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Preservation of Cultural and Historical Heritage of Northern Kazakhstan Using Three-Dimensional Technologies

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Abstract

This study explores various criteria for assessing cultural and historical heritage, emphasizing the role of social practice in providing an objective evaluation of the historical, scientific, and artistic significance of heritage sites. The primary objective of this research is to enhance knowledge and ensure the preservation of the cultural and historical heritage of Northern Kazakhstan through the application of digital technologies. First, the study examines the criteria for including Kazakhstan's cultural and historical sites in the UNESCO World Heritage List, analyzing their relevance and proposing a weighted characteristic method to prioritize historical monuments in Northern Kazakhstan for digitization. Second, it introduces the use of three-dimensional (3D) technologies as a means of preserving cultural and historical heritage. This approach represents the first initiative in Kazakhstan aimed at developing a digital database of cultural and historical objects, aligning with the national program Digital Kazakhstan.The creation of a digital repository of historical and cultural sites will facilitate access to historiographical materials on Northern Kazakhstan, enhance the effectiveness of scientific research, and promote integration into the global academic community. Moreover, through web technologies, these digital models will be widely accessible to scholars, government institutions, and the general public. The findings of this study contribute to the development of digital models that can be utilized by various stakeholders, including governmental bodies responsible for heritage conservation. Additionally, the results can serve as educational resources in the teaching of historical disciplines at secondary and higher education institutions.

Keywords: *Cultural Heritage, Heritage Conservation, Historical and Cultural Monuments, Evaluation Criteria, Digital Preservation, Three-Dimensional Technologies.*

Introduction

Cultural and historical heritage serves as a vital testament to the historical legacy of the Kazakh people. Understanding and preserving this heritage is fundamental to shaping the nation's future. Without a profound knowledge of its past, a state lacks the foundation necessary for sustainable development. The protection of cultural and historical heritage from all potential threats is not merely a governmental responsibility but a moral obligation for all citizens of the Republic of Kazakhstan.

Globally, nations recognize the importance of preserving their cultural and historical heritage as an integral part of their identity. This awareness led to the adoption of the *Convention Concerning the Protection of the World Cultural and Natural Heritage* by UNESCO on November 16, 1972, in Paris. Initially ratified by only 21 countries in 1975, the convention has now been signed by 196 nations, reflecting a broad international commitment to safeguarding

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heritage sites. This convention defines *World Heritage* as possessing outstanding cultural or natural value, thereby constituting a shared legacy of all humankind (UNESCO, 2017).

Criteria for Inclusion in the World Heritage List

The criteria for the inclusion of cultural and historical sites in the UNESCO World Heritage List have been systematically developed, periodically reviewed, and adjusted by the World Heritage Committee. These revisions are necessitated by the discovery of new artifacts, historical and archaeological findings, and evolving interpretations of heritage. Continuous monitoring ensures that the concept of *World Heritage* remains dynamic and reflective of emerging cultural and scientific perspectives.

To be inscribed on the World Heritage List, a cultural or historical site must demonstrate outstanding universal value and meet at least one of the following ten criteria (Law, 2019):

1. Represent a masterpiece of human creative genius.

2. Exhibit an important interchange of human values over time or within a cultural area, particularly in architecture, technology, monumental arts, town planning, or landscape design.

3. Bear a unique or exceptional testimony to a cultural tradition or a civilization, whether living or extinct.

4. Be an outstanding example of a type of building, architectural or technological ensemble, or landscape that illustrates significant stages in human history.

5. Be an outstanding example of a traditional human settlement, land-use, or sea-use representative of a culture or interaction with the environment, particularly under the impact of irreversible change.

6. Be directly or tangibly associated with events, living traditions, ideas, beliefs, artistic, or literary works of outstanding universal significance (this criterion is typically used in conjunction with others).

7. Contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance.

8. Represent major stages of Earth's history, including records of life, geological processes, or significant landform developments.

9. Represent significant ecological and biological processes in the evolution and development of terrestrial, freshwater, coastal, and marine ecosystems.

10. Contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those housing threatened species of outstanding universal value. (Law of the Republic of Kazakhstan, 1992)

In addition to meeting these criteria, a nominated site must be protected under an internationally recognized management system and uphold the principles of authenticity and integrity. Since 1992, UNESCO has also recognized *cultural landscapes*—sites that exemplify significant interactions between human activity and the natural environment.

Kazakhstan's Commitment to Cultural Heritage Protection

Kazakhstan has actively engaged in global heritage preservation efforts. The country was a member of the UNESCO Executive Board from 1997 to 2001 and officially joined the *Convention on the Protection of the World Cultural and Natural Heritage* on April 29, 1994. Since its accession, Kazakhstan has successfully nominated five sites to the UNESCO World Heritage List, including three cultural and two natural sites (World Heritage in Kazakhstan, 2020). Additionally, Kazakhstan remains actively involved in international heritage programs, serving as a member of the Intergovernmental Council of the International Hydrological Program and the Intergovernmental Council of the International Communication Development Program for 2021–2025.

