

# INTEGRATING METAVERSE FOR THE RESTORATION OF NIAS CULTURE: AN APPROACH TO HERITAGE PRESERVATION AND REGIONAL REVENUE OPTIMIZATION

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## ABSTRACT

Globalization, modernization, and the limited digital documentation of indigenous heritage have created an urgent need for information technology-based approaches that can preserve, represent, and create sustainable value from local culture. Existing metaverse-based heritage studies have mainly emphasized virtual exhibitions or museum extensions, while fewer studies have integrated architectural reconstruction, community validation, digital ownership, and tourism-oriented value creation in one framework for a living indigenous culture. This study addresses this gap by developing a participatory metaverse framework for the restoration of Nias cultural heritage. The research design combines human-centered design, ethnographic documentation, architectural visualization, and applied computing. Data were collected through field observations, interviews with local stakeholders, literature review, and documentation of Nias traditional houses and village layouts. The development process included basic 3D modeling, architectural detailing, material texturing, environmental reconstruction, final rendering, and conceptual integration with blockchain-based authenticity and asset ownership mechanisms. The results show that Nias traditional houses and village compositions can be digitally reconstructed as immersive and culturally meaningful environments. Compared with prior museum-centered metaverse studies, the proposed framework contributes an IT-based heritage restoration model that integrates 3D visualization, participatory validation, blockchain-enabled authenticity, and digital tourism potential. The practical implication is that local governments, cultural institutions, and creative industries can use the framework to support heritage education, virtual tourism, digital asset governance, and regional revenue diversification. Limitations include the absence of large-scale user testing, limited empirical measurement of economic impact, and the need for long-term infrastructure validation. Future work should evaluate user experience, community acceptance, and implementation readiness in real metaverse platforms.

**Keywords:** *Metaverse, Cultural Heritage, Nias, Digital Preservation, Virtual Tourism, Commas*

## 1. INTRODUCTION

Globalization and digital transformation have created both challenges and opportunities for the preservation of minority ethnic cultural heritage. The Nias Archipelago, located off the western coast of Sumatra, Indonesia, represents an important case because its cultural identity is strongly reflected in customary practices, megalithic traditions, traditional settlement patterns, and distinctive architecture [1], [2]. However, modernization, limited digital documentation, and the declining

transmission of local knowledge have increased the risk of cultural erosion [3], [4]. This condition highlights the need for information technology-based approaches that can document, reconstruct, and transform Nias cultural heritage into an interactive digital environment for preservation, education, and virtual tourism.

Previous studies have shown that metaverse, virtual reality, augmented reality, and digital heritage technologies can improve cultural accessibility and immersive learning [5], [6]. Nevertheless, many existing implementations

remain concentrated on virtual museum exhibitions, object display, or institutional collection access. Although these approaches are valuable, they often provide limited attention to living cultural spaces, community participation, local cultural validation, and long-term value creation for indigenous communities. Therefore, this study positions the metaverse as an information technology platform that integrates 3D reconstruction, participatory cultural validation, immersive visualization, and digital tourism development.

This study aims to develop and discuss a participatory metaverse-based framework for the restoration and digital preservation of Nias cultural heritage. Specifically, the study focuses on reconstructing Nias traditional houses and village layouts through 3D modeling and rendering, integrating human-centered and participatory processes to support cultural authenticity, and identifying the practical implications of the framework for heritage education, creative industries, virtual tourism, and regional revenue optimization. Blockchain-based ownership validation and digital asset tokenization are not treated as core implemented components in this study, but are positioned as possible future extensions to support authenticity tracking and community-based benefit-sharing mechanisms.

The main contribution of this research lies in its IT-based integration of cultural heritage restoration and digital value creation. Unlike studies that only digitize cultural objects or extend museum access, this work proposes a framework that connects architectural visualization, immersive metaverse interaction, community participation, and virtual tourism-oriented cultural promotion. This contribution is expected to help local governments, cultural institutions, and creative economy actors design more sustainable digital heritage initiatives.

Several international projects demonstrate the potential of immersive technologies for heritage and cultural memory. Digital reconstruction initiatives in Japan have been used to represent historical events and support intergenerational learning, while museum-based metaverse applications in France have expanded public access to cultural collections [9], [10]. However, the Nias case differs because it focuses on a living indigenous culture and emphasizes the reconstruction of traditional settlements as socio-cultural spaces rather than as isolated artifacts.

