SECTION «SOCIAL COMMUNICATIONS»

EUROPEAN MODELS OF DIGITAL PRESERVATION OF CULTURAL HERITAGE IN COMMUNICATION ECOSYSTEMS: LESSONS FOR UKRAINE

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Abstract. The study examines European models of digital preservation of cultural heritage through the conceptual framework of communication ecosystems and identifies their methodological and practical relevance for Ukraine. The subject of the research is the transformation of cultural heritage preservation under the influence of digital infrastructures, interoperable platforms, metadata standards, artificial intelligence, and changing patterns of institutional and public communication. The purpose of the study is to analyse how European digital heritage initiatives combine technological, institutional, and communicative mechanisms to ensure the long-term preservation, accessibility, interpretation, and international circulation of cultural resources, and to determine which elements of these models can inform Ukrainian preservation strategies. The methodology is based on an interdisciplinary approach combining the analysis and synthesis of scholarly literature, comparative analysis of European and Ukrainian practices, a systemic approach to digital infrastructures, and conceptual analysis of communication ecosystems. Particular attention is given to Europeana and national digital heritage infrastructures, as well as to the role of libraries, archives, and museums as active participants in knowledge production and information exchange. The results demonstrate that European digital preservation has developed from isolated digitization projects toward integrated ecosystems based on interoperability,

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standardized metadata, distributed repositories, cross-platform integration, and participatory access. Artificial intelligence expands these capacities by supporting automated classification, optical character recognition, semantic enrichment, and large-scale processing of cultural data, although its use requires responsible institutional and ethical governance. The Ukrainian case demonstrates that digital preservation has an additional strategic function under wartime conditions: it mitigates the risks associated with the destruction of physical collections, supports continuity of cultural memory, and maintains communication with researchers, citizens, and international partners. The study also identifies persistent challenges, including fragmented digitization initiatives, uneven technological capacity, limited resources, and the absence of sufficiently coordinated national standards. The conclusion is that European experience provides Ukraine with a transferable methodological framework rather than a ready-made institutional model. Its adaptation should focus on interoperable infrastructures, metadata standardization, distributed preservation, international cooperation, responsible use of artificial intelligence, and stronger coordination among cultural and research institutions. Further research should examine practical mechanisms for integrating Ukrainian digital heritage resources into European and global information ecosystems while maintaining national cultural and informational sovereignty.

INTRODUCTION

The relevance of the communication-ecosystem perspective is determined by the fact that digital preservation changes the relationships among the object being preserved, the institution responsible for it, the technological infrastructure through which it is represented, and the users who interpret and reuse the resulting information. A digitized manuscript, photograph, architectural object, or archival record does not simply acquire a new carrier. It enters a network of descriptions, identifiers, links, interfaces, search mechanisms, repositories, and interpretive practices. Consequently, the preservation problem becomes inseparable from the problem of communication: information that cannot be discovered, correctly identified, contextualized, or reliably reused remains only partially effective as a form of heritage preservation.

The scientific relevance of the study also follows from the need to distinguish digitization from digital preservation. Digitization is primarily the creation of a digital representation of a physical object, whereas preservation includes the organization of storage, metadata, integrity control, migration, access, contextualization, and long-term institutional responsibility. The latter therefore requires a systemic approach. A communication ecosystem makes it possible to connect these dimensions and to consider preservation as a continuing process in which technical decisions influence scholarly interpretation and public access, while communicative demands, in turn, influence the design of digital infrastructures.

The novelty of the present approach lies in combining the analysis of European digital heritage practices with the concept of communication ecosystems and applying this combination to the Ukrainian context. The study does not treat Europeana, national digital libraries, metadata standards, artificial intelligence, or distributed repositories as isolated technological instruments. Instead, they are interpreted as mutually dependent elements of a broader institutional and communicative configuration. Such an approach is particularly important for Ukraine, where the preservation of cultural memory is simultaneously a research, cultural-policy, security, and social-communication task.

The study is organized according to a gradual analytical logic. First, the theoretical foundations of the communication-ecosystem approach are clarified. Second, the main characteristics of European digital heritage infrastructures are examined, with attention to interoperability, metadata, aggregation, and participation. Third, the Ukrainian situation is considered as a specific environment in which preservation must respond to wartime risks and institutional constraints. Fourth, the European experience is translated into practical directions for adaptation rather than mechanical copying. This sequence allows the technological, institutional, and communicative dimensions of digital preservation to be considered as parts of one analytical model.