The following sites in Kazakhstan are currently inscribed on the UNESCO World Heritage List:

1. Mausoleum of Khoja Akhmet Yassawi (2003)
Located in Turkestan, South Kazakhstan, this mausoleum is a significant architectural monument representing the Timurid era.

2. Tamgaly Petroglyphs (2004)
Situated within the archaeological landscape of Tanbaly, these petroglyphs are among the most ancient and striking examples of rock art. Discovered in the late 1950s and studied extensively in the 1970s and 1980s, the site provides invaluable insights into the Bronze Age.

3. Saryarka – Steppe and Lakes of Northern Kazakhstan (2008)
This vast ecological region encompasses unique steppe landscapes and wetlands, playing a crucial role in biodiversity conservation.

4. Korgalzhyn Nature Reserve (included as part of Saryarka, 2008)
The Korgalzhyn Nature Reserve is a key natural conservation area, home to diverse flora and fauna, including migratory bird species of international significance.

5. Silk Road: The Chang'an-Tianshan Corridor Route Network (2014)
Spanning 5,000 km, this corridor is part of the extensive Silk Road network. It includes rich cultural and natural heritage, living traditions (many of which are recognized as UNESCO Intangible Heritage), and valuable historical artifacts that illustrate centuries of trade and cultural exchange.

Kazakhstan's continued efforts to preserve and digitize its historical and cultural heritage align with its broader commitment to the *Digital Kazakhstan* initiative. By integrating three-dimensional (3D) technologies, the country aims to enhance accessibility, promote historical research, and ensure the longevity of its invaluable cultural assets.

Research Methods

Currently, the legislation governing cultural heritage in Kazakhstan lacks clearly defined criteria for determining the historical and cultural significance of heritage objects. This absence hinders the prioritization of measures aimed at their preservation, utilization, and protection.

To establish criteria for selecting cultural and historical sites in Northern Kazakhstan for digitization, this study employed research methods based on an analysis of existing legislation and methodologies for assessing the value of cultural heritage objects. A weighted coefficient method was applied to develop a list of priority sites for digitization. The weighting factor is a numerical coefficient that represents the relative importance of each criterion in determining an

object's inclusion in the list. This coefficient serves as a comparative indicator of the various factors influencing the historical or cultural value of an object (Kurashov, 2016).

To create digital models of cultural and historical objects, the study utilized advanced technological methods, including photogrammetry, laser scanning, and three-dimensional (3D) printing using fused deposition modeling (FDM) technology.

Main Part

One of the primary challenges facing contemporary Kazakhstani society is the low level of public awareness and engagement with the country's cultural and historical heritage. This lack of knowledge translates into diminished interest in preserving and appreciating significant historical sites. The current state of museums and heritage institutions highlights the pressing need for modern technological interventions.

Beyond the digitization of historical documents and archival materials, contemporary digital tools now allow for the 3D preservation of sacred and cultural-historical sites in Northern Kazakhstan—many of which remain vulnerable to deterioration or destruction.

The Role of Digital Technologies in Heritage Preservation

Kazakhstan's *Digital Kazakhstan* program underscores the importance of integrating digital technologies across all sectors, including cultural heritage conservation. A well-structured approach to digital preservation can significantly contribute to fostering patriotism among younger generations by providing accessible, research-based information that objectively represents the country's historical milestones (Mukhamadeyeva, 2020).

Virtual Reconstruction and 3D Technology

The integration of technical and humanities-based knowledge plays a pivotal role in contemporary historical research. Virtual reconstruction has emerged as a particularly valuable tool when a cultural heritage object has been partially or completely lost due to natural disasters, conflicts, or gradual decay. In such cases, 3D reconstruction and augmented reality (AR) technologies offer innovative solutions for preserving historical data (Digital Technologies, 2018).

According to Article 4 of the *Law on the Protection and Use of Historical and Cultural Heritage Objects* of the Republic of Kazakhstan, historical and cultural monuments are categorized into three types:

1. Monuments of urban planning and architecture
2. Archaeological sites
3. Architectural ensembles

These monuments are subject to mandatory protection and preservation under national law. They have a special legal regime governing their use, changes in ownership, and classification as objects of international, national, or local significance (Mukhamadeyeva, 2023).

Legal Framework for Heritage Protection

The *Law on the Protection and Use of Historical and Cultural Heritage* outlines a set of measures aimed at ensuring the identification, conservation, and promotion of heritage sites. These measures include:

1. Research and documentation of historical and cultural heritage objects.
2. Official recognition and legal designation of sites as historical and cultural monuments.
3. Protection against destruction, vandalism, falsification, and distortion of historical contexts.
4. Preservation efforts, including archaeological excavations and scientific restoration projects.
5. Regular maintenance of monuments to prevent degradation.
6. Integration into educational and research programs to enhance public engagement with cultural heritage.

