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# A 3D Virtual Object Repository Model for the Preservation of Lan Xang Buddhist Art

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**ABSTRACT**

Lan Xang Buddhist Art is a vital cultural heritage of Northeastern Thailand, rich in historical and religious significance. This study aimed to (1) develop a 3D virtual object repository model for preserving Lan Xang Buddhist Art and (2) evaluate a prototype system based on this model. Using a research and development (RD) approach grounded in systems theory, data were synthesized from: (1) a comparative analysis of ten international 3D repository systems, (2) expert interviews (n = 15) in relevant fields, and (3) a user needs survey (n = 32). A prototype was developed using the SDLC framework and evaluated by five experts and 50 users. The proposed model consists of three core components: (1) education and research, (2) access and usability, and (3) preservation and dissemination. The system supports portable devices and secure access, allowing high-resolution 3D storage of Lan Xang artifacts. Evaluation results showed high system performance (M = 4.66, S.D. = 0.62) and very high user satisfaction (M = 4.63, S.D. = 0.55). This model facilitates the digital preservation of art object forms, patterns, and cultural contexts, enhancing public and academic accessibility. It provides a scalable framework for cultural heritage management in the digital age.

**Keywords:** 3D virtual object repository; Digital cultural preservation; Lan Xang Buddhist art; Metadata; Model development

## 1. Introduction

The registration of antiquities is essential for preserving cultural heritage, providing academic evidence in history, art, and local wisdom, and supporting long-term conservation and education [1]. Such registers also aid museum exhibitions, cultural promotion, legal protection, and creative reproduction [2], contributing to community development and identity

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[3]. Northeastern Thailand hosts Lan Xang Buddhist Art, a distinct cultural legacy shaped by Lanna, Sukhothai, and ancient Khmer influences [4]. This art, divided into royal and folk artisan schools, features unique elements such as oval faces, flame-shaped ushnisha, and traditional casting techniques [5]. However, environmental degradation, illicit trade, and social change threaten its survival [6], necessitating effective conservation systems.

Digital documentation efforts have utilized metadata to describe and manage cultural data, enhancing accessibility and preservation [7, 8]. Metadata types—descriptive, technical, administrative, use, and preservation—are key to organizing digital repositories [9]. Yet, a standardized metadata framework specific to Lan Xang Buddhist Art is lacking, causing fragmented and inconsistent data storage. Advances in 3D photogrammetry using accessible devices allow detailed, cost-effective digital replicas of artifacts. These support 3D virtual object repositories applicable in education, design, cultural tourism, and restoration.

Despite these advances, Northeastern Thailand lacks a comprehensive digital repository model for Lan Xang Buddhist Art. This study thus aims to (1) develop a 3D virtual object repository model for its preservation and (2) evaluate a prototype system based on this model. Using a Research and Development (R&D) approach grounded in Systems Theory, the study integrates artifact data, metadata analysis, 3D modeling, system output, user feedback, and contextual factors. The developed prototype has been implemented at the Office of Academic Resources and Information Technology of Ubon Ratchathani Rajabhat University and the Maneewanaram Temple Museum in Ubon Ratchathani Province, Thailand, to support the management and preservation of Lan Xang Buddhist Art in practical settings.

## 2. Research Methods

This research employed the Research and Development (R&D) methodology, with an emphasis on designing an effective, comprehensive, and applicable 3D virtual object repository model for the preservation of Lan Xang Buddhist Art. The study was conducted within the conceptual framework of Systems Theory, which conceptualizes the system as comprising five key components:

1) Input: such as photographs and information about Lan Xang Buddhist Art objects,

2) Process: including metadata analysis and 3D model generation,

3) Output: referring to a 3D virtual object repository that can be searched and accessed,

4) Feedback: derived from users to inform further development,

5) Environment: encompassing cultural diversity, technological factors, and the specific context of the Northeastern region of Thailand. The research process was divided as follows:

### 2.1 Literature review

This phase involved a comprehensive review of literature and theories related to Lan Xang Buddhist Art, 3D virtual object repository systems, system development processes, and the emerging trends in the use of technology for the conservation of antiquities.

### 2.2 Development of 3D virtual object repository model

In this phase, the researcher developed a 3D virtual object repository model

for the preservation of Lan Xang Buddhist Art through two main steps, the details of these steps are as follows:

### *2.2.1 Identification of components for the 3D virtual object repository system*

1) Comparative study of international best practices systems: to study the characteristics, structure, and functionalities of successful global 3D digital object repository systems, focusing on best practices that can be adapted to design a prototype suitable for the context of Lan Xang Buddhist Art. Ten existing 3D digital object repository systems were selected based on criteria including the credibility of managing organizations, accessibility via web browsers, openness of public data, and user interactivity. The researcher conducted hands-on testing of these systems, analyzed their features, and compared the common characteristics across systems (see Table 1.). In summary, all ten systems share five common strengths: (1) education & research suitability, (2) metadata management, (3) long-term preservation, (4) multilingual support, and (5) mobile & tablet support. The second most frequently observed characteristic is museum & archive suitability. Overall, the ten 3D digital library systems emphasize open access to and dissemination of 3D digital media, while also supporting educational use and structured data storage to facilitate efficient information retrieval.