Digital transformation has fundamentally redefined the ontology, accessibility, and communicative functionality of cultural heritage. In the twenty-first century, heritage artefacts increasingly function as not only physical objects preserved in museums, archives, and libraries but also as informational constructs embedded in complex digital communication

environments [1; 3]. Digitization is therefore no longer limited to the technical conversion of analogue objects into digital formats. It also enables reinterpretation, recontextualization, integration, and global dissemination of cultural content.

Despite the growing body of research on digital heritage, an important analytical gap remains: technological, communicative, and institutional dimensions are often examined separately rather than as components of a single ecosystem. This gap determines the relevance of an approach that considers digital preservation as a process involving infrastructures, metadata, institutions, platforms, researchers, and users. European experience is particularly valuable because many European initiatives have developed mechanisms for integrating distributed cultural collections into interoperable digital environments [2; 4; 5].

For Ukraine, the issue has acquired additional urgency because military aggression creates direct risks to museums, archives, libraries, historical collections, and other cultural infrastructure. Digital copies, distributed repositories, and remote-access systems can contribute to the preservation of cultural memory when physical collections are endangered. The V. I. Vernadsky National Library of Ukraine is an important national institution in this context because its digital collections and information resources illustrate the transition toward technology-driven models of cultural heritage preservation [13].

The purpose of this study is to analyze European models of digital cultural heritage preservation through the framework of communication ecosystems and to identify their methodological and practical relevance for Ukraine. The research objectives are to clarify the theoretical foundations of the communication-ecosystem approach; examine major European digital heritage infrastructures and practices; assess the role of interoperability, metadata, and artificial intelligence; analyze the specific conditions of digital preservation in Ukraine during wartime; and formulate directions for adapting relevant European practices to the Ukrainian context.

The methodology combines interdisciplinary analysis, synthesis of scholarly literature, comparative analysis of European and Ukrainian practices, a systemic approach to digital infrastructures, and conceptual analysis of communication ecosystems. The logic of the study proceeds from the theoretical framework to the European model, then to the Ukrainian

case, and finally to conclusions concerning institutional, technological, and communicative development.

1. Communication Ecosystem Framework

1.1. Structure of Digital Communication Ecosystems

A communication ecosystem may be represented as a system of interrelated actors, resources, technological means, rules, and flows of information. In the field of cultural heritage, its central components include memory institutions, digital collections, repositories, metadata, identification systems, research communities, educational users, public audiences, and platform operators. Each component performs a distinct function, but the overall effectiveness of the ecosystem depends on the quality of their interaction. A technologically advanced repository cannot compensate for poor metadata, just as high-quality metadata cannot provide sustainable preservation if storage and institutional responsibility are unstable.

The ecosystem perspective also changes the understanding of the cultural object itself. A physical artefact is usually encountered in a specific institutional and spatial context, while its digital representation can circulate between several contexts. A single object may be described in a catalogue, linked to a person or event, included in a thematic exhibition, indexed by a search engine, used in educational materials, and processed by computational tools. Each new connection adds communicative value but may also create a risk of decontextualization. Therefore, the preservation of digital heritage requires not only the integrity of a digital file but also the preservation of information about its origin, provenance, meaning, and relations with other resources.

Another structural feature is the distributed character of contemporary digital heritage. Collections are often created and maintained by different institutions, located in different regions, and governed by different technical procedures. Integration is possible only when common rules allow systems to exchange descriptions and identify resources consistently. Interoperability should therefore be understood not simply as a technical property of software but as an organizational agreement about data structures, identifiers, metadata, access procedures, and responsibilities. This explains why European digital heritage initiatives place considerable emphasis on coordination and standardization.

1.2. Institutional Roles and Responsibilities

Libraries, archives, and museums occupy a special position within the ecosystem because they combine custodianship, description, expertise, and public communication. Their role is no longer limited to protecting physical collections. They increasingly create digital surrogates, maintain electronic catalogues, curate online exhibitions, provide research interfaces, and support the reuse of cultural data. In this environment, the institution becomes an information mediator that determines how an object is described and under what conditions it can be discovered and interpreted.

Institutional responsibility also extends to the sustainability of digital resources. A digital collection must remain intelligible when software, storage technologies, interfaces, or organizational structures change. This requires long-term planning rather than project-based digitization alone. Preservation strategies consequently need procedures for backup, version control, metadata maintenance, integrity checking, migration, and documentation of technological dependencies. From the ecosystem perspective, these procedures are part of communication continuity because they ensure that information remains usable by future researchers and audiences.