Reassessing Heritage Site Evaluation Criteria

This study hypothesizes that new evaluation criteria for cultural monuments are necessary to establish a comprehensive inventory of historical sites. The *World Heritage Committee* emphasizes the importance of authenticity in preservation, meaning that an object's historical and cultural value should be defined based on its integrity, significance, and physical condition (Akhmetkhan, 1995). Figure 1 illustrates the fundamental requirements for digitizing real-life heritage objects.

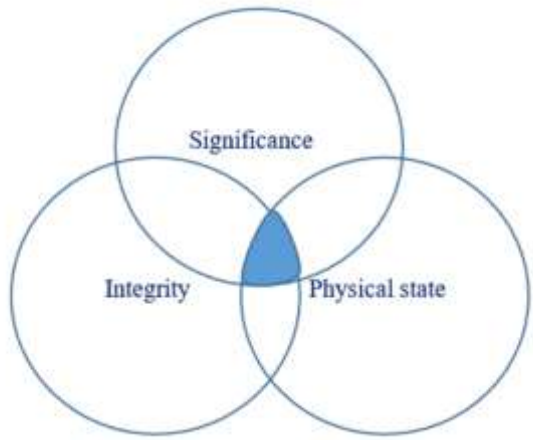

Figure 1. Fundamental Requirements for Digitizing a Stored Object in Real Life

Criteria for Assessing Cultural Heritage Objects

The assessment of cultural and historical objects must be conducted by experts based on a detailed comparative analysis of multiple knowledge domains. The research identifies four fundamental criteria for determining the value of a historical monument (Kurashov, 2016):

1. Historical Value
   - Date of construction and period of significance
   - Historical events associated with the object
   - Authenticity and historical integrity

2. Architectural Value
   - Distinctive stylistic features
   - Proportional and spatial composition within architectural ensembles
   - Unique artistic and decorative elements
   - Structural innovations and durability of materials
3. Artistic Value
   - Emotional impact and aesthetic appeal
   - Integration within the surrounding environment
   - Extraordinary decorative and interior elements
4. Scientific Value
   - Potential for public education and scholarly research
   - Suitability for museumization
   - Structural reliability and usability in academic contexts

Challenges in Heritage Classification and Protection

The research highlights that the assessment of heritage value is often subjective, influenced by political and ideological factors. Existing legal frameworks provide broad definitions of archaeological, scientific, aesthetic, and socio-cultural value, but they lack a standardized methodology for determining the official recognition, management, and preservation of cultural sites. Consequently, many sites are placed under state protection without clear evaluation criteria.

Application of 3D Technologies in Heritage Preservation

To ensure the long-term preservation and accessibility of Kazakhstan's historical and cultural heritage, it is imperative to integrate three-dimensional technologies into conservation efforts (Mukhamadeyeva, 2022a, 2023).

The first step in this process involves establishing a standardized framework for digitization. However, existing UNESCO criteria for World Heritage designation are not entirely suitable for prioritizing local cultural sites for digitization. For example, Figures 2 and 3 compare two mausoleums—while the Bespakyr Mausoleum is historically significant, its preservation through 3D modeling may not be feasible due to structural limitations.

Figure 2. Khazret Mausoleum

Figure 3. Bespakyr Mausoleum

Conclusion

This study underscores the necessity of developing a systematic approach to the selection, evaluation, and digital preservation of Kazakhstan's cultural and historical heritage. By integrating cutting-edge digital technologies, including photogrammetry, 3D scanning, and augmented reality, researchers and policymakers can significantly enhance heritage conservation efforts. Moreover, the use of these technologies will contribute to broader public engagement, allowing individuals worldwide to explore and appreciate Kazakhstan's rich cultural legacy.

Digitization of Cultural and Historical Sites in Northern Kazakhstan

The Bespakyr Mausoleum, along with numerous other cultural and historical sites, holds significant potential for digitization and restoration. The application of 3D technologies can aid in reconstructing and preserving these sites, restoring them to their pristine historical appearance while ensuring long-term conservation.

In 2023, as part of this study, two historical objects were successfully digitized. To systematically determine which sites should be prioritized for digitization, the method of weighted coefficients was implemented. This method was used in the initial phase to establish specific evaluation criteria for assessing historical sites for digital preservation.

To begin, five significant cultural and historical sites in Northern Kazakhstan were selected for evaluation, as presented in Table 1.