In addition to preservation, the proposed framework also addresses educational, tourism, and

governance dimensions. The reconstructed digital environment can support heritage learning, cultural promotion, and virtual tourism experiences by allowing users to explore Nias traditional architecture and settlement layouts in an immersive manner. In future development, blockchain-based validation may be explored to support digital ownership, authenticity tracking, and transparent benefit-sharing models for local communities [12], [16]. This direction is particularly relevant for indigenous communities because digital innovation must protect cultural meaning while creating opportunities for community participation in creative industries.

Accordingly, this paper is organized as follows. The literature review discusses metaverse-based cultural heritage preservation and identifies the research gap. The methodology section presents the research design, data collection, development stages, and validation approach. The result and discussion section reports the 3D reconstruction outcomes, comparative analysis, limitations, unintended outcomes, and practical implications. The conclusion summarizes the contribution and future research directions.

## 2. LITERATURE REVIEW

Metaverse-based cultural heritage research has expanded rapidly as immersive technologies have become more accessible for education, tourism, and digital preservation. Recent studies indicate that VR, AR, XR, and 3D reconstruction can support heritage preservation by enabling users to access cultural spaces that are geographically distant, physically fragile, or difficult to experience directly [13]. In cultural heritage informatics, these technologies are valuable because they transform heritage documentation from static archives into interactive environments that can support interpretation, learning, and engagement.

However, the literature also reveals several limitations. A large proportion of metaverse-related heritage projects focus on virtual exhibitions, digital museums, or visual representation of individual objects [18], [19]. These works demonstrate the value of immersive access, but they do not always address how local communities participate in validating the cultural meaning of digital assets. In the context of indigenous heritage, this limitation is important because architectural forms, settlement layouts, and ritual spaces are closely connected to social hierarchy, collective memory, and local knowledge.

This study therefore differs from previous studies in three significant ways. First, it reconstructs Nias heritage at the settlement scale by combining traditional houses, village composition, and environmental context, rather than focusing only on isolated artifacts. Second, it integrates participatory validation to reduce the risk of culturally detached digital representation. Third, it extends metaverse development toward digital asset governance and regional economic value through blockchain-enabled authenticity and tourism-oriented use. These differences clarify the research contribution and justify the need for a specific framework for Nias cultural heritage restoration.

### 3. Methodology

This study used a design-oriented qualitative research approach supported by applied computing development. The research design was structured to answer the main problem of how Nias cultural heritage can be restored and represented through an interactive metaverse framework. The study combined cultural data collection, 3D architectural reconstruction, participatory validation, and conceptual technology integration. The unit of analysis was the digital reconstruction of Nias traditional houses and their village environment as a foundation for a future metaverse-based heritage platform.

- Human-Centered Data Collection - This stage involved field observations, interviews with local stakeholders, ethnographic documentation, and literature review. The purpose was to identify cultural elements, architectural characteristics, spatial arrangements, and community expectations that should be represented in the digital environment.
- Architectural Visualization - This stage reconstructed traditional houses, village layouts, and supporting environmental elements using 3D modeling techniques. The models were developed by considering proportions, roof structure, wooden pillars, settlement orientation, and the presence of Omo Sebu as a socio-cultural focal point.
- Applied Computing and Metaverse Integration - This stage focused on preparing interactive digital assets for future VR/AR and metaverse implementation. Blockchain integration was conceptualized as a mechanism for validating digital authenticity, cultural ownership, and potential cultural asset monetization.

- Participatory Validation and Digital Ecosystem Design - The reconstructed assets and framework were reviewed conceptually through cultural and community-oriented considerations. This stage also formulated how local communities, researchers, tourists, cultural institutions, and policymakers could participate in a sustainable digital heritage ecosystem.

The overall workflow of the methodology is illustrated in Figure 1.