Professional expertise is equally important. Automated systems can accelerate classification and description, but cultural heritage information often contains ambiguity, historical terminology, multilingual material, incomplete provenance, and context-dependent meanings. Human specialists therefore remain responsible for evaluating automated results and resolving cases that cannot be reliably handled by general algorithms. The institutional model should consequently combine automation with expert review, rather than presenting artificial intelligence as an independent authority on cultural meaning.

1.3. Users, Access, and Participation

The communicative effectiveness of digital preservation can be assessed partly through the possibilities it creates for different categories of users. Researchers require precise metadata, stable identifiers, downloadable or machine-readable data, and reliable provenance information. Educators need understandable descriptions and materials that can be incorporated into learning environments. General audiences benefit from intuitive interfaces,

contextual explanations, visualization, and multilingual access. These requirements are different, yet a well-designed ecosystem can support them through layered access rather than through a single universal interface.

Participation adds another dimension. Users may contribute annotations, corrections, transcriptions, translations, contextual information, or links to related materials. Crowdsourcing can therefore expand the informational value of a collection, especially when institutions possess large volumes of materials that cannot be processed manually within a reasonable period. At the same time, participatory mechanisms require moderation and provenance tracking. Contributions should be distinguishable from authoritative institutional descriptions, and mechanisms for correction should be transparent. Participation is valuable when it strengthens the reliability and contextual richness of the collection rather than simply increasing the quantity of user-generated information.

Access should also be considered together with cultural sensitivity and legal restrictions. Not every heritage resource can be openly reproduced or freely reused. The ecosystem must therefore incorporate differentiated access regimes, rights information, and explanations of restrictions. This is particularly relevant when collections contain sensitive personal data, sacred or community-specific materials, or objects whose circulation requires contextual safeguards. Thus, accessibility and responsibility should be treated as complementary principles rather than mutually exclusive goals.

The transformation of cultural heritage preservation requires a theoretical framework capable of explaining the interaction between technological infrastructures, information flows, institutional actors, and users. The concept of communication ecosystems provides such a framework by interpreting cultural heritage not as a static collection of artefacts but as a dynamic informational environment in which cultural institutions, technological platforms, researchers, and audiences interact through digital channels.

From the perspective of information science and digital humanities, digital heritage infrastructures can be understood as complex knowledge systems structured through metadata standards, semantic relations, interoperability protocols, and repositories. These elements make it possible to integrate heterogeneous collections into unified environments and to

support both long-term preservation and new forms of interpretation and public engagement [1; 3].

The communication dimension is equally important. Libraries, archives, and museums increasingly operate as active nodes within broader information networks. They curate digital collections, manage metadata, facilitate access, support research, and mediate communication between cultural resources and diverse audiences. Consequently, the societal value of digital heritage depends not only on technical preservation but also on discoverability, accessibility, contextualization, and user participation.

Ethical considerations constitute another component of the ecosystem. The expansion of digital platforms and artificial intelligence raises questions concerning transparency, cultural sensitivity, responsible interpretation, and the governance of knowledge production. Therefore, technological innovation should be accompanied by institutional practices that preserve informational integrity and cultural responsibility [7].

The communication-ecosystem approach thus makes it possible to analyze technological infrastructures, institutional strategies, ethical principles, and communication dynamics as interconnected elements of a single system. Within such ecosystems, cultural heritage becomes an active component of knowledge exchange rather than a passive object of preservation.

2. European Digital Heritage Model

2.1. Europeana as an Integrative Platform

The Europeana model is significant because it demonstrates the value of aggregation. Instead of requiring every cultural institution to build a single central repository, aggregation allows distributed collections to remain institutionally managed while their descriptive information becomes discoverable through a common environment. This configuration supports both decentralization and visibility. The participating institutions retain responsibility for their collections, while the aggregation layer creates additional opportunities for cross-collection search, thematic discovery, and international circulation [5].

The main methodological lesson of aggregation is that integration does not necessarily mean physical centralization. Digital heritage can be connected through metadata, persistent identifiers, semantic relationships,

and harvesting mechanisms. Such an approach reduces duplication of infrastructure and makes it possible to preserve institutional diversity. At the same time, aggregation creates a dependency on common standards and quality-control procedures. If descriptions use incompatible structures or inconsistent terminology, the integrated environment becomes less useful for both human and machine discovery.