No.	Name	Type	Age	Classification	Image
1	Monument of Kos Batyr in the Archaeological and Ethnographic Complex Kumai	Archaeological site	VI century	Historical monument	
2	Building of the Museum of Fine Arts (former house of merchant Yuzefovich)	Urban planning and architecture	1909	Architectural heritage	
3	Kenesary Cave	Natural site	Undetermined	Natural heritage	
4	Mausoleum of Baubek Batyr	Urban planning and architecture	20th century	Architectural heritage	
5	Mausoleum of Bektemir	Urban planning and architecture	Early 18th century	Architectural heritage	

Table 1. Cultural and Historical Objects of Northern Kazakhstan

Note: Compiled by the author.

The selected sites represent diverse categories of cultural heritage, including historical, architectural, and natural sites. This classification ensures a comprehensive approach to heritage preservation, enabling the prioritization of sites based on historical significance, structural integrity, and feasibility of digital restoration.

The next phase of this research will involve applying 3D scanning and photogrammetry techniques to digitize these sites, creating accurate digital models for further analysis and potential virtual reconstruction.

Prioritization and Digitization of Cultural and Historical Objects in Northern Kazakhstan

To evaluate the selected heritage objects for digitization, the weighting method was applied. This approach assigns maximum scores to prioritize sites based on their historical and cultural significance (Anokhin et al., 1997). A five-point scoring system was chosen, with rankings distributed as follows:

- Kos Batyr Monument – 5
- Museum of Fine Arts Building – 4

- Kenesary Cave – 4
- Mausoleum of Baubek Batyr – 3
- Bektemir Sopa Mausoleum – 1

The assessment was conducted using the expert method, where a panel consisting of historians, archaeologists, and social researchers assigned scores based on a structured survey.

Evaluation Criteria and Weighting Factors

In addition to historical significance, two supplementary criteria were considered:

1. Integrity (preservation state and structural completeness).
2. Physical Condition (extent of deterioration and restoration feasibility).

The final score was determined using weighted coefficients, where:

- Historical significance was assigned a weight of 1.0.
- Integrity was assigned a weight of 0.3.
- Physical condition was assigned a weight of 0.5.

The results of the analysis are presented in Table 2.

Object	Significance Score	Integrity Score	Physical Condition Score	Final Assessment	Overall Score
Kos Batyr Monument (Kumai Complex)	5	3	1	0.5	6.4
Museum of Fine Arts (Yuzefovich House)	4	4	3	1.5	6.7
Kenesary Cave	4	3	4	2.0	6.9
Mausoleum of Baubek Batyr	3	5	5	2.5	7.0
Bektemir Sopa Mausoleum	1	1	2	1.0	2.3

Table 2. Prioritization of Cultural and Historical Objects for Digitization in Northern Kazakhstan

Note: Compiled by the author.

Selection of the Baubek Batyr Mausoleum for 3D Digitization

Based on the final assessment, the Mausoleum of Baubek Batyr received the highest overall score (7.0) and was selected as the first site for digital three-dimensional modeling.

Historical Context of Baubek Batyr

The Mausoleum of Baubek Batyr is located in Zhaksyn District, Ishimka Village. Baubek Batyr was a companion of the legendary Kazakh leader Kenesary Khan. At just 15 or 16 years old, he

participated in a major battle and defeated the Kyrgyz warrior Otynshy, earning him the title of *batyr* (hero).

His father, Bekmyrza, and mother, Shuga, were of noble descent. At 20 years old, Baubek Batyr married the daughter of an influential *bai* from the Altai family, which further strengthened his status among the people. However, he opposed administrative reforms and was subsequently accused of rebellion and theft, leading to his arrest and a seven-year sentence in 1872. Before leaving his homeland, Baubek Batyr cut off his finger and instructed that it be buried in his native land as a symbolic connection to his people (Akhmetkhan, 1995).

Although little is known about Baubek Batyr himself, Chokan Valikhanov, in his article *Notes on Judicial Reform*, mentioned that Baubek was condemned by the court of biys as a thief and a close associate of Kenesary. In 1993, his descendants built a 7-meter-high mausoleum in his honor, with an official opening on October 16, 1993.

Digitization Process of Cultural and Historical Objects

The digitization of cultural heritage sites follows a structured five-stage process, as outlined below:

1. Prioritization Phase
   - Objects are ranked according to selected evaluation criteria.
2. Scanning Phase
   - The site is scanned to create a point cloud using a portable 3D scanner from the EinScan Pro series.
3. Photogrammetry
   - A sequence of overlapping photographs is taken from multiple angles.
   - The software compares each image and reconstructs the object's geometry.
4. Object Rendering and Detail Enhancement
   - Small details such as cracks, damages, and missing fragments are visualized and restored.
   - This stage requires significant labor and computational resources.
5. Conversion into a Viewable Format
   - The final digital model is processed for public viewing and research applications (Mukhamadeeva et al., 2023).

