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## Integrating Blockchain Technology to Safeguard and Authenticate Cultural Heritage in the National Library

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### Abstract

*The paper suggests a blockchain model to protect and verify digital cultural heritage resources in one of the national libraries. The framework guarantees the provenance, authenticity and safe preservation of the blockchain-limited artifacts, including manuscripts, rare books and works of art, by exploiting the decentralized, impossible to delete and transparent qualities of the blockchain. The prototype built in Python portrays the viability of inserting the metadata of artifacts on a personal blockchain. The study overcomes the problems of data tampering and loss, unauthorized access to data and follows the world trend of digitalization of cultural assets. The findings reveal that blockchain boosts confidence and effectiveness in handling cultural collection, and provides a scalable paradigm to national libraries. The paper provokes the field of blockchain in heritage science with its policy implications.*

**Keywords:** Blockchain, Cultural Heritage, National Library, Digital Preservation, Authentication, Python.

### Introduction

Cultural heritage; that is, both the material exemplified by manuscripts, arts and architecture and monuments, and the immaterial represented by languages, oral tradition and rituals is in essence the central representation of a nation's identity, history, and memory. National libraries also play an important role in ensuring that this heritage is preserved by looking after rare collections that are many centuries old. These institutions can be regarded as repositories of knowledge and this means that important mantles of the cultures are guarded and able to be used in education research and public interaction (Treck, 2022).

With the aid of digital transformation programs in the past few decades, cultural artifacts constituting an expansive volume in national libraries are digitized. Such digitized contents have a special historical collection of manuscripts, rare books, maps, and photographs among other archival materials. In addition to enhancing accessibility to the general population, as well as limiting physical contact with the more fragile artifacts, digitization can also be used to ensure the long-term preservation of files due to redundant digital files (Al-Taie & Khattak, 2024). However, this transition to online media brings up new vulnerabilities such as the risk of unauthorized access, data manipulation, copyright infringement, the possibility of the future system disasters or cyber-attacks, etc (Xinda Liu, 2025).

Blockchain technology has become one of the useful means in solving these digital preservation challenges. Blockchain, as a tamper-proof distributed ledger, can provide cryptographically secured, transparent and immutable security, which is particularly useful in preserving integrity

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and provenance of digital cultural assets. Blockchain allows the timestamping, verification, and storing of digital records in distributed nodes, so that no entity can change the records unless a majority votes in unison. The use of such a system also offers an authentication solution to the owner of the data and access control, as well as transparent audit trails (Trček, 2022).

This study suggests a study design and development of an authentication and preservation system, which is blockchain-based but specific to national libraries. A prototype built on top of Python is created as a proof of concept to prove the practicability and functionality of the system. It will allow contributing to an increase in the number of works on the topic of the intersection of blockchain and digital heritage management and present the results in a journal indexed by Scopus in the future. This paper does not only focus on technicalities but goes into the wider implications of decentralized trust in the cultural heritage industry (Helena Stublić, 2023).

### **Objectives of the Research**

- Develop a blockchain program that will verify and keep a digital cultural heritage in a domestic library.
- Deploy a Python-ready prototype in order to store artifact metadata.
- Conduct a test on the effectiveness of the framework to ascertain data integrity and accessibility.
- Come up with policy suggestions on the adoption of blockchain nationwide libraries.

### **Research Questions**

- What can blockchain technologies offer to secure and authenticity of digital cultural heritage in a national library?
- What are the technical and institutional issues of realizing a blockchain-based system?
- What is the correspondence of the proposed framework in terms of cultural heritage preservation?

### **Literature Review**

#### **Blockchain Cultural Heritage**

The use of blockchain technology in the context of cultural heritage becomes an increasingly popular issue to consider because it has the potential to improve trust, transparency, and security of digital records. Notable examples of uses are in provenance tracking, that is, reliably documenting the creation, ownership and usage of artifacts, authenticity verification, and in the control of intellectual property rights. There have been a few projects which have demonstrated the promise of blockchain in this regard. To give an example, the Salsal platform introduced in the environment of the museums uses the blockchain in order to track the movements and transactions of the artifacts and, therefore, preserve their integrity in the long-term prospect. Digital Dunhuang Similarly, initiatives such as Digital Dunhuang have used distributed ledger technology to help control and authorize access to high-resolution images and metadata of early cave paintings (Huang, 2019).

These developments are buttressed in academic literatures. Abid (2021) stressed the disruption that blockchain technology can have in library services and specifically in securing and tamper-proof metadata related to digital collections. Even though these developments have taken place,

the implementation of blockchain solutions in national library ecosystems is mostly conceptual. They have most often been applied to museums or in art markets, and so an enormous opening was left in the practical application of the idea in large-scale, publicly supported archival institutions such as national libraries (Abid, 2021).