2) In-depth expert interviews: semi-structured interviews were employed to collect opinions, recommendations, and knowledge from experts in relevant fields, including art and culture, technology, and digital information management. The focus was on identifying essential components for designing a comprehensive, academically rigorous, and practically applicable system for storing Lan Xang Buddhist Art. Fifteen experts participated in the in-depth interviews, divided into five groups of three experts each, selected through purposive sampling. The selection of fifteen experts was deemed appropriate for qualitative research aimed at model development, as the objective was to extract key conceptual and practical components necessary for system design rather than to achieve statistical generalization. The groups included experts in Buddhism, art and culture, multimedia and technology, system development, and librarianship. Purposive sampling enabled the researcher to obtain in-depth insights from individuals with direct professional experience in these specific domains, which is consistent with research and development (R&D) methodology. The interview data were then analyzed through content analysis, selecting frequently occurring themes and grouping similar content into categories, in alignment with qualitative analytical approaches used in model synthesis studies.

3) User requirement survey: a five-point Likert scale questionnaire was used to analyze the needs of the target user group knowledgeable in Lan Xang Buddhist Art. The survey focused on identifying the expected system functionalities, problems or limitations previously encountered, and desired features for the 3D virtual object repository system. This aimed to ensure that the system design effectively meets practical usage requirements within the local context. The sample consisted of 32 participants with expertise in Lan Xang Buddhist Art, selected through snowball sampling within the Art Language and Buddhist Art Club at Ubon Ratchathani Rajabhat University, Thailand. Snowball sampling was employed because the target population consisted of individuals with

**Table 1.** Color fastness ratings of dyed yarns to alkaline artificial sweat, assessed according to ISO 105-E04:2013.

| Item | 3D visualization support | Web-based 3D support | VR support | AR support | 3D object interaction | Open-source API support | Education & research suitability | Museum & archive suitability | 3D scanning support | External 3D model support | 3D model download | Metadata management | Long-term preservation | Multilingual support | Mobile & tablet support |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Library of Congress 3D | ✓ | ✓ | ✓ | × | ✓ | × | ✓ | ✓ | ✓ | × | × | ✓ | ✓ | ✓ | ✓ |
| Europeana | ✓ | ✓ | × | × | ✓ | ✓ | ✓ | ✓ | × | ✓ | × | ✓ | ✓ | ✓ | ✓ |
| Smithsonian 3D | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Sketchfab | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Google Arts & Culture | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| DPLA | × | × | × | × | × | × | ✓ | × | × | × | × | ✓ | ✓ | ✓ | ✓ |
| World Digital Library | × | × | × | × | × | ✓ | ✓ | ✓ | × | × | × | ✓ | ✓ | ✓ | ✓ |
| Internet Archive | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Virtual Library of Bibliographical Heritage | × | × | × | × | × | ✓ | ✓ | ✓ | × | × | × | ✓ | ✓ | ✓ | ✓ |
| Khan Academy | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | × | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| **Total** | **7** | **7** | **6** | **5** | **7** | **7** | **10** | **8** | **6** | **6** | **5** | **10** | **10** | **10** | **10** |

specialized knowledge in Lan Xang Buddhist Art, for whom a complete sampling frame could not be clearly identified. Utilizing the network of the Art Language and Buddhist Art Club enabled access to participants who met the specific criteria of the study. Nevertheless, the researcher acknowledges that snowball sampling may introduce selection bias. To mitigate this limitation and enhance the validity of the findings, the user requirement data were triangulated with evidence from the comparative analysis of international best-practice systems and the in-depth expert interviews, thereby strengthening the credibility of the synthesized model components.

### *2.2.2 Synthesis of components and model development*

1) Content analysis & thematic categorization: data obtained from the comparison of international best practices systems, in-depth expert interviews, and user requirement surveys were categorized according to key themes using the principles of content analysis, in order to identify and present the frequency of occurrence of each data cluster. Subsequently, the themes that appeared repeatedly in two or more data sources were identified as ”common components”. These components were then grouped based on the contextual similarity of their attributes, and new component names were assigned accordingly.

2) Model development: a prototype model was developed to encompass the core components synthesized from the previous stages. The model was visually represented in diagrammatic form to illustrate the relationships among the components, serving as a conceptual framework for developing a 3D virtual object repository system for the preservation of Lan Xang Buddhist Art.