As a result of this process, a fully detailed three-dimensional model of the Baubek Batyr Mausoleum was created using 3ds Max software. The digital model has been made publicly accessible on the Sketchfab platform at:

https://sketchfab.com/3d-models/0e50976b2678425ab9b5518fa7b97c22

Figure 4: Three-dimensional model of Baubek Batyr Mausoleum (photo taken from a computer monitor)

Post-Processing, Data Storage, and Accessibility of 3D Models

Once a 3D model of a cultural heritage object has been generated, a post-processing phase is essential to refine the digital replica and ensure high-quality preservation. This step involves:

- Noise reduction to remove extraneous data points.
- Correction of distortions caused by scanning inaccuracies.
- Elimination of unwanted elements that may interfere with the model's integrity.

The removal of imperfections is crucial for producing an accurate and high-resolution digital representation of the object. For this purpose, 3ds Max software was selected due to its advanced capabilities in model refinement and rendering.

Data Storage and Public Access

After digitization and processing, appropriate data storage and management strategies must be implemented to ensure the long-term preservation and accessibility of the digital models. Best practices include:

- Archiving models in secure digital repositories to prevent data loss or corruption.
- Implementing multiple backup solutions to safeguard against accidental deletion or system failures.
- Developing online archives and virtual museum exhibitions to enhance public access to historical artifacts.

By leveraging modern technology, cultural heritage institutions can ensure wider accessibility to historical objects through web-based platforms and digital repositories. The integration of virtual museum exhibitions allows for broader public engagement, enabling users worldwide to

explore, study, and interact with Kazakhstan's rich cultural heritage in an immersive digital environment.

Although the digitization of historical objects requires specialized expertise, recent advancements in 3D scanning, photogrammetry, and laser technologies have made the process more efficient and cost-effective. This technological progress ensures that heritage preservation remains sustainable and accessible to future generations, researchers, and the general public.

Results and Discussion

The Evolving Role of Cultural Heritage in the 21st Century

The globalization process, economic crises, and social transformations of the 21st century have significantly altered societal attitudes toward cultural heritage. Today, heritage is increasingly regarded as a national asset and a pillar of sustainable development, shaping the identity, economy, and social cohesion of nations (Aliyasova, 2017).

However, cultural heritage faces constant threats from:

- Natural disasters (earthquakes, floods, wildfires).
- Climate change (rising temperatures, erosion, extreme weather events).
- Man-made threats (urbanization, neglect, vandalism, armed conflicts).

Protecting this heritage is vital, as it plays an essential role in preserving artifacts, traditions, and, in some cases, entire cultures for future generations.

Impact of Digital Photogrammetry and Laser Technologies on Heritage Conservation

The emergence of digital photogrammetry and laser scanning technologies has revolutionized the documentation and preservation of archaeological and historical sites. These advanced methods allow for high-precision data collection without requiring physical presence at excavation sites. As a result:

- Archaeological surveys can now be conducted in controlled environments, reducing exposure to harsh weather conditions.
- Data processing and analysis can be performed remotely, ensuring greater efficiency and accuracy.
- 3D models provide an alternative to physical site visits, facilitating education, research, and public engagement.

Despite these advantages, the adoption of 3D digitization in archaeology presents two key challenges:

1. Accessibility of specialized equipment – Advanced 3D scanning and photogrammetry tools may not be widely available or affordable for all institutions.
2. Reliability of digital models – While 3D technologies capture detailed representations, some archaeologists question their ability to fully replace on-site analysis and human interpretation.

Interdisciplinary Research and Project Implementation

To address these challenges, the IRN AR19676333 Project, titled "Three-Dimensional Technologies in the Process of Preserving the Cultural and Historical Heritage of Northern Kazakhstan," was launched. Funded by the Science Committee of the Ministry of Science and Higher Education of Kazakhstan, the project integrates:

- Historians – Providing expertise on cultural significance and heritage documentation.
- Information technology specialists – Handling data processing, model refinement, and digital storage.
- 3D modeling and additive manufacturing experts – Implementing advanced scanning and printing techniques.

Each team member has at least 15 years of experience, ensuring high-level interdisciplinary collaboration. The project's primary objectives include:

- Digitizing eight large cultural and historical objects over a three-year period (2023–2026).
- Establishing a comprehensive digital archive of Kazakhstan's cultural heritage.
- Enhancing public engagement by integrating interactive 3D heritage models into educational and museum settings.

Although digital heritage preservation is not a new concept, its application in Northern Kazakhstan is pioneering. Over the past five years, the research team has accumulated extensive data, presented findings at international conferences, and published multiple articles in peer-reviewed journals.

Advancements in 3D Archaeological Research

Over the past 15 years, technological advancements have improved archaeological documentation and cultural heritage conservation. Tools such as photogrammetry, laser scanning, and drones have:
✓ Enabled the creation of high-resolution 3D models of historical sites and artifacts.
✓ Improved accessibility and user-friendliness of digital models for both experts and the public (Dorina Mullu, 2024).