The communicative function of the Europeana model is equally important. Aggregated resources can be incorporated into exhibitions, educational projects, research workflows, and public cultural communication. A digital heritage platform therefore acts not merely as a catalogue but as an intermediary between collections and multiple communities of users. This intermediary role is one of the main reasons why the European experience is relevant for the Ukrainian context: it demonstrates how national and local resources can acquire wider visibility without eliminating the identity of the institutions that created them.

2.2. National Platforms and Cooperation

National digital heritage platforms complement transnational infrastructures by organizing resources within a specific legal, linguistic, cultural, and institutional environment. The Deutsche Digitale Bibliothek illustrates this principle through the integration of materials from German cultural institutions and the creation of a common discovery environment [3]. The national level can therefore perform functions that are difficult to organize exclusively at the international level: coordination of domestic institutions, development of common professional practices, adaptation to national legislation, and preservation of linguistic and historical context.

Cooperation among libraries, archives, museums, universities, and research centers is a decisive condition for such platforms. Digital heritage crosses institutional boundaries because the same historical phenomenon may be documented in books, manuscripts, photographs, museum objects, audiovisual records, maps, and scholarly publications. If each type of material remains isolated in a separate information environment, users receive only fragments of the available evidence. Interoperable platforms can reconnect these fragments and support a more comprehensive interpretation of cultural phenomena.

Institutional cooperation also has a resource dimension. Digitization equipment, storage capacity, metadata expertise, preservation specialists, and software development require significant investment. Coordinated infrastructures allow institutions to share knowledge, develop common solutions, and avoid unnecessary duplication. For countries with uneven institutional capacity, this model is particularly important because a network can combine strong national centers with smaller regional or specialized collections.

2.3. Metadata and Interoperability Principles

Metadata performs several functions simultaneously: identification, description, discovery, contextualization, management, and preservation. In a communication ecosystem, metadata is the language through which otherwise heterogeneous collections can become interoperable. A common metadata framework makes it possible to compare records, harvest descriptions, establish links, and expose resources to external discovery services. The value of standardization therefore extends beyond cataloguing practice; it determines the extent to which digital cultural heritage can participate in wider information exchange.

Interoperability should be developed at several levels. Syntactic interoperability concerns the ability of systems to exchange data in compatible structures. Semantic interoperability concerns the interpretation of concepts and values used in descriptions. Organizational interoperability concerns agreements between institutions about responsibilities, workflows, access, and data quality. A technically compatible interface is insufficient if participating institutions use incompatible meanings or have no procedures for maintaining shared data. Sustainable interoperability consequently requires coordination of technology, semantics, and governance.

Metadata quality also affects the future use of artificial intelligence and other computational methods. Algorithms require structured and sufficiently consistent data for classification, entity recognition, semantic linking, and retrieval. Poorly described collections are harder to process automatically and harder for users to understand. Metadata investment therefore creates cumulative value: it improves current discovery while also increasing the capacity of the collection to participate in future digital research environments.

2.4. Artificial Intelligence and Participation

Artificial intelligence introduces a new stage in the development of digital heritage infrastructures. Optical character recognition can transform scanned historical texts into machine-readable material; image recognition can assist in identifying visual features; automated classification can reduce the time required to organize large collections; and semantic processing can establish relationships between entities, places, dates, and subjects. These applications are especially relevant when institutions hold large quantities of material that cannot be processed manually at the same speed.

However, the introduction of AI creates a distinction between computational efficiency and epistemic reliability. An automatically generated transcription may contain errors; a classification model may reproduce biases present in training data; semantic enrichment may assign an inappropriate category; and image recognition may confuse visually similar objects. Cultural heritage institutions therefore need procedures for confidence assessment, expert verification, correction, and documentation of automated interventions. Responsible AI in heritage should be understood as a controlled institutional process rather than a simple deployment of software.

Participatory technologies can complement AI by combining automated processing with human contribution. For example, specialists or users can correct machine-generated transcriptions, while uncertain classifications can be reviewed through collaborative annotation. This combination can create a feedback loop in which computational systems accelerate routine work and human participants improve the quality of difficult or context-sensitive cases. Such hybrid models are particularly promising for large-scale collections, if provenance and editorial responsibility remain visible.

European countries have developed digital heritage models based on institutional cooperation, technological standardization, interoperability, and communication-oriented strategies. These models increasingly move beyond isolated digitization projects toward coordinated infrastructures that support research, education, preservation, and public engagement [11].