3) Expert review: the researcher presented the model to three experts with knowledge in both information technology and Lan Xang art. After the presentation, the experts were asked to evaluate the model using a five-point Likert scale assessment form along with open-ended feedback. The purpose of the evaluation was to examine the model’s accuracy, appropriateness, and applicability for prototype system development. The expert feedback was then analyzed, and the model was revised and refined accordingly before being used in the prototype development phase (Phase 3).

### 2.3 Prototype system development and testing

#### *2.3.1 Prototype system development*

The developed model was used as a guideline for designing the prototype system. The system was designed based on the model and developed following the seven-step Software Development Life Cycle (SDLC) [10].

1) Problem recognition: the digital archive of the Office of Arts and Culture at Ubon Ratchathani Rajabhat University, Thailand, has traditionally preserved data in a static digitization format. As a result, the photographic records of Lan Xang Buddhist Art were limited to conventional document formats and stored as two-dimensional multimedia. This gap highlights the necessity for preserving Buddhist Art data in a 3D virtual object repository format, which can better support students, researchers, conservators, and interested individuals by providing easier access to the information.

2) Feasibility Study: the researcher conducted a field survey and analysis of the information resources at the Office of Arts and Culture, Ubon Ratchathani Rajabhat University, Thailand. This involved assessing the software, hardware, network infrastructure, and relevant reporting forms associated with the system. Additionally, cost and time evaluations were performed to achieve satisfactory outcomes. The researcher identified stakeholder requirements in three key areas: technical tools and equipment, personnel and readiness, and cost-effectiveness. The findings were then presented to management for approval to proceed with implementation.

3) Analysis: at this stage, an analysis was conducted based on the comparison of international best practice systems, in-depth expert interviews, and user requirement surveys. The findings were synthesized into a 3D virtual object repository model for the preservation of Lan Xang Buddhist Art.

4) Design: the design of the prototype system derived from the conceptual model for the preservation of Lan Xang Buddhist Art.

From Fig. 1, the system design diagram, the prototype system consists of key features grouped into three main components.

(1) Educational and Research Component–comprising three subcomponents: support for searching, structural linking, descriptive metadata.

(2) Access and Usability Component–comprising three subcomponents: technical metadata, rights metadata, multi-platform compatibility.

(3) Preservation and Dissemination Component–comprising two subcomponents: presentation, preservation metadata.

The graphic user interface (GUI) of the prototype system was designed using a red–brown–gold color palette, selected for its strong visual presence and its association with the spiritual and cultural atmosphere of Buddhism. The Thai text employs a traditional Lan Xang-style font to reflect historical authenticity, while English translations are also included to ensure accessibility for a broader audience.

5) Development & Test: the 3D models were generated through a photogrammetric process using multiple-angle digital photographs, captured with digital single-lens reflex (DSLR) camera and smartphone cameras. This method allowed for high-resolution, cost-effective documentation of culturally significant artifacts.

6) The database was managed using Google Sheets as a backend solution. This platform was selected due to its ease of use, sustainability, no expiration or usage limi-

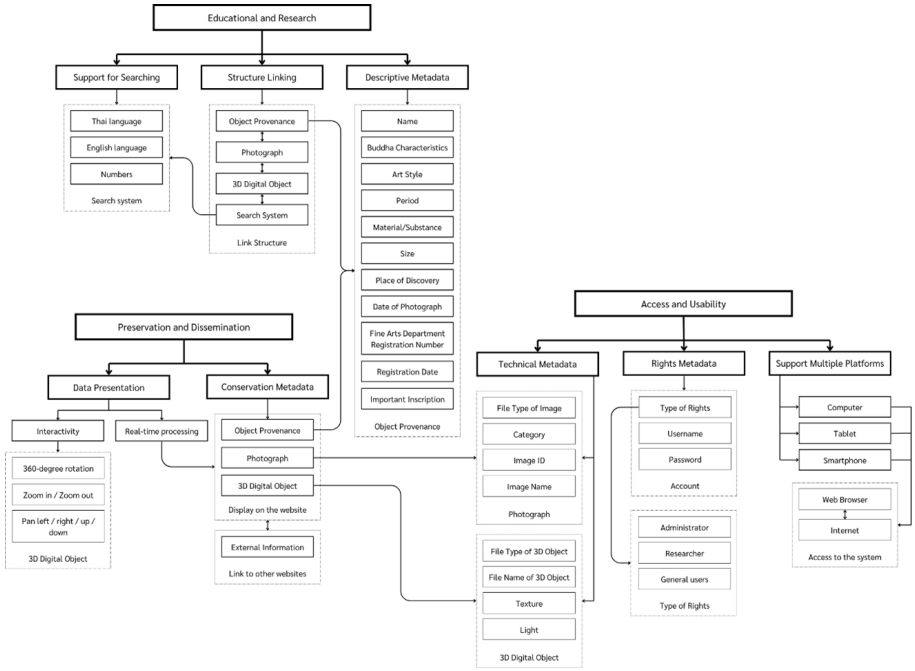


**Fig. 1.** Design of the prototype system for the preservation of Lan Xang Buddhist Art.


**Fig. 2.** Graphic user interface of the prototype system.

**Fig. 3.** 3D Reconstructed model (Photogrammetry).

tations, and zero cost. Google Sheets was used specifically to store textual and non-encrypted metadata, while large files such as 3D models and image files were stored on a cloud server. In this architecture, Google Sheets functioned as a metadata management interface that stored links referencing the corresponding 3D and image files for web-based display. This approach allows administrators to add, delete, and update metadata directly through Google Sheets without logging into the internal system components. The system then automatically retrieves and renders the linked 3D models and images on the web interface. End users can access and interact with both image and 3D files seamlessly via a standard web browser.