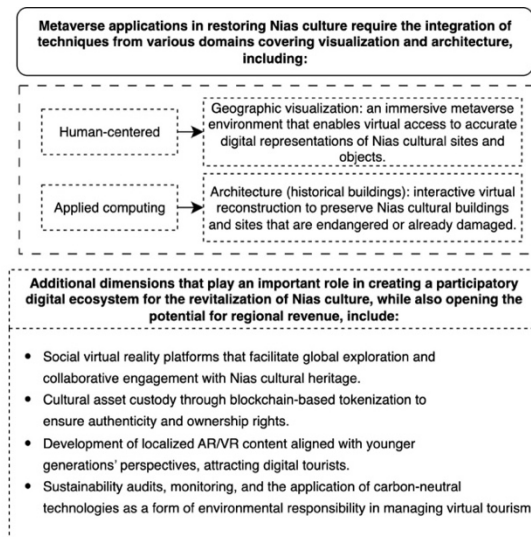


Figure 1: Workflow of The Methodological Framework for Developing a Metaverse Application to Restore Nias Culture

Based on Figure 1, the research began with cultural data collection through a human-centered approach. The collected data were translated into architectural visualization, including the reconstruction of traditional houses and village spatial composition. These outputs were then connected to applied computing components to support interactive engagement, authenticity validation, and digital asset governance. The final stage produced a participatory digital ecosystem concept in which local communities, researchers, tourists, and policymakers can collaborate to preserve, interpret, and promote Nias culture within a sustainable virtual environment

### 4. RESULT AND DISCUSSION

This section presents the outcomes of the modeling, reconstruction, and visualization of Nias traditional houses and village settings. The results are discussed in relation to the study objectives: reconstructing Nias cultural spaces, supporting cultural authenticity through participatory logic,

and identifying the potential integration of the outputs into a metaverse-based digital heritage ecosystem. The section also compares the contribution with previous studies, explains limitations and unintended outcomes, and presents practical implications before the conclusion.

The research process was carried out in several structured phases, beginning with the creation of the basic building model, followed by the addition of architectural details, initial rendering tests, and the arrangement of the surrounding environment to replicate the authentic setting of Nias traditional villages. The developed model was later integrated into a traditional spatial layout that reflects the socio-cultural hierarchy of the Nias community, ensuring that the digital environment is not only visually accurate but also socially meaningful.

The final 3D visualization demonstrates that Nias traditional houses and their broader

environment can be represented in both realistic and contextual forms. This achievement supports the research objective of producing a digital foundation for cultural preservation, immersive education, and metaverse-based tourism. However, the results should be interpreted as a development and conceptual validation stage rather than a fully deployed commercial metaverse platform.

#### 4.1. Basic Modeling of Nias Traditional Houses

In the first stage, the basic form of the Nias traditional house was modeled using Blender software, as shown in Figure 2. This modeling focused on the primary structures of the building, such as the foundation pillars, wall framework, and roof shape. This step was crucial to ensure accurate proportions and geometry before adding detailed textures.

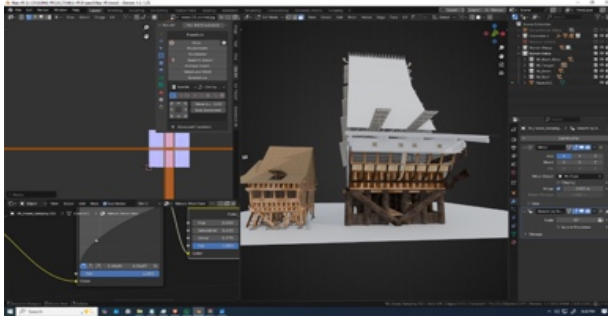
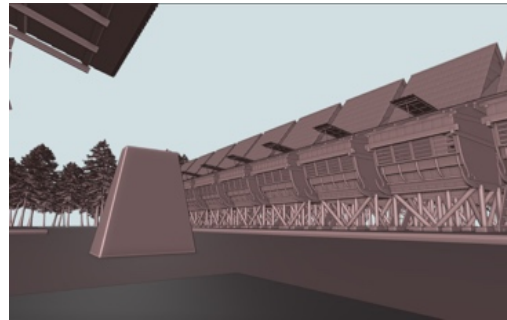


Figure 2: Basic Modeling of Nias Traditional House



As illustrated in Figure 2, the first stage involved modeling the basic form of the Nias traditional house using Blender software. The modeling emphasized the main structural components, including the foundation pillars, wall framework, and roof shape, in order to establish accurate proportions and geometry before the addition of detailed textures.

#### 4.2. Addition of Architectural Details and Wooden Textures

Following the basic modeling, architectural details were added, including wooden wall panels, supporting structures, and roofing elements, as shown in Figure 3. UV mapping techniques were applied to provide wooden textures and natural materials to the house surfaces. This stage aimed to enhance realism, so the building would not merely appear as plain shapes.