One of the most influential initiatives is Europeana, which aggregates digital resources from museums, archives, libraries, and audiovisual collections across Europe [5]. Its model demonstrates how standardized metadata and shared digital infrastructures can integrate heterogeneous

cultural objects into a common semantic environment. Such integration facilitates cross-collection search, thematic aggregation, contextual interpretation, and international visibility.

At the national level, comparable approaches are implemented through coordinated digital library initiatives. The Deutsche Digitale Bibliothek, for example, integrates collections from German cultural institutions through a unified portal and emphasizes decentralized content management, interoperability, and collaborative metadata development [3]. National platforms can therefore function as intermediaries between local collections and transnational digital heritage infrastructures.

Standardized metadata frameworks and interoperability protocols are central to this model because they enable automated harvesting, cross-platform integration, and semantic linking between collections. They also reduce fragmentation and make it possible for researchers to work with integrated datasets across institutional and national boundaries.

Technological innovation further strengthens these infrastructures. Artificial intelligence can support automated classification, optical character recognition, image recognition, semantic enrichment, and large-scale processing of cultural data. At the same time, participatory approaches such as crowdsourcing, collaborative annotation, and educational tools allow users to contribute to knowledge production. European experience therefore demonstrates that sustainable digital preservation requires the combination of infrastructure, institutional coordination, technological innovation, and public participation.

3. Digital Preservation in Ukraine

3.1. Wartime Risks and Cultural Resilience

For Ukraine, digital preservation has acquired an additional dimension because the physical survival of cultural collections cannot always be guaranteed. Armed conflict can damage buildings, destroy storage environments, interrupt electricity and communications, displace specialists, and make access to collections impossible. In such conditions, a digital copy may become more than a convenience for remote access: it can represent a form of risk reduction and continuity of cultural memory. This does not make digitisation a substitute for the physical object, but it changes the urgency and strategic value of digital preservation.

The resilience perspective requires institutions to think in terms of multiple layers of protection. A single digital copy stored in the same physical location as the original collection remains vulnerable to the same event. Distributed repositories, geographically separated backups, controlled replication, and documented recovery procedures reduce this concentration of risk. The objective is not simply to possess copies but to ensure that copies remain authentic, identifiable, accessible, and technically usable after disruption.

Wartime preservation also has a communicative dimension. When physical institutions are inaccessible, digital collections can maintain connections among researchers, displaced communities, educators, citizens, and international partners. Online access can help document cultural losses, preserve evidence, support scholarly work, and maintain continuity in public narratives. Digital heritage thus becomes part of cultural resilience because it helps institutions continue their social and informational functions under extraordinary conditions.

3.2. National Research Libraries as Nodes

The V. I. Vernadsky National Library of Ukraine illustrates the role that a national research library can play within a resilient digital knowledge infrastructure. Electronic collections, bibliographic databases, and information-analytical resources create channels through which scholarly and cultural information can remain available even when traditional communication conditions change [13]. The library can therefore be understood not only as a repository but also as a node connecting collections, researchers, institutions, and users.

This role places particular emphasis on the integration of bibliographic and digital-heritage functions. A digital object becomes more valuable when it can be connected with publications, authors, historical events, subjects, and related collections. Research libraries possess expertise in description, authority control, bibliographic linking, and information retrieval that can support this integration. Strengthening such functions would help Ukrainian digital heritage move from isolated collections toward interconnected knowledge environments.

National institutions can also contribute to professional coordination. Common recommendations for digitization quality, metadata, identifiers, storage, and access can reduce fragmentation among regional and specialized

institutions. Coordination does not require complete centralization. Instead, it can establish shared principles while allowing individual institutions to retain responsibility for their collections and adapt workflows to local conditions.

3.3. Institutional and Technological Constraints

The development of Ukrainian digital heritage faces several constraints identified in the study: fragmented digitization initiatives, uneven technological capacity, limited resources, and insufficiently coordinated standards. These constraints reinforce one another. When institutions work independently, standards may diverge; divergent standards increase the cost of integration; high integration costs reduce incentives for cooperation; and limited resources make it difficult to correct accumulated inconsistencies. A strategic response therefore needs to address the system rather than a single technical problem.

Resource limitations make prioritization necessary. Institutions cannot digitize every collection simultaneously or implement every emerging technology. A rational strategy should distinguish materials according to cultural significance, physical vulnerability, demand, uniqueness, and feasibility of processing. Priority-based planning can ensure that scarce resources produce the greatest preservation and communicative effect. The same principle applies to metadata: improving the description of high-value collections may generate more immediate benefits than attempting to process all records to an identical level at once.