The prototype system was evaluated using black-box testing to assess performance (https://pagespeed.web.dev). When accessed via desktop devices (CPU Intel Core i5, GPU NVIDIA GeForce RTX 3060Ti, 15.6" Full HD 144Hz IPS, RAM


**Fig. 4.** 3D Reconstructed model within the prototype system.

DDR4-16GB, HDD SSD 512GB, Windows OS), the system achieved a First Contentful Paint (FCP) of 1.4 seconds and a Time to First Byte (TTFB) of 0.7 seconds. On smartphone devices (Xiaomi Mi 8 Pro, Android OS), the FCP was 1.8 seconds, and the TTFB was 0.9 seconds. Based on these results, the researcher optimized the prototype by reducing image file sizes and simplifying the structure of 3D models. These adjustments were implemented to enhance the system's loading speed and overall performance on mobile devices.

7) Implementation: the researcher deployed the prototype system for practical use at the Office of Academic Resources and Information Technology of Ubon Ratchathani Rajabhat University and at the Maneewanaram Temple Museum in Ubon Ratchathani Province, Thailand.

8) System maintenance: the Office of Academic Resources and Information Technology of Ubon Ratchathani Rajabhat University, Thailand, appointed a system administrator to ensure the prototype system remains complete, up-to-date, and effectively maintained. At this stage, the administrator's role is defined at a conceptual level and focuses on overseeing general system sustainability rather than implementing institution-specific operational policies. Typical responsibilities include monitoring system availability, supporting data integrity, and coordinating content management activities. Detailed maintenance procedures—such as backup schedules, update cycles, and content review workflows—are expected to be determined by the host institution in accordance with its organizational context, resources, and long-term management policies.

### *2.3.2 System quality evaluation*

The prototype system was evaluated for its effectiveness by five experts selected through purposive sampling, specifically targeting specialists in digital information resources with expertise in Lan Xang Buddhist Art. The evaluation employed a five-point Likert scale rating form, encompassing five key aspects: (1) system structure and design quality, (2) 3D technology and visualization quality, (3) database and security quality, (4) UX/UI and interaction quality, and (5) cultural and Buddhist Art quality. The assessment instrument was validated for content relevance using Item-Objective Congruence (IOC) analysis by three experts in measurement and evaluation. Data were analyzed using mean and standard deviation, and interpreted according to the five-point Likert scale criteria.

The user satisfaction evaluation was conducted with 50 participants selected using snowball sampling from those knowledgeable in Lan Xang art through referrals in the Art and Buddhist Language Club at Ubon Ratchathani Rajabhat University, Thailand. The selection of 50 users was considered appropriate for Research and Development (R&D) research, as the primary objective was to conduct a formative evaluation of the prototype system's preliminary performance and practical applicability rather than to make population-level generalizations. Prior to testing, the researcher provided participants with rele-

vant knowledge and guidance. Participants then tested the prototype system via a web browser using various electronic devices, including computers, tablets, and smartphones. During the evaluation, users were asked to perform predefined tasks that reflected real usage scenarios, such as locating a specific artefact, manipulating a 3D object (e.g., rotating and zooming), and comparing information across multiple items. Task completion rates, interaction behaviour, and observable usage difficulties were monitored to assess how effectively the 3D interface supported user interaction. The evaluation employed a five-point Likert scale questionnaire covering three key dimensions: (1) content and information satisfaction, (2) system usability satisfaction, and (3) perceived benefits of the system. The involvement of users with prior knowledge of Buddhist art ensured that the evaluation was context-specific and capable of reflecting the system's quality and usability in real-world cultural and educational applications. The instrument was validated for content relevance through an Item-Objective Congruence (IOC) analysis by three experts in measurement and evaluation. Data were analyzed using mean and standard deviation and interpreted based on the five-point Likert scale criteria.

## 3. ResultS

### 3.1 The result of developing a 3D virtual object repository model for the preservation of Lan Xang Buddhist Art

The research findings revealed that the essential components of a 3D virtual object repository system for storing Lan Xang Buddhist Art are: 1) components related to educational and research purposes, 2) components related to access and usability, and 3) components related to the preservation and dissemination of art.

