper education and knowledge about digital heritage management was described.

"As far as technology is concerned there are very limited professionals in Pakistan who can handle sophisticated digital documentation systems. It is advisable to state that even if we have the equipment, we also need to build the capacity in order to utilize the equipment proficiently."

Challenges in Implementing Digital Technologies

While the assessment of the tools showed that they have their benefits in general, the document analysis and interviews pointed out some barriers to the efficient use of the tools in Taxila. The issues such as inadequate funding, lack of resources and experience, and absence of policies were cited most often. A government official who was directly involved in heritage management emphasized the matter as follows:

"The biggest hurdle is financial. Many digital conservation tools in many institutions are expensive; consequently, most of the finance is used in life-threatening contingencies rather than digital curation."

While making field observations, there was poor apparent of the use of digital tools in the restoration while most of the works were highly intensive and carried out manually and by traditional techniques. Pertaining to this, a site manager at Taxila said this:

"As we are aware of 3D scanning and remote sensing for instance; but with incorrect budget and training how can they be applied? These make very good theoretical technologies though they are not applicable for use in our context."

Interview also shows that because organizations do not have a consistent action plan towards digital conservation, efforts are dispersed. A technology expert in the field of conservation of cultural property stated:

"However, if we proceed systematically and consequently—beginning with the creation of a single digital database of historical attractions in the country—Pakistan will be able to make a great leap forward. However, program lacks a clear policy and in the absence of it we have projects here and there and they are virtually useless."

Real-Time Monitoring and Threat Detection

According to the interviews, remote sensing, drones, and AI-based monitoring suggestions were considered as some of the best ways that would help in safeguarding Taxila's heritage from various adversities that may lead to damage. This literature review of the available research studies and studies of selected countries established that similar to the Italian scenario, China has also adopted the use of satellite imagery and drone for monitoring site condition and for providing early indications of undesirable activities such as looting.

But studies in Taxila revealed that the usage of such technologies in their fields were rare. Some of them included human intensive areas of the site showed signs of erosion cracking and structural deterioration while monitoring was done manually. A heritage site supervisor noted:

"We perform physical verification periodically, but they are rather time-consuming. In_-shoring could be done through products such as digital monitoring tools like drones that could supply data in real time, but such cannot be afforded for regular use."

One of the limitations in the AI researcher's interview was to outline the

applicability of machine learning approach in the early detection of threats.

"This would mean that if we were to use satellite data in training the AI models we shall be in a position of preventing environmental disasters before they occur. This is already a practice adopted in other countries, and Pakistan should also try to follow such policies."

Nonetheless, what has become evident is that the implementation process tends to be slow. They noted that digital monitoring might help but blamed such steps as bureaucracy and lack of experienced workforce.

Enhancing Public Engagement through Virtual and Augmented Reality

Another major topic of the papers included papers relating to the Application in Virtual Reality (VR) and Augmented Reality (AR) in the field of heritage education and tourism. Another consideration that emerged from the analysis of the documents is that different UNESCO sites globally implement digital approaches and platforms that enable interaction of the society and create awareness. Nevertheless, the usage of these technologies is still at its infancy in Pakistan.

In my observation of the tourist while in Taxila, besides using guide, there were no digital means of touring or physical markers to guide them. A scholarship holder in cultural education and an elder and associate professor in a University said:

"It is almost observed that, history, in most cases, is transacting, with aids of digital platforms. If museums were to introduce AR applications and enabling visitors to 'look' at how Taxila looked several centuries ago, it is very likely to draw newer and interested individuals into embracing the causes of heritage conservation."

The official from the Pakistan's department of tourism had similar sentiments to this:

"Other countries have used virtual museum environment and Augmented Reality to tell stories. We need to adopt these tools should we want to make our heritage site more attractive to the outside world."

As one of the major issues the student distinguished the essential absence of cooperation between the representatives of tech industry and heritage authorities. A digital heritage specialist noted:

"Overall, we have the competence for VR and AR application development, but there is still no strong link to some heritage organizations. As much as such ideas areaira developed, they are merely on paper if practice is not given with adequate funding and backing from institutions."

Discussion

The study establishes the possibilities and impossibilities of implementing digital technologies in the protection of Taxila archaeological site. The study also corresponds to the earlier studies according to the advocates of the values of documentation, monitoring and virtual participation to foster the sustainable conservation of heritage in the long-term as echoed (Ronchi et al., 2023). Yet, the Pakistan's approach to the DM and preservation of digital heritage is still quite reactive and mostly defined by such factors as limited funding, personnel shortage, and the lack of a unified policy on the matter (Campiani, et al., 2022).

Observations made in the field indicated that none of the new age technological approaches such as GIS mapping, 3d scanning and Ai monitoring and control where used in the Taxila conservation and restoration. Thus, respondents had awareness about versatility of using information technologies, but respondents identified lack of the systematic approach toward its application, bureaucracy, and non-coordinated institutional initiatives as the main challenges. These challenges are in line with international research that suggests that heritage conservation in developing countries faces challenges of funding and skills in adopting and using digital technology (Vilbig et al., 2020).

Another key discovery was regarding the use of exogenous technology like 'Virtual Reality (VR)' 'Augmented Reality (AR)' in making the past of Taxila more tangible and interactive. Nearly all the respondents preserved the idea that new approaches are expected to be undertaken in the sphere of heritage education. This is in congruence with other studies that argue that IT can increase people's awareness and interest towards heritage and attract the younger generation towards visibility sites (Tapete & Cigna, 2021). However, this has not yet taken off in Pakistan due to the absence of any institutionalized relationship between the heritage sector and the IT specialists, as far as developing VR and AR-based experiences around historical sites are concerned.

In all, this study corroborates the increasing necessity of the inclusion of digitally mediated practices in Pakistan's conservation approaches to heritage. Despite imminent threats of slow degradation, Taxila's archaeological site has the potential to remain a point of pride to the country and region at large if proper financial support, technical know-how, and proper institutions are accorded to it. The following are the recommendations that can effectively help in achieving the aimed objectives of preserving the historical evidences of Taxila city:

Conclusion

The use of advanced technologies offers a great potential for better protection of the Taxila heritage but their application is still very limited due to shortage of funds, lack of technical expertise and inadequate legislation and policies. Although GIS mapping, 3D scanning, remote sensing, and immersing technology has great conservation applications, their penetration in Pakistani museums is limited and inconsistent. Results from field observations and document analysis reveal that majority of the preservation activities continue to receive traditional support without much Realtime interactions and aspirations to embracing new technologies. Meeting these challenges entails cooperation of government ministries, universities, IT specialists as well as heritage preservation bodies. Thus, the digital preservation and management of Taxila's heritage can be strengthened by creating a unified digital heritage database in Pakistan, funding capacity-building initiatives, using AI-based monitoring, innovatively engaging the public through VR/AR, and ensuring the policy-level integration of digital solutions. An early intervention digital preservation approach will not only serve the purpose of cultural preservation but will also help in enhancing the tourism in Pakistan due to better portrayal of its heritage assets to the world.

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