Despite these benefits, digital archaeology faces certain limitations:

1. Data Overload – The large volume of digital data collected during archaeological surveys can sometimes obscure critical insights by overwhelming researchers with irrelevant details.

2. Reduced Field-Based Observations – The transition from on-site excavation to office-based data analysis raises concerns about the loss of direct archaeological interpretation (Remondino, 2019).

Implementation of 3D Models in Museums and Educational Institutions

As part of the IRN AR19676333 Project, 30 digitized cultural objects will be transferred to the National Museum of Kazakhstan. This initiative aims to:
✓ Expand the use of 3D models in history education and public exhibitions.

✓ Enhance the preservation of cultural artifacts through digital means.
✓ Ensure greater accessibility to Kazakhstan's heritage via online platforms.

The first 3D model, developed using photogrammetry and laser scanning, was 3D-printed and formally handed over to:
◇ KSU "Center for the Protection and Use of Historical and Cultural Heritage" (Akmola Region Department of Culture).

A certificate of implementation (Appendix B) was issued, authorizing the use of the digital model for:

- Museum exhibitions showcasing Kazakhstan's historical legacy.
- History lessons in educational institutions.
- Public demonstrations of 3D-printed heritage objects.

The printed 3D model of the Kos Batyr Monument (Fig. 5) remains stored at the Center for the Protection and Use of Historical and Cultural Heritage, while its digital version is available for online exploration (Fig. 6).

Digital Public Access to Heritage Models

Although physical 3D-printed models remain in museum collections, their digital versions are accessible online. For example, the Kos Batyr Monument can be explored via:

Sketchfab

This web-based accessibility allows researchers, students, and history enthusiasts worldwide to interact with Kazakhstan's cultural heritage in an immersive digital format.

Conclusion

The digitization of Kazakhstan's cultural heritage through 3D technologies is an innovative step toward sustainable preservation. The Baubek Batyr Mausoleum and Kos Batyr Monument exemplify how advanced digital techniques can contribute to heritage conservation, education, and public engagement.

Moving forward, future research should:

Expand virtual and augmented reality applications in heritage studies.

Address ethical and methodological challenges in digital archaeology.
Develop standardized protocols for long-term digital heritage management.

By leveraging technology and interdisciplinary expertise, this project ensures that Kazakhstan's historical legacy remains accessible, preserved, and celebrated for generations to come.

Figure 5 – Digital model printed on a 3D printer at a scale of 1:30

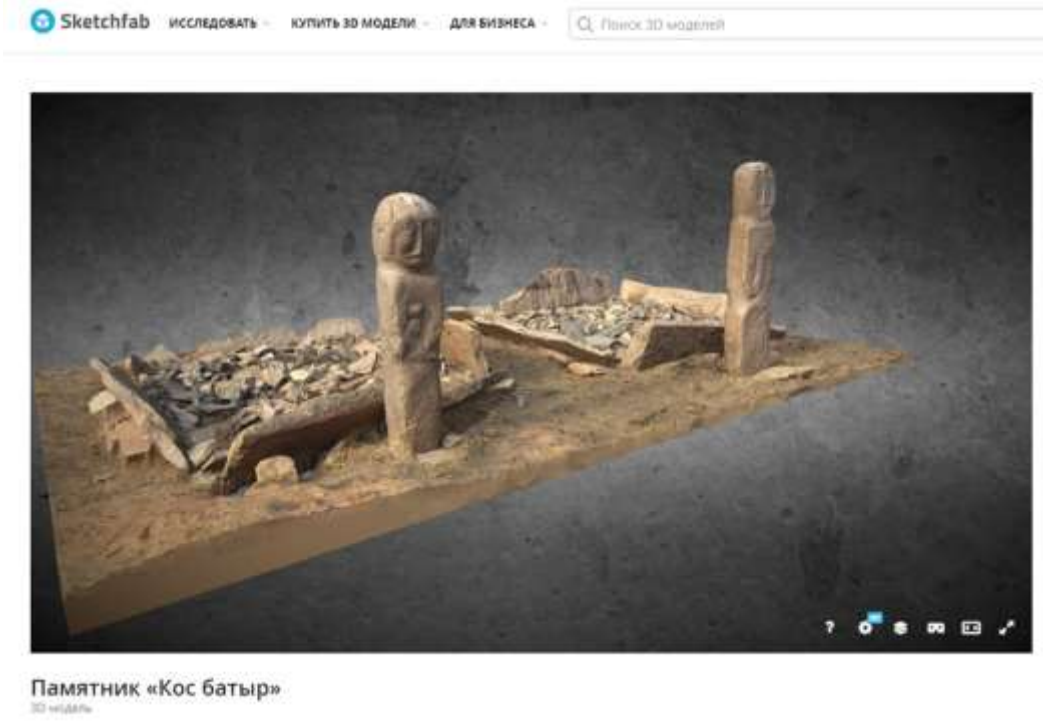

Figure 6 – Digital model of the historical and cultural heritage monument "Kos Batyr"