From Fig. 5, the researcher explains the relationships among the components within the model as follows: 1) Educational and Research Purpose Component: this component emphasizes the creation of a system that is not merely a "data repository" but also serves as an effective "learning resource" and a "medium for cultural transmission." It supports both in-depth research and public accessibility in the digital age. The system design prioritizes academic usability, focusing on accurate, comprehensive, and reliable data storage to serve as a learning platform and database for researchers, students, and the general public. The system is designed to be easily accessible via the Internet and supports mobile devices such as smartphones and tablets, allowing users to conveniently access educational and research information anytime and anywhere. This approach helps overcome spatial and temporal limitations in accessing knowledge. The researcher's system design guidelines include:

(1) Storing descriptive metadata, such as the history of the art object, patterns, materials, dimensions, and cultural meanings, which facilitates effective conservation-oriented utilization.

(2) Structural linking that connects related content, including research studies, articles, and other art databases, thereby enhancing the dissemination of knowledge about Lan Xang Buddhist Art to the wider public through digital channels.

(3) Supporting advanced search functions, such as searching by era, artist, material, and geographic area, enabling the general public to easily access and understand the artistic and cultural values of the local heritage.

2) Access and Usability Component: this component highlights that "easy accessibility" and "appropriate control" are the

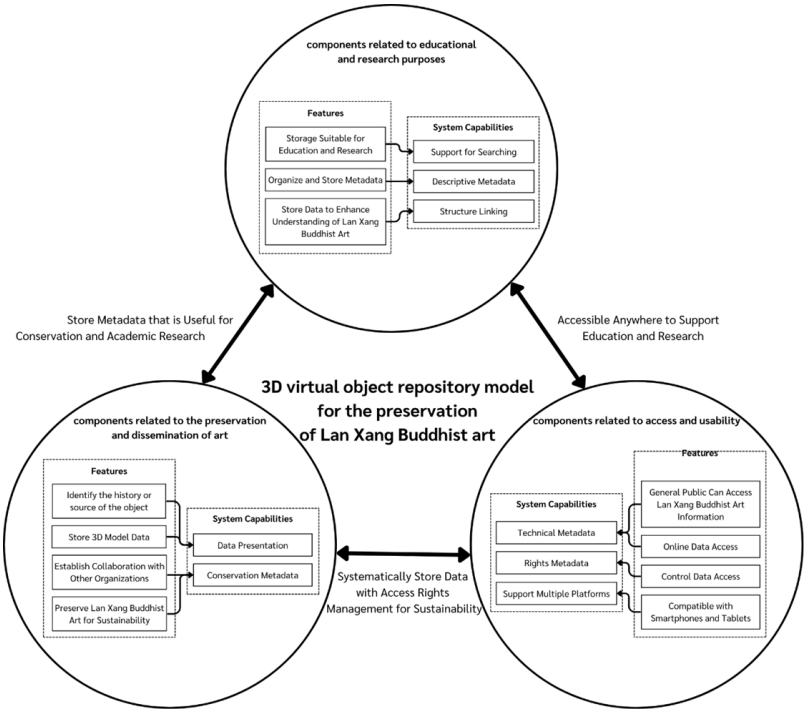


**Fig. 5.** 3D Virtual Object Repository Model for the Preservation of Lan Xang Buddhist Art.

core elements of a quality system. Beyond facilitating user convenience, it also ensures the long-term security of data and cultural values. It considers the system's capability to allow users to access information easily, conveniently, and securely—both through technology that supports multiple devices and through management of user permissions. This enables the system to respond appropriately to diverse user groups. The ability to access data anytime and anywhere removes the necessity for users to be physically present at a museum or institution, thereby promoting continuous, flexible, and efficient learning and research processes. Access control measures, such as user permission systems, help ensure that important cultural and artistic data are disseminated appropriately. This protects the information from unauthorized alteration or misuse beyond its intended purpose. The researcher's system design guidelines include:

(1) Rights Metadata, implementing access control measures to differentiate permission levels for researchers, students, and the general public.

(2) Technical Metadata, enabling the system to store detailed digital file information such as file size, 3D model format, and metadata compatibility with other systems.

(3) Multi-platform Support, ensuring users can access the system from various mobile devices.

3) Preservation and Dissemination Component: this component concerns the storage and presentation of Lan Xang Buddhist Art data in a manner that preserves cultural heritage over the long term. It emphasizes that "preservation" and "dissemination" are not separate processes but should develop concurrently. Data storage for preservation is not merely about safe-

guarding information but also ensuring that the data is complete, accurate, and academically reliable. This supports effective research and study in art and culture. Particularly, storing Lan Xang Buddhist Art in 3D format, which captures the shape, patterns, and intricate artistic details comprehensively, allows users to "see" and "understand" the artistic elements as if experiencing the original artifact—without needing to visit the physical location. Additionally, providing online and mobile access to this data broadens opportunities for learning and public engagement. The researcher's system design guidelines include:

(1) Conservation Metadata, designing a data structure that supports preservation and dissemination of knowledge related to Buddhist Art, such as recording the current condition of artifacts, noting any changes or damages, and maintaining conservation history.