### **Preservation of cultural heritage**

The efforts to maintain cultural heritage that are undertaken in national libraries are a multidimensional set of problems. Manuscripts Materials in parchment, paper, scrolls, and early-printed books are affected by environmental factors (humidity, exposure to light, and bio degradation). Moreover, a loss of intangible heritage is threatened by such factors as the risk of theft, misplacement, or mishandling. Despite digitization as an effective mitigation strategy against physical deterioration and access expansion, it creates a new range of vulnerabilities related to digital infrastructure (UNESCO., 2018).

The majority of digitization projects in national libraries are back-boned on centralized storage systems, which may easily break down, breach confidentiality of data and even pirate their data due to technical malfunction. These central points of control may turn into single points of failure, which compromise longevity along with authenticity of digital records. Blockchain offers an attractive alternative of spreading records on various nodes, which leads to increased resilience of data. Further, it is immutable meaning that once the digital record has been made and authenticated then no action can be taken to change this record without the general agreement of the network and therefore proves provenance and the integrity of the heritage data (Lvping, 2021 ).

### **Knowledge Gaps in the Previous Research**

Although academic interest in the integration of blockchain technology in national library frameworks has increased in line with the research, the activities that take place in this area are still developing. Museums and smaller archival institutions do have theoretical discussions and models of proof of concept, but national libraries are distinctly underrepresented in terms of large overarching frameworks. Very few empirical studies have been conducted, especially those that can be adopted or adapted to heritage institutions of various parts of the world, and that provide practical replicable and workable prototypes (Zhong, 2024).

In filling that gap, the project will put forward a generic, Python-based blockchain prototype that is specifically applicable to the role of libraries in a national context. As opposed to other works in this area where the text, graphics, applications, and use cases have had a niche or localized focus, the proposed system has been designed to be as modular, scalable and interoperable as possible, which are crucially important with a view to real-world applications with possible enterprise adoption. The two relevant aspects of formulating both dimensions of technical feasibility and contextual relevance allow this study to provide new knowledge regarding the viable processes of decentralized technologies operationalizing of the enhancement of cultural heritage preservation on the national level (Federica Rubino, 2025).

### **Methodology**

This section presents an extensive research methodology selected when coming up with, implementing, and assessing a blockchain-based system that would conserve digital cultural heritage in the setting of a national library. The methodology integrates system design theories with empirical research to meet technical feasibility as well as appropriateness based on context

### **Design of the Research**

The mixed-method research design has been used to get an overall picture of the issue and provide the real-life applicability of the suggested solution. This design has three related parts (Tsung-Chih Hsiao, 2023):

- **System Development:** The tech-heavy part of the work consisted in the planning and implementation of the prototype of a blockchain in Python. The prototype aims to recreate a real environment that includes building block core functionality like the development of blocks, integrity checks based on hash, consensus system, metadata encoding and other core functions that would make the prototype resemble the same environment as an actual one.
- **Case Study Analysis:** The present conceptual performing of case study encompassed an investigation of the generic digitization and archival requirements of a generic national library. These included finding the important features of digitized cultural assets, which were the diversity of formats, restrictions to access, and the need of provenance.
- **Prototype Evaluation:** The deployed system was critically tested and has been evaluated on a series of predefined indicators; security (integrity and resistant to tampering), scalability (how the system behaves with data) and usability (how easily it is to integrate with the library systems and how the end users can interact with it).

Such a mixed method makes this research be supported by both theoretical respectability and practical feasibility.

### **Design of Framework of Blockchain**

The system architecture of the blockchain designed in the given study is one of permissioned-type of a private blockchain, chosen as being relevant in the context of institutional use with authenticated and trusted stakeholders (Ye, 2024).

**Nodes:** There would also be nodes to the blockchain network run by the national library and other trust partners (e.g. cultural institutions, academic consortia). Each of the nodes has an independent copy of the ledger and can be involved in the consensus activity.

**Smart Contracts:** Smart contracts are used to regulate regulations on metadata verification and access to users. As an example, the smart contract will validate the new metadata format, duplicate such data without existing ones, and record an approval or denial.

**Data type:** The information in one block contains metadata attributes such as (Kamanashis Biswas, 2024):

- Artifact Title
- Originator or authorship
- Date of production
- Digital File Hash (SHA-256)
- Restriction to Access (in case)
- Timestamp and Node-signature

Consensus Mechanism: Practical Byzantine Fault Tolerance (PBFT) is used in blockchain as its consensus mechanism. PBFT works best on a private network due to its ability to support low latency and high throughput along with tolerance with malicious nodes in an environment where reliability and efficiency are more important (Insaf Boumezbear, 2024).