Figure 3: Addition of Details and Wooden Textures



As illustrated in Figure 3, the addition of architectural details, including wooden wall panels,

supporting structures, and roofing elements, significantly improved the realism of the model.

The application of UV mapping also enabled the use of wooden textures and natural material appearances, which enhanced the visual depth and emphasized the distinctive characteristics of Nias traditional architecture.

#### 4.3. Initial Rendering of Nias Traditional house

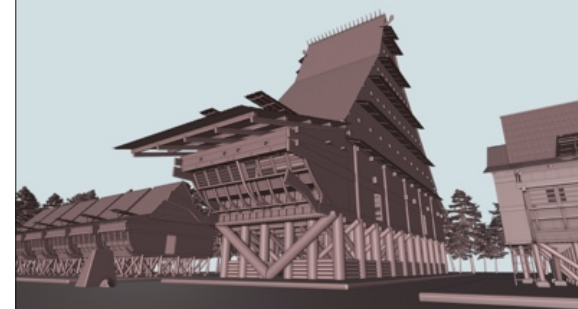


Figure 4: Initial Rendering of Nias Traditional House

As illustrated in Figure 4, the rendering test was conducted to evaluate lighting, shadows, and textures under more realistic visual conditions. Artificial sunlight simulation was applied to recreate the daytime atmosphere of a traditional Nias village. The results show that the wooden textures successfully conveyed the appearance of natural materials, while the enhanced lighting made the roof and wall structures more visually prominent.

#### 4.4. Environmental and Contextual Setting

To contextualize the traditional house, environmental elements such as trees, stone pathways, and soil textures were added. This step aimed to recreate the authentic atmosphere of a Nias traditional village. The surrounding environment plays a vital role in providing an immersive experience for metaverse users.



Figure 5: Environmental Setting of Nias Traditional Village

The added elements, including stone yards, soil textures, and tree rows, enhanced realism and demonstrated that the modeling process went beyond the building itself, encompassing the broader cultural ecosystem.

#### 4.5. Composition of Nias Traditional Village

Nias traditional houses do not stand alone but form a distinctive village layout. Hence, the buildings were arranged in a traditional spatial composition, with rows of houses facing each other and the Omo Sebua (chief's or noble's house) as the central focal point. This composition reflects the socio-cultural structure of Nias society.

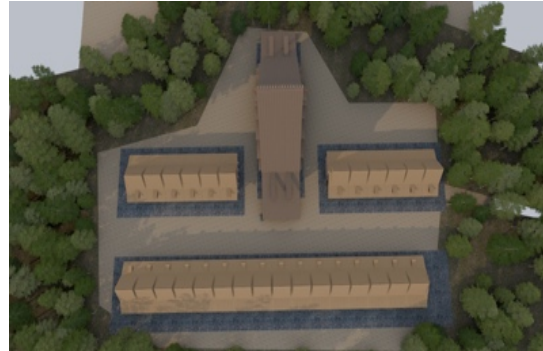
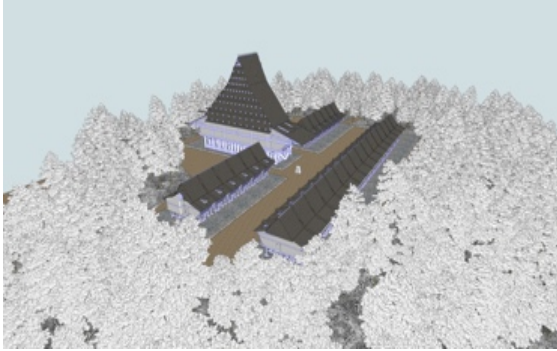


Figure 6: Spatial Layout of Nias Traditional Village

The layout illustrates cultural hierarchy, where the grand Omo Sebua stands prominently surrounded by villagers' houses. This arrangement represents not only architecture but also the traditional social structure.

#### 4.6. Final Rendering of Nias Traditional Village

The final stage combined all elements—buildings, environment, and lighting—into a high-resolution rendering output. The goal was to ensure that details such as wooden textures, roofing, stone elements, and trees appeared as realistic as possible.



Figure 7: Final Rendering of Nias Traditional Village

As illustrated in Figure 7, the final stage integrated all components, including buildings, environmental elements, and lighting, into a high-resolution rendering output. The resulting visualization presents an authentic virtual representation of the Nias traditional village, in which the Omo Sebua stands prominently as the central structure, surrounded by the orderly arrangement of villagers' houses. This final reconstruction demonstrates strong potential for educational use, cultural preservation, and metaverse based digital tourism.