(2) Presentation, ensuring the system supports 3D file formats and supplementary data that help contextualize the Buddhist Art, such as information on lighting, shadows, and surface textures, to enable realistic 3D visualization.

### 3.2 The evaluation result of the prototype system developed based on the 3D virtual object repository model for the preservation of Lan Xang Buddhist Art

#### *3.2.1 Results of the evaluation of the prototype system's quality*

The prototype system was evaluated by five experts selected through purposive sampling based on their expertise in digital information resources and Lan Xang Buddhist Art. The overall system quality was rated as good, with a mean score of 4.46 out of 5.00. Among the evaluated categories, the cultural and Buddhist Art content received the highest rating at a very good level, with a mean score of 4.66. The 3D technology and visualization category was rated good with a mean score of 4.47. User experience (UX/UI) and interaction also received a good rating at 4.46, followed closely by database and security with a score of 4.45. The system structure and design category received the lowest rating, yet remained in the good range with a mean score of 4.31. Qualitative feedback from the experts indicated that this result was primarily due to the prototype-oriented nature of the system structure, which emphasizes simplicity and practical usability within a specific local context. Experts noted that while the system structure is appropriate and functional for a prototype, it could be further enhanced to support large-scale institutional deployment, such as managing larger and more complex databases or enabling future integration with external systems. These results indicate that the prototype system adequately meets the required criteria and performs efficiently overall.

#### *3.2.2 Results of user satisfaction evaluation for the prototype system*

The user satisfaction evaluation of the prototype system was conducted with 50 participants. Overall user satisfaction was rated at the highest level, with a mean score of 4.63 out of 5.00. The aspect with the highest satisfaction was the perceived benefits of the system, receiving a mean score of 4.68. This was followed by system usability, which also achieved the highest satisfaction level with a mean score of 4.66. Content and information quality received a mean satisfaction score of 4.58. These findings demonstrate a highly positive user response across all evaluated dimensions. In addition, qualitative feedback from open-ended comments provided by both experts and users revealed several common themes.

These included requests for more detailed explanatory guidance on interacting with 3D models, improved clarity of the navigation menu structure, and the addition of multilingual support to enhance international accessibility. Furthermore, experts in Buddhist art suggested that conservation status information of the art objects should be more explicitly presented to better support academic and research-oriented use of the system.

## 4. Conclusion and Discussion

This study focused on the development of a 3D virtual object repository model for the preservation of Lan Xang Buddhist Art, applying the Research and Development (R&D) methodology within the conceptual framework of Systems Theory. The model was synthesized from three data sources: a comparative analysis of international 3D object repository systems, in-depth interviews with experts in relevant fields, and a survey of user requirements. The final model comprises three systematically integrated components: (1) Educational and Research Purpose, (2) Access and Usability, and (3) Preservation and Dissemination. The developed model was used to build a prototype system, which was evaluated by both experts and users. The expert evaluation rated the system's performance as "good," particularly in the categories of cultural relevance and 3D visualization. User satisfaction was rated at a "very high" level, indicating the prototype system's potential for real-world application in the areas of education, preservation, and public access to cultural heritage.

These findings are consistent with the literature on virtual 3D object repositories. Hardesty et al. [11] emphasized that 3D repositories function not merely as data storage, but as dynamic platforms supporting interaction, access, and educational reuse. Doerr et al. [12] identified ten essential components of virtual object repositories. These components—including visualization, metadata, access control, and updating systems—were integrated by the researcher into the model developed in this study. The use of photogrammetry in this research further supports earlier studies demonstrating its effectiveness in cultural heritage documentation. Seemuangngam [13] found that mobile-based photogrammetry offered a low-cost yet accessible method for preserving architectural and landscape heritage. Thong-in et al. Reference [14] applied similar techniques in archaeological site preservation, affirming its accuracy and utility for academic use. These approaches align with the methodology used in this study, which employed DSLR and smartphone cameras for 3D reconstruction. Moreover, the success of the system is closely tied to the integration of metadata. Rowell [7] argued that metadata plays a central role in enhancing the searchability and management of digital information resources. Kandregula [9] classified metadata into several categories: descriptive, technical, administrative, usage, and preservation. The researcher selectively applied each type of metadata to align with the prototype system developed in this study, ensuring effective long-term data storage, usability, and interoperability across systems.