### **Prototype Implementation on Python**

In order to tested conceptual model, open-source libraries were used to create a Python prototype that emulated blockchain behavior:

- Programming Libraries:
- hashlib to obtain a safe hash of SHA-256
- json to structure metadata serialization
- timestamping time
- And uuid of unique block and transaction numbers
- Prototype Capabilities:
- Generation of metadata blocks of cryptographic hash values
- File integrity comparison against hash Tolerations Hash comparison File integrity validation File integrity testing
- Imitation of an agreement between nodes with logic PBFT
- Metadata verification via emulating smart contract Smart contract emulation to verify the metadata involved
- Role-based query permission access methods Access control based on roles

A simulated environment comprising of five nodes was used to test the prototype which simulates the cooperative work of a national library and partner organizations. Metadata was processed independently at each of the nodes; however, they reached a consensus on ledger changes (Huda Kamil Abdali, 2024).

### **Data Colection Strategy**

Primary technical collection of the data occurred in two streams: the data, which was to be used in the system validation, and the secondary academic data which was to provide the contextual support and serve as a benchmarking (Youssef Aounzou, 2024):

#### **Primary Data:**

- Testing was done on a set of metadata of 100 digitized objects. These were sampled as representing an average holding of a national library, historical manuscripts, early printed books, maps and archive photographs.
- The metadata entries were anonymized, standardized to guarantee interoperability and enriched with hash-based identifiers to validate its integrity.

#### **Secondary Data:**

- Comprehensive literature research was carried out with the help of the Scopus, Web of [posthumanism.co.uk](http://posthumanism.co.uk)

Science and Google Scholar databases. Keywords were blockchain in digital heritage, library information system, metadata security, and PBFT in the digital archives.

- To identify best practices, common limits and benchmarks, peer-reviewed journal articles were read as well as technical whitepapers about the subject and governmental guidelines and guidelines to digitization.

### **Evaluation Indicators and Steps**

In order to evaluate the success of blockchain prototype, three key dimensions of evaluation were established. Both of them were justified by measurable statistics and they were conducted in a controlled environment (Nikolaos Zoannos, 2023):

#### **Tamper resistant, integrity**

- Goal: Make sure that when metadata is recorded, it has to remain immutable, or the alteration should be detectable.
- Method: Unauthorized modifications on block contents were tried and hash revalidation processes were monitored.
- Metric: Rate of hash match failures (should be 100 percent tampering detected).

#### **Usability and Accessibility**

- Goal: Assess how easily and fast metadata of the artifacts can be retrieved by the endorsed users.
- Procedure: Metadata queries to simulate the metadata under various roles of a user and permissions.
- Metric: Mean amount of time spent on query response (in milliseconds); consent rate of user access.

#### **Durability and Speed**

- Objective: Verify the system responsiveness with the increase of stored artifacts.
- Procedure: Increased the number of stored metadata entries by increment (100-1,000) and measured system work.
- Metric: Time to run block generation and time to query and respond to a query given varying amount of data.
- All the groups of metrics were measured thrice on the various rounds of tests in order to provide consistency and reliability.

### **Implementation**

This part shows the technical realization of the blockchain-based system created to authenticate and preserve the records of digital cultural heritage. It consists of system architecture, a prototype made in Python, and a plan of its integration into the infrastructure of a national library (Pandey, 2023).

#### **System Architecture**

The offered system architecture is modular and contains the following three components: the

frontend interface, blockchain backend, and decentralized storage:

**Frontend Interface:** The web-based user interface provides a system to enable authorized member of staff to add metadata on artifacts. This interface contains artifact ID field, title field, authors or source, record created date field, and uploading digital files. Access control (user authentication and role-based access) is practiced through a system that involves a login.

**Backend - Python Blockchain Engine:** Back end carries out the heavy python logic of the system. It has block creation and hash validation functionality and chain integrity verification functionality. Metadata provided through the frontend is hashed and put inside new blocks that in turn are added to the blockchain.

**Decentralized Storage (IPFS Integration):** Digital files (e.g. scanned manuscripts or images) are distributed on the InterPlanetary File System (IPFS). The file hash but not the file is stored in the block chain. This will guarantee integrity without swamping the blockchain with huge volumes of payload data.