#### 4.7. General Discussion

The modeling process of Nias traditional houses in this study was conducted using 3D modeling technology in Blender software. This technology enables precise digital reconstruction, allowing accurate representation of the form, structure, and architectural details of Nias traditional houses. The workflow encompassed creating basic models, adding architectural details, applying materials and textures, configuring lighting, and

simulating the surrounding environment. Broadly speaking, the results not only represent the physical aspects of Nias traditional houses but also convey the philosophical values embedded within them. Characteristic elements, such as wooden pillar foundations supported by stones, natural wooden wall textures, and large roofs made of thatch or palm fibers, were digitally reconstructed with high accuracy to enhance understanding of Nias traditional architecture.

Moreover, the visualization was designed at the settlement scale, showcasing the village layout where the Omo Sebua stands prominently as the chief's residence, surrounded by villagers' houses (Omo Hada). This spatial arrangement illustrates the social hierarchy inherent in Nias society.

In addition, the results demonstrate how 3D technology supports cultural conservation. Traditional houses, which are vulnerable to physical deterioration, can now be digitally documented to ensure that future generations can study, research, and appreciate this heritage. Beyond academic purposes, the visualization also holds great potential

for interactive educational media and metaverse-based tourism development.

#### 4.8. Comparative Analysis with Previous Studies and Research Contribution

The outcomes of this research are consistent with earlier digital heritage studies, but they also extend the literature in several ways. Studies in Japan have demonstrated how immersive reconstruction can support historical memory and intergenerational learning, while museum-based initiatives in France show how virtual access can expand cultural participation and create new institutional tourism models [9], [10]. These studies confirm the relevance of metaverse technology for cultural education and heritage accessibility.

Compared with those cases, the Nias framework provides a different contribution because it integrates architectural reconstruction, socio-cultural settlement logic, participatory validation, and blockchain-oriented asset governance. Instead of presenting heritage only as a virtual exhibition, this study treats Nias heritage as a living cultural ecosystem that includes spatial hierarchy, community ownership, and economic participation. This difference is significant because it links cultural preservation with information technology research contributions in digital modeling, metaverse system design, and digital asset management.

The comparison also reveals several unintended or potentially negative outcomes. The transformation of heritage into digital assets may create risks of cultural commodification, oversimplification of sacred meanings, or unequal benefit distribution if community governance is weak. These risks were not observed as empirical impacts because the platform has not yet been commercially deployed, but they must be considered in future implementation. Therefore, the framework requires ethical guidelines, community consent, and transparent revenue-sharing mechanisms before large-scale adoption.

Overall, the achievement of this study lies in demonstrating that metaverse development for indigenous heritage can move beyond visual preservation toward an integrated digital ecosystem. The proposed model is scalable for other minority cultures, but its success will depend on cultural validation, technical infrastructure, policy support, and continuous community involvement.

The differences from prior literature can be summarized in four areas. First, the unit of digitalization is broader: previous works often digitize museum objects or institutional collections,

whereas this study reconstructs Nias houses, spatial composition, and environmental context. Second, the governance logic is stronger: previous studies commonly emphasize user access, whereas this study introduces community participation and blockchain-based authenticity as part of the framework. Third, the expected impact is more integrated: the proposed model connects preservation, education, virtual tourism, and regional revenue rather than focusing only on exhibition. Fourth, the study explicitly recognizes implementation risks, including cultural commodification, infrastructure dependency, and unequal benefit distribution, which must be managed through ethical and participatory governance.

#### 4.9. Discussion of Findings, Limitations, and Practical Implications

The findings demonstrate that metaverse-based cultural restoration can function as more than a digital documentation strategy. In the Nias context, the metaverse provides a medium for reconstructing architectural objects and the socio-cultural environment in which those objects are embedded. The reconstruction of traditional houses, village composition, and environmental context shows that heritage can be represented in a way that preserves both physical authenticity and symbolic meaning. This directly addresses the research objective of developing a digital restoration framework for Nias cultural heritage.