The development of the prototype system followed the SDLC methodology to ensure systematic and iterative progress. Boobpachote & Liamthaisong [15] proposed a seven-phase SDLC model for complex systems, such as digital repositories, including phases for maintenance and real-world deployment. This study adopted their full-cycle approach to design, build, and

evaluate the prototype. In addition, the emphasis on UX and UI design in this study echoes the principles introduced by Don Norman [16]. Ramadhan & Aji [16] outlined four essential aspects of good UX: usability, equity, enjoyability, and usefulness. These principles directly informed this system's interface design, resulting in highly positive feedback from users.

Based on the evaluation results and qualitative feedback from experts and users, several design implications for future system development can be identified. Future enhancements should focus on improving the flexibility of the data structure to better support system scalability and long-term management. In addition, the implementation of hierarchical navigation menus would improve clarity and usability, particularly for systems with increasing data complexity. The incorporation of interactive explanatory functions for 3D models would further enhance user understanding and engagement. Moreover, the development of multilingual support modules and the integration with external databases would significantly expand the system's applicability and facilitate its use in broader institutional and international contexts.

Despite these strengths, the study has certain limitations. The sample population primarily consisted of users from a single academic institution and was selected using non-probability sampling methods. Therefore, the findings should be interpreted within this specific contextual scope. In addition, the prototype system was tested primarily within an academic environment in Northeastern Thailand, and its application in broader national or international contexts remains to be validated. Future research may expand the sample to include museums or cultural institutions in other regions to further validate the model's broader applicability and generalizability. Future studies could also focus on scaling the model, integrating AI-based metadata tagging, and enhancing multilingual support. Longitudinal studies of user engagement would further contribute to optimizing system functionality and sustainability.

In conclusion, this research provides a practical and theoretically grounded model for preserving Lan Xang Buddhist Art in digital form. The model bridges technological innovation with cultural preservation and offers a scalable framework for building virtual object repositories in similar cultural contexts. This study contributes to the field of Thai cultural preservation through the integration of digital technologies with traditional Buddhist art heritage, which has been underrepresented in previous digital cultural heritage studies. Ultimately, this system is not only a tool for digital storage but also a medium for learning, cultural engagement, and knowledge transmission—ensuring that the artistic and spiritual legacy of Lan Xang Buddhism is preserved and accessible for future generations.

## Acknowledgements

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# Appendix

**Table 2.** Mean, standard deviation, and interpretation of system quality analysis.

| Item | Mean | S.D. | Quality Level |
|---|---|---|---|
| **System Structure and Design Quality** | **4.31** | **0.68** | **Good** |
| The system categorizes Buddhist art data systematically | 4.71 | 0.49 | Excellent |
| The layout adapts appropriately across various devices | 4.57 | 0.53 | Excellent |
| The system has a clear and organized structure | 4.43 | 0.53 | Good |
| Navigation is clear and user-friendly | 4.29 | 0.76 | Good |
| The visual design aligns with the content | 4.29 | 0.49 | Good |
| The use of color and typography is appropriate and easy to read | 4.14 | 0.69 | Good |
| The system provides appropriate error messages or usage guidance | 3.71 | 0.95 | Good |
| **3D Technology and Visualization Quality** | **4.47** | **0.65** | **Good** |
| The system accurately renders 3D models of Buddhist art | 4.86 | 0.38 | Excellent |
| Users can rotate, zoom, and examine model details smoothly | 4.71 | 0.49 | Excellent |
| Appropriate technologies (e.g., WebGL, Three.js, Babylon.js) are used for 3D rendering | 4.71 | 0.49 | Excellent |
| 3D model loading times are acceptable and not delayed | 4.43 | 0.53 | Good |
| The system supports various 3D file formats (e.g., .glTF, .OBJ, .STL) | 4.43 | 0.79 | Good |
| Users can download 3D models for further use | 4.14 | 0.90 | Good |
| The system allows comparison of 3D models from different perspectives | 4.00 | 0.58 | Good |
| **Database and Security Quality** | **4.45** | **0.58** | **Good** |
| e efficiently stores and manages virtual objects | 4.71 | 0.49 | Excellent |
| Data storage aligns with digital data management standards | 4.57 | 0.53 | Excellent |
| The system appropriately restricts unauthorized access | 4.43 | 0.79 | Good |
| The system can handle multiple simultaneous users effectively | 4.43 | 0.53 | Good |
| The system logs user activity for further analysis | 4.43 | 0.53 | Good |
| Security measures protect Buddhist art data | 4.29 | 0.49 | Good |
| The system has data backup and loss prevention measures | 4.29 | 0.76 | Good |
| **User Experience (UX/UI) and Interaction Quality** | **4.46** | **0.64** | **Good** |
| The design promotes understanding of Buddhist art | 4.86 | 0.38 | Excellent |
| The system performs well on major browsers (Chrome, Firefox, Safari, Edge) | 4.86 | 0.38 | Excellent |
| Accessible across various devices (e.g., computers, tablets, smartphones) | 4.71 | 0.49 | Excellent |
| Usable by general users without technical background | 4.57 | 0.53 | Excellent |
| Clear and understandable user guides are provided | 4.43 | 0.79 | Good |
| The system responds quickly to user input | 4.43 | 0.53 | Good |
| Operable even under low-speed internet conditions | 4.29 | 0.76 | Good |
| Allows users to customize 3D model displays | 4.14 | 0.69 | Good |
| Supports multilingual interfaces for diverse user groups | 3.86 | 0.69 | Good |
| **Cultural and Buddhist Art Quality** | **4.66** | **0.48** | **Excellent** |
| art through 3D models enhances understanding | 4.86 | 0.38 | Excellent |
| 3D storage preserves the artistic and cultural value | 4.71 | 0.49 | Excellent |
| Data such as size, material, technique, and cultural context are complete and appropriate | 4.57 | 0.53 | Excellent |
| 3D Buddhist art data is deemed applicable and beneficial | 4.57 | 0.53 | Excellent |
| Supports scholars, monks, and artisans in learning and transferring knowledge | 4.57 | 0.53 | Excellent |
| **Overall System Quality** | **4.46** | **0.62** | **Good** |