Technological resilience also requires attention to infrastructure independence and maintainability. Digital preservation systems should not depend excessively on undocumented proprietary configurations or on a single specialist, whose departure would interrupt the workflow. Documentation, staff training, interoperable formats, and clear institutional procedures are therefore as important as hardware and software. Sustainability is fundamentally an organizational property supported by technology, not a technological property alone.

3.4. International Integration and Sovereignty

International cooperation can strengthen Ukrainian digital preservation through shared expertise, infrastructure, standards, training, and access to

wider discovery environments. Integration with European initiatives may increase the visibility of Ukrainian collections and facilitate scholarly exchange. It can also provide opportunities to preserve metadata and copies of selected resources in distributed environments, reducing the risk associated with the concentration of digital assets in one national infrastructure.

At the same time, international integration should not be equated with loss of national control. Cultural heritage carries historical, linguistic, and symbolic meanings that require national and institutional responsibility. Ukraine therefore needs an approach that combines openness with sovereignty: resources should be made interoperable where this supports research and cultural communication, while provenance, rights, contextual information, and institutional authority remain protected. The appropriate model is cooperation through clearly defined rules rather than uncontrolled export of cultural information.

This balance is especially important for metadata and identifiers. Once Ukrainian collections become part of international aggregation systems, descriptions may be copied, transformed, translated, or enriched by external platforms. National institutions should consequently maintain authoritative records and clear mechanisms for updating information. In this way, international interoperability can expand the circulation of Ukrainian cultural heritage without weakening the ability of Ukrainian institutions to govern its description and contextualization.

Digital preservation of cultural heritage in Ukraine has become strategically important under conditions of military aggression and large-scale threats to cultural infrastructure. Armed conflict creates risks of physical damage, loss of documentation, disruption of institutional communication networks, and irreversible destruction of collections. Digital preservation therefore functions not only as a technological activity but also as a mechanism of cultural resilience and protection of national memory [10; 14].

Digital technologies enable cultural institutions to mitigate these risks through virtual copies, distributed repositories, and remote-access systems. Such infrastructures can maintain continuity of cultural communication even when traditional institutional environments are disrupted. In wartime

conditions, digitization consequently acquires an emergency-response function in addition to its traditional preservation role.

The V. I. Vernadsky National Library of Ukraine occupies an important position in this process. Its electronic collections, bibliographic databases, and information-analytical resources demonstrate the capacity of a national research library to support access to cultural and scholarly information under changing conditions [13]. The development of such resources contributes to the formation of resilient digital knowledge infrastructures.

The wartime context also accelerates interest in artificial intelligence and automated data processing. AI-based systems can assist with text recognition, metadata generation, classification, and the processing of large archival collections. Nevertheless, technological solutions should not be treated as substitutes for institutional governance. Effective digital preservation also depends on standards, professional expertise, resource allocation, communication strategies, and international cooperation.

International collaboration is particularly important for Ukraine. Joint digitization projects, data-sharing initiatives, and cooperation with European partners can improve interoperability and strengthen the integration of Ukrainian cultural heritage into wider communication ecosystems. At the same time, fragmented digitization, uneven technological capacity, limited resources, and the absence of sufficiently coordinated national standards remain significant challenges. European practices should therefore be adapted selectively to Ukrainian institutional and wartime realities.

4. Directions for Adaptation

4.1. Coordinated National Strategy

The first direction for adaptation is the development of a coordinated national strategy that defines priorities, standards, responsibilities, and mechanisms of cooperation. Such a strategy should not simply prescribe a single technical platform. Its purpose should be to establish a common framework within which libraries, archives, museums, universities, and research institutions can develop compatible digital resources. The framework should identify minimum requirements for digitization quality, metadata, persistent identification, storage, preservation copies, access, and documentation.

Coordination should be accompanied by an inventory of existing digital collections and digitization projects. Without a clear overview of what has already been created, institutions may duplicate work or overlook valuable collections. An inventory can also reveal differences in metadata structures, formats, access conditions, and levels of preservation readiness. This information would provide a practical basis for prioritizing harmonization and integration efforts.

4.2. Distributed Preservation Infrastructure

The second direction concerns distributed preservation. A resilient architecture should separate the locations and, where possible, the organizational dependencies of original collections, working copies, preservation copies, and public-access services. Replication reduces the probability that a single incident will eliminate both the cultural object and its digital representation. It also creates opportunities for cooperation with trusted national and international partners.