From a technological perspective, the staged development process proved effective in translating ethnographic and architectural data into immersive digital assets. The progression from basic modeling to detailed texturing, environmental setting, and final rendering illustrates that 3D visualization technologies can support highly contextual representations of traditional settlements. The inclusion of the Omo Sebu as the focal point within the village layout particularly strengthens the cultural interpretation of the digital model, since it reflects the hierarchical social organization of Nias society. Thus, the results suggest that metaverse development for cultural heritage should not be limited to isolated object reconstruction, but should include the surrounding environment and social logic that give meaning to the heritage itself.

These results also confirm the importance of combining human-centered and participatory methods in digital heritage development. The use of field observations, interviews, and ethnographic documentation made it possible to align the virtual

reconstruction with community knowledge and cultural expectations. This approach reduces the risk of producing a visually impressive but culturally detached digital environment. In this sense, the study supports the view that local communities should be treated as active contributors in digital preservation projects rather than merely as sources of data. Their involvement is essential for maintaining authenticity, especially when the reconstructed heritage belongs to a living culture that continues to evolve.

Compared with earlier studies, this research offers a broader development orientation. Previous metaverse-based heritage projects in Japan and France have shown the value of immersive reconstruction for historical education, memory preservation, and museum accessibility. In contrast, the Nias case extends the application of metaverse technology toward the reconstruction of living indigenous cultural spaces, participatory representation, and community-oriented value creation. This distinction clarifies the significance of the proposed contribution within the literature.

Another important contribution lies in the integration of economic and governance dimensions into the cultural restoration framework. The proposed use of blockchain technology expands the role of the metaverse from archival and educational functions toward a sustainable digital cultural economy. Through tokenization and digital ownership validation, cultural assets may be protected while also creating opportunities for transparent benefit sharing and regional income generation. This is aligned with current industry trends in immersive tourism, digital twins, creative economy platforms, and blockchain-based asset authentication.

Several limitations must be acknowledged. First, the study has not yet conducted large-scale user testing with tourists, students, local communities, or cultural experts; therefore, usability, immersion quality, learning impact, and acceptance remain to be empirically measured. Second, the economic impact of the proposed metaverse platform has not been quantified, so claims about regional revenue optimization should be treated as potential implications rather than measured outcomes. Third, the blockchain component is still conceptual and requires further technical implementation, governance design, and ethical review. Fourth, the 3D reconstruction depends on the availability and accuracy of cultural documentation, so future work should involve more detailed community-based validation.

The practical implications are relevant to the current industry scenario. For local governments, the framework can support digital tourism strategies and cultural promotion without relying only on physical visitor access. For cultural institutions and museums, it provides a model for developing interactive archives and virtual exhibitions that remain connected to community ownership. For creative industries and technology developers, the results offer a pathway for building culturally grounded 3D assets, VR/AR experiences, and blockchain-supported digital heritage products. For education, the reconstructed environment can become an immersive learning medium for introducing Nias culture to national and international audiences.

## 5. CONCLUSION

This study concludes that a participatory metaverse framework can support the restoration and revitalization of Nias cultural heritage by integrating human-centered design, architectural visualization, applied computing, and digital asset governance. The results are consistent with the study objectives because the research produced 3D reconstructions of Nias traditional houses, represented the spatial composition of traditional villages, and formulated a framework for future metaverse-based cultural preservation and digital tourism development.

The main IT research contribution is the integration of 3D cultural reconstruction, participatory validation, blockchain-based authenticity, and tourism-oriented value creation into a single framework for indigenous heritage restoration. Compared with previous studies that primarily emphasize virtual exhibitions or museum access, this work highlights a broader ecosystem approach in which local communities can participate in preserving, managing, and potentially benefiting from digital cultural assets. The findings also indicate practical value for current industry needs, especially in immersive tourism, digital heritage education, creative economy development, and regional revenue diversification.

The conclusions are subject to several limitations. The study has not yet measured user experience, learning outcomes, economic impact, or long-term technical sustainability in a deployed metaverse platform. In addition, unintended outcomes such as cultural commodification, unequal benefit distribution, and dependency on digital infrastructure must be carefully managed. Future research should conduct usability testing,

community acceptance studies, economic feasibility analysis, and full-scale platform implementation with ethical governance and transparent benefit-sharing mechanisms.

Furthermore, the framework established in this study can serve as a replicable model for other minority cultures worldwide that face similar threats from globalization and modernization. Future research is recommended to expand this framework into larger-scale implementations, focusing on integrating carbon-neutral technologies and ensuring long-term sustainability of metaverse-based heritage ecosystems.

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