**Table 3.** Mean, standard deviation, and interpretation of user satisfaction levels with the system.

| Item | Mean | S.D. | Satisfaction Level |
|---|---|---|---|
| **Content and Information Satisfaction** | **4.58** | **0.59** | **Very High** |
| Text content is easy to read | 4.74 | 0.44 | Very High |
| Image display is clear and loads quickly | 4.68 | 0.55 | Very High |
| 3D Buddhist art models load quickly | 4.66 | 0.48 | Very High |
| 3D Buddhist art models appear realistic | 4.62 | 0.60 | Very High |
| Descriptive text enhances understanding of Buddhist art | 4.58 | 0.61 | Very High |
| Information presented is interesting | 4.48 | 0.54 | High |
| Categorization of Buddhist art is easy to understand | 4.46 | 0.71 | High |
| **Information is detailed enough to support study or research** | **4.40** | **0.67** | **High** |
| System Usability Satisfaction | 4.66 | 0.51 | Very High |
| System is compatible with mobile devices (smartphones, tablets, computers) | 4.70 | 0.51 | Very High |
| System performs efficiently with multiple concurrent users | 4.70 | 0.51 | Very High |
| 3D models are easy to zoom, rotate, and interact with | 4.68 | 0.51 | Very High |
| Search functions are accurate and easy to use | 4.68 | 0.51 | Very High |
| The system is convenient, user-friendly, and uncomplicated | 4.64 | 0.48 | Very High |
| The system operates quickly and efficiently | 4.56 | 0.54 | Very High |
| **Perceived Benefits of the System** | **4.68** | **0.53** | **Very High** |
| The system supports conservation and dissemination of Buddhist art | 4.78 | 0.42 | Very High |
| Satisfaction with the virtual 3D Buddhist art repository system | 4.76 | 0.43 | Very High |
| The system can serve as a resource for education and research | 4.66 | 0.48 | Very High |
| The system can be used as a model for developing other 3D digital archives | 4.66 | 0.63 | Very High |
| The system helps users understand Buddhist art | 4.62 | 0.57 | Very High |
| The system promotes cultural tourism and Buddhist art education | 4.60 | 0.61 | Very High |
| Overall Satisfaction with the System | 4.63 | 0.55 | Very High |
| **User Experience (UX/UI) and Interaction Quality** | **4.46** | **0.64** | **Good** |
| The design promotes understanding of Buddhist art | 4.86 | 0.38 | Excellent |
| The system performs well on major browsers (Chrome, Firefox, Safari, Edge) | 4.86 | 0.38 | Excellent |
| Accessible across various devices (e.g., computers, tablets, smartphones) | 4.71 | 0.49 | Excellent |
| Usable by general users without technical background | 4.57 | 0.53 | Excellent |
| Clear and understandable user guides are provided | 4.43 | 0.79 | Good |
| The system responds quickly to user input | 4.43 | 0.53 | Good |
| Operable even under low-speed internet conditions | 4.29 | 0.76 | Good |
| Allows users to customize 3D model displays | 4.14 | 0.69 | Good |
| Supports multilingual interfaces for diverse user groups | 3.86 | 0.69 | Good |
| **Cultural and Buddhist Art Quality** | **4.66** | **0.48** | **Excellent** |
| art through 3D models enhances understanding | 4.86 | 0.38 | Excellent |
| 3D storage preserves the artistic and cultural value | 4.71 | 0.49 | Excellent |
| Data such as size, material, technique, and cultural context are complete and appropriate | 4.57 | 0.53 | Excellent |
| 3D Buddhist art data is deemed applicable and beneficial | 4.57 | 0.53 | Excellent |
| Supports scholars, monks, and artisans in learning and transferring knowledge | 4.57 | 0.53 | Excellent |
| **Overall System Quality** | **4.46** | **0.62** | **Good** |