Distributed preservation should be accompanied by integrity and recovery procedures. Institutions need mechanisms for checking whether files have changed unintentionally, documenting versions, recording preservation actions, and testing the restoration of data. A backup that has never been tested cannot be considered a fully reliable preservation measure. Consequently, resilience is achieved through a combination of redundancy, monitoring, documentation, and regular recovery exercises.

4.3. Responsible AI-Assisted Processing

The third direction is the controlled introduction of artificial intelligence into heritage workflows. Priority applications include OCR, transcription, classification, entity extraction, semantic enrichment, translation support, and image analysis. The greatest benefit can be expected where collections are large and repetitive processing consumes significant professional time. AI should therefore be positioned as an instrument for increasing institutional capacity rather than as a replacement for domain expertise.

A responsible workflow should distinguish machine-generated information from verified institutional metadata. Records may include confidence indicators, processing history, and a mechanism for correction. Human review should be mandatory for high-impact interpretive decisions

and for culturally sensitive materials. Such procedures make it possible to benefit from automation while maintaining transparency and accountability.

4.4. Communication and Public Value

The fourth direction is the strengthening of the communicative function of digital collections. A successful digital heritage resource should answer not only the question of where an object is stored but also why it matters, how it is related to other objects, and how different audiences can use it. Contextual descriptions, thematic collections, timelines, maps, educational materials, and multilingual interfaces can transform a repository from a storage-oriented service into an environment for knowledge exchange.

Public value should also be evaluated through actual patterns of use. Analytics can show which collections attract researchers, educators, students, and general audiences, while qualitative feedback can identify difficulties that cannot be captured by numerical indicators. Such evidence can inform future digitization priorities and interface development. The communication ecosystem therefore creates a feedback relationship between preservation decisions and public demand.

4.5. Research and Education Integration

A further direction is the closer integration of digital heritage with research and education. Machine-readable collections can support digital humanities, historical research, linguistic analysis, corpus construction, visual studies, and interdisciplinary projects. Educational access can encourage students to work directly with primary cultural materials rather than relying exclusively on secondary summaries. This expands the social function of preservation because digitized heritage becomes an active resource for knowledge production.

For this purpose, institutions should consider not only presentation interfaces but also research-oriented access. Stable identifiers, structured metadata, downloadable datasets where legally appropriate, APIs, and clear reuse conditions can facilitate scholarly work. The resulting ecosystem connects preservation with new forms of analysis and interpretation, creating additional reasons to maintain and improve digital collections over the long term.

The comparison of European and Ukrainian practices indicates several directions for further development. First, Ukraine needs stronger coordination of digitization initiatives and the gradual harmonization of metadata and interoperability standards. Second, distributed preservation infrastructures should be developed to reduce dependence on individual physical locations and institutional systems. Third, digital heritage resources should be designed for integration into European and international platforms where appropriate.

A further direction concerns the responsible use of artificial intelligence. AI can substantially increase the efficiency of processing large collections, but its application should remain subject to professional verification, transparency, and ethical governance. Automated classification and semantic enrichment should support, rather than replace, expert interpretation and institutional responsibility.

Finally, the communication function of digital heritage requires greater attention. Digital collections should not be conceived merely as storage systems. Their effectiveness depends on discoverability, contextual information, accessibility, user participation, and the ability to connect cultural resources with research, education, and public communication. In this sense, the development of digital heritage in Ukraine should combine technological resilience with institutional and communicative resilience.

CONCLUSIONS

The analysis permits a more detailed formulation of the relationship between digital preservation and communication. Preservation is not completed at the moment when a high-quality digital image or scan is produced. The digital representation acquires long-term value only when it is embedded in a sustainable environment of description, storage, identification, access, contextualization, and institutional responsibility. The communication-ecosystem model makes these dependencies visible and therefore provides a more comprehensive framework for evaluating preservation strategies.

First, the theoretical analysis confirms that digital cultural heritage should be understood as a dynamic information environment. Its components include not only digital copies of physical objects but also metadata, semantic links, repositories, interfaces, professional practices, and user

interactions. The value of a digital collection is consequently relational: it increases when resources can be connected, discovered, interpreted, and reused without losing their provenance and context.

Second, the European experience demonstrates the practical importance of interoperability and institutional cooperation. Europeana and national platforms show that distributed collections can acquire transnational visibility without requiring complete centralization. The essential condition is the existence of common descriptive and technical principles. Metadata standardization therefore represents a strategic infrastructure for communication, not merely a cataloguing requirement.