The Role of Sketchfab and Digital Heritage Challenges

Sketchfab as a Platform for 3D Cultural Heritage Visualization

Sketchfab is a web-based service that allows users to share and visualize 3D models in an interactive format. The platform provides comprehensive metadata for each digital artifact, including:

Traditional object details (name, artist, date, material, dimensions, restorations, and bibliography).
Technical metadata (author of the 3D model, methods used for digital reconstruction).

Geolocation-based annotations, enabling users to explore narratives and historical contexts embedded within the model.

With high-resolution 3D geometry and textures, users can navigate around models, zoom in on intricate details, and engage with both formal and narrative elements in ways that are not possible in conventional museum settings. This interactivity is particularly beneficial for conservators, researchers, and educators, simplifying and accelerating the analysis of artifacts and materials (Stylianidis, 2022).

Furthermore, accessing these interactive 3D models requires only a simple device (computer, tablet, or smartphone) with an active internet connection.

Challenges in the Digital Transformation of Cultural Heritage in Kazakhstan

While digital technologies offer unprecedented opportunities for heritage preservation, their implementation in Kazakhstan's museums and cultural institutions presents several challenges.

1. Internet Accessibility and Digital Literacy Gaps

A major barrier to digital heritage access is the unequal distribution of internet connectivity across the country. Remote areas, small towns, and villages often lack sufficient technical infrastructure, financial resources, and human expertise to fully integrate digital platforms and applications into heritage preservation efforts.

The digital divide is a well-documented issue, but its impact was especially pronounced during the COVID-19 pandemic, which forced the rapid digitization of all aspects of public life. This divide is evident in Kazakhstan's regional disparities in internet access. While urban populations can freely engage with digital heritage exhibits, certain demographics—including rural communities, elderly citizens, and people with limited access to technology—are effectively excluded from these virtual resources.

- As of 2023, Kazakhstan ranks 54th globally in digital development, positioned between Argentina (53rd) and Romania (55th) ([NCSI, 2023](https://kapital.kz/gosudarstvo/118940/kazakhstan-zanimayet-54-place- v-mire-po-urovnyu-tsifrovogo-razvitiya-ncsi.html)).
- In 2024, the coverage of high-speed internet in secondary education institutions is projected to increase from 65% to 80% (Zakon.kz, 2024).
- Mobile internet speeds rank Kazakhstan 67th globally (average 35.49 Mbps), while fixed broadband internet ranks 94th (average 51.41 Mbps).

These statistics highlight significant connectivity challenges, particularly for rural and underserved populations. The paradox is evident: digital heritage initiatives are crucial for increasing access to cultural artifacts, especially for remote communities, yet these very communities often lack the resources to benefit from digital technologies.

2. Legal and Technical Issues in Digital Heritage Protection

The digitization of cultural and historical objects raises complex legal, intellectual property, and classification challenges.

A significant milestone in Kazakhstan's digital heritage efforts was the issuance of Author's Certificate No. 40789 (dated November 28, 2023) for the Kos Batyr Monument, part of the Turkic Archaeological and Ethnographic Complex "Kumai" in the Buiratau State National Park. However, filing the copyright application revealed major technical and bureaucratic hurdles:

- The Institute of Intellectual Property struggled to determine the appropriate file format classification for 3D-printed heritage artifacts.
- The most logical submission format was STL (Stereolithography), a standard format for 3D printing. However, STL files require specialized software (e.g., Blender, Geomagic Explorer, KOMPAS-3D) for viewing.
- As a result, instead of recognizing 3D models as independent digital heritage artifacts, the certificate classified the file under "Works obtained by methods similar to photography."

3. Lack of Integration in Educational Institutions

Despite efforts to introduce 3D digital heritage models into Kazakhstan's education system, real-world implementation remains limited.

- Over a six-month period, not a single educational institution in the Akmola region successfully opened the Kos Batyr 3D model file.
- Meanwhile, approximately $3,000 was spent on digitizing the site, covering:
  - Transportation rental for field research.
  - Rental of a FARO Focus S150 Premium 3D scanner (Fig. 7).
  - Hiring a specialist for technical execution.

Photographic and Scanning Equipment Used in the Study

To ensure high-quality 3D reconstruction, professional-grade equipment was used:

- 3D Scanning – FARO Focus S150 Premium 3D Scanner (Fig. 7).
- Photogrammetry – Sony α7R IV Camera, featuring:
  - Full-frame 35mm sensor.
  - 61MP resolution for capturing detailed surface textures.
  - FE 35mm f/1.8 prime lens for optimal focal clarity (Fig. 7).

Conclusion and Future Directions

The integration of digital technologies into Kazakhstan's cultural heritage sector presents both opportunities and challenges.

✓ Opportunities:

- Sketchfab and similar platforms enhance global accessibility to Kazakhstan's cultural heritage.

- 3D models provide detailed, immersive experiences that surpass traditional museum displays.
- Digital archives ensure long-term preservation of endangered historical artifacts.

❌ Challenges:

- Internet accessibility and digital literacy gaps hinder widespread adoption of digital heritage resources.
- Legal ambiguities in copyright registration complicate the recognition and protection of 3D models as heritage assets.
- Limited practical use of 3D models in educational institutions, despite significant financial investments.

Recommendations for Addressing These Challenges:

1. Enhancing Digital Infrastructure:
   - Expansion of high-speed internet access to rural and underserved regions.
   - Subsidized digital literacy programs for educators, researchers, and the public.
2. Legal and Institutional Reforms:
   - Standardizing 3D file formats for cultural heritage protection.
   - Establishing national policies on digital intellectual property rights for heritage artifacts.
3. Strengthening Educational Integration:
   - Developing user-friendly software solutions for educational institutions.
   - Implementing government-funded projects that facilitate the adoption of 3D models in history curricula.

By addressing these challenges, Kazakhstan can ensure a more inclusive and sustainable approach to digital heritage preservation, allowing its rich cultural history to be accessible to both present and future generations.


FARO

Figure 7 - Laser scanning in the Project was performed with a scanner FARO Focus S150 Premium, Photographing was performed with a Sony α7R IV camera

Photography and Digitization Process

For the 3D digitization process, the historical object was photographed from multiple angles to capture its full structure and details. A total of 218 high-resolution photographs were taken using aperture priority mode (f/22) to ensure maximum sharpness and depth of field, allowing both the subject and the background to remain in focus.

- Due to the closed aperture, the shutter speed was significantly increased, necessitating the use of a tripod for stability.
- The white balance was manually set (e.g., sunny, cloudy) rather than relying on automatic adjustments to maintain color accuracy.

The digital preservation of historical objects enables their long-term use in research, education, virtual tours, and digital exhibitions. To ensure their accessibility and security, it is critical to implement robust data storage solutions, including:

- Dedicated databases for digital archives.
- Cloud-based storage to enhance availability and prevent data loss.

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Conclusion

Kazakhstan is home to over 25,000 monuments of historical, archaeological, architectural, and monumental significance. The preservation and restoration of these cultural treasures is essential for maintaining national identity and ensuring that future generations can access and appreciate their historical heritage.

The application of modern scientific and technological advancements is fundamental to this endeavor. By integrating digital technologies and online platforms, Kazakhstan can: Make cultural heritage more accessible to a global audience.

Enhance public engagement through interactive digital content.

Ensure the long-term sustainability of historical artifacts through advanced documentation methods.

Integration of Technology in Heritage Preservation

To digitize large-scale historical sites such as the Botai Settlement or Abylai Khan Glade, the use of drones and quadcopters is essential. These aerial imaging tools have become indispensable for archaeological research, offering: Aerial perspectives that reveal structural details not visible at ground level. Improved mapping and documentation of large heritage sites. Greater efficiency and precision in archaeological fieldwork.

The ability to view and analyze large archaeological sites from above has provided new insights into historical structures such as the fortresses of Northern Kazakhstan.

Cultural Heritage as a Pillar of National Revival

The preservation of cultural heritage is more than an academic endeavor—it is a key element in national identity and historical continuity. As former President Nursultan Nazarbayev emphasized:

"National revival can take place only when it rests on the life-giving soil of centuries-old culture, nourished by the noble juices of the historical past… The restoration of historical and cultural heritage is also the recreation of such a connection of times, which has a clear projection into the future. By asking questions about the real content of our past, we enrich our understanding of the present and can construct inspiring images of our future."

This perspective underscores the importance of integrating digital heritage preservation into broader national development strategies.

Future Directions

Although Kazakhstan has numerous well-documented sacred sites along the Great Silk Road, ongoing archaeological research continues to uncover new insights. However, limited information is available regarding studies conducted in previous centuries (Zherebyatyev, 2019).

By introducing three-dimensional technologies in cultural and historical heritage preservation, Kazakhstan can:
Revolutionize historical research by offering detailed, high-resolution digital models. Boost cultural tourism by making virtual heritage experiences available worldwide. Ensure historical continuity, making Kazakhstan's rich cultural heritage more accessible to researchers, educators, and the public.

The successful implementation of digital preservation methods will provide a new impetus for historical studies and tourism development in Northern Kazakhstan, helping to bridge the past, present, and future through technological innovation.

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