Third, artificial intelligence should be incorporated into digital preservation selectively and responsibly. Its capacity to process large volumes of material can significantly expand institutional productivity, especially in OCR, classification, transcription, image analysis, and semantic enrichment. However, automated results remain subject to error and contextual limitations. Professional verification, transparent workflows, and preservation of processing history are therefore necessary to maintain the reliability of cultural information.

Fourth, the Ukrainian situation gives digital preservation an additional function of cultural resilience. Under wartime conditions, digitization and distributed storage can reduce the consequences of physical destruction and maintain access to knowledge when institutions or collections are temporarily inaccessible. The strategic value of digital preservation in Ukraine is thus broader than technological modernization: it concerns continuity of cultural memory, scholarly communication, public access, and institutional resilience.

Fifth, the analysis indicates that the principal Ukrainian challenge is systemic fragmentation. Separate projects may produce valuable digital objects, but without common standards and coordination, their long-term integration remains difficult. The development of a national framework should therefore focus on shared principles, inventories of existing resources, compatible metadata, persistent identifiers, distributed preservation, and mechanisms for cooperation among institutions with different levels of technological capacity.

Sixth, the role of national research libraries deserves particular attention. Their expertise in bibliographic description, information retrieval,

scholarly communication, and digital collections allows them to function as coordinating nodes between cultural heritage and research infrastructures. Strengthening this role could support the transition from isolated repositories toward interconnected national knowledge ecosystems.

Seventh, European practices should be adapted rather than copied. Institutional structures, resource availability, wartime risks, linguistic requirements, legal conditions, and national priorities shape the Ukrainian environment differently. The most transferable elements are therefore methodological: interoperability, distributed preservation, shared standards, institutional cooperation, responsible automation, and communication-oriented access. Their implementation should be phased and prioritized according to risk and cultural significance.

The prospects for further research are associated with moving from conceptual analysis to measurable implementation models. Future studies should develop criteria for evaluating the maturity of Ukrainian digital heritage infrastructures, compare metadata practices across institutions, analyze the effectiveness of distributed preservation architectures, and assess the reliability of AI-assisted processing for Ukrainian-language and multilingual collections. It is also important to investigate user behavior in digital heritage environments and determine which forms of contextualization and participation most effectively support scholarly, educational, and public use.

Another promising direction is the development of mechanisms for sustainable international integration. Research should address how Ukrainian collections can participate in European and global aggregation systems while retaining authoritative national metadata, provenance information, cultural context, and institutional control. The strategic objective should be an open but responsible ecosystem in which international visibility strengthens rather than weakens cultural and informational sovereignty.

Overall, the study supports the conclusion that the future of digital preservation depends on the convergence of technology, institutional governance, professional expertise, and communication. The most sustainable model is not a repository considered in isolation but a distributed ecosystem in which cultural institutions exchange information through interoperable infrastructures, users participate in knowledge circulation, and technological tools remain subject to human and ethical oversight. For

Ukraine, this model offers a practical conceptual basis for strengthening cultural resilience and integrating national heritage into wider knowledge networks.

The study demonstrates that digital preservation of cultural heritage is most effectively understood as an integrated communication ecosystem rather than as a narrowly technical process. Digital heritage combines infrastructures, metadata, institutions, technologies, researchers, and users, and its sustainability depends on the interaction of these components.

European practice shows that interoperability, standardized metadata, distributed infrastructures, transnational platforms, and participatory mechanisms can significantly improve the preservation, accessibility, and circulation of cultural resources. Europeana and national digital heritage platforms illustrate the value of coordinated approaches that connect local collections with wider information ecosystems.

The Ukrainian case confirms that digital preservation has a specific strategic function under wartime conditions. Digitization, distributed repositories, electronic collections, and remote access can reduce the consequences of physical destruction and support continuity of cultural memory and knowledge communication. The experience of the V. I. Vernadsky National Library of Ukraine demonstrates the importance of national research libraries as resilient information institutions.

The study also identifies limitations that require further institutional development: fragmented digitization initiatives, uneven technological capacity, resource constraints, insufficiently coordinated standards, and the need for responsible governance of artificial intelligence. Consequently, European practices should not be copied mechanically; they should be adapted to Ukrainian institutional, technological, cultural, and security conditions.

Future research should focus on practical models for interoperable Ukrainian digital heritage infrastructures, harmonization of metadata standards, distributed preservation, responsible AI-assisted processing, and mechanisms for integrating Ukrainian collections into European and global information ecosystems while safeguarding cultural and informational sovereignty.

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