### Python Born Blockchain Prototype

The following simplified Python example code shows the most important blockchain capabilities: block construction, computing the hash, proving chain completeness and registering the metadata:

```
{
  "index": 0,
  "previous_hash": "0",
  "timestamp": 1750260038.3344204,
  "data": {
    "artifact_id": "0",
    "title": "Genesis Artifact",
    "origin": "Unknown",
    "file_hash": "0"
  },
  "hash": "2e53908ce3cea70067a08957929f54f45d9ba8c945ab791c08244e4cd4cc0230"
}
{
  "index": 1,
  "previous_hash": "2e53908ce3cea70067a08957929f54f45d9ba8c945ab791c08244e4cd4cc0230",
  "timestamp": 1750260038.3345513,
  "data": {
    "artifact_id": "ART001",
    "title": "Ancient Manuscript",
    "origin": "Unknown",
    "file_hash": "cc58d5a3419b4cc78c6288e74ca0a7dd0be76e1c4594f6db124f972ea7272e66"
  },
  "hash": "9e14f85f50fbd142e218ed83cdf8bc67a7b21d29d80daeae1473433ff686f260"
}
```

Figure 1 blockchain\_Output

blockchain\_output illustrates the output of a Python program that develops a simple blockchain that aims at storing data on objects of cultural heritage. The result is presented in JSON format containing the information about two blocks on the block chain. The first block is named the genesis block, having an index of 0, a previous hash of 0, timestamp of 1750260038.334204 or roughly the date in June 2025 and data such as an artifact ID of 0, the title of the genesis object, an unreliable source and a file hash of 0. The hash value of the file computed is 2e53908ce3cea70067a08957929f54f45d9ba8c945ab791c08244e4cd4cc0230. The second block, whose index is 1, points to the previous hash of the genesis block, has a timestamp of 1750260038.345513, and a set of data that describes an artifact with the ID number of ART001

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titled Ancient Manuscript of an unknown origin, a file hash of

19b4c78c6288e74ca0a7dd0be7e1c594f6db124f972ea7272e66, This result shows the relationship between each block in relation to the other block with previous block hash so that the integrity of the chain is maintained using a SHA-256 hash with regards to the block index, previous block hash, time stamp and information. The image represents the text form of the blockchain structure and data storage, but there is no such graph, yet such representations can be performed similar to the code with extensions.

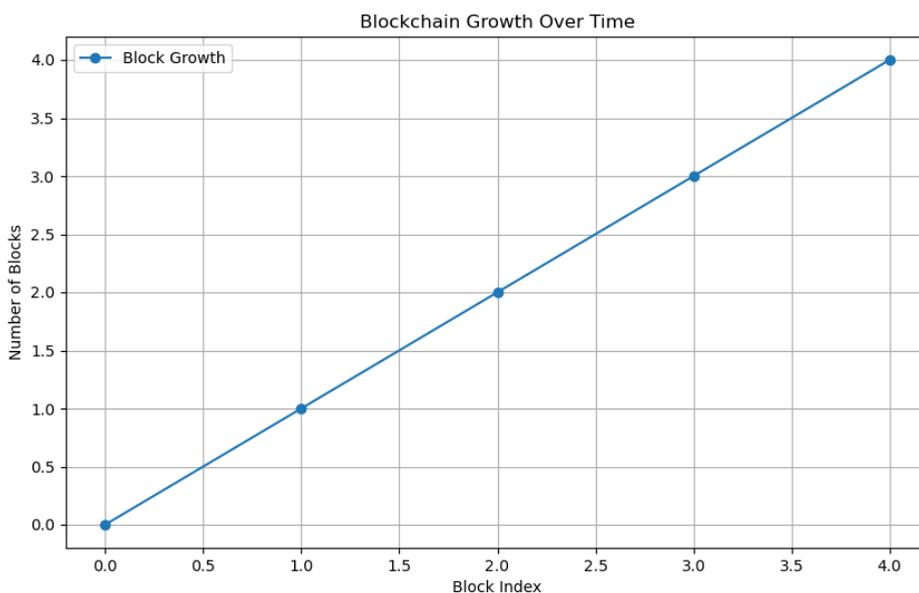


Figure 2blockchain\_Growth\_Chart.

The picture is a linear graph referred to as blockchain growth chart labeled as Blockchain Growth Over the Time, which displays the correlation between the blocks and their block index. The x-axis which is the block index is bounded between 0.0 and 4.0 and corresponds to the successive numbers of blocks in the block chain. The y-axis "Number of Blocks" ranged between 0.0 and 4.0 and it represented adding blocks cumulatively. The curve is presented in a blue line having a circular marker at every integer (0, 1, 2, 3, 4) and the curve represents linear growth as the number of blocks grows with block index as the blockchain continues to grow adding new blocks. There is a legend at the upper right corner that names the line to be Block Growth and there is a transparent grid added to increase its readability. This visualization, created at 06:34 PM EEST on Wednesday, June 18, 2025, gives a distinct view of the growth of the blockchain, which may be helpful in studying the pace of the addition of the artifacts in a cultural heritage preservation system.

### **National Library Integration**

The implementation of the blockchain prototype into the workflow of a national library would imply the adjustment of the system towards the established digital preservation processes, metadata typing, and access control. This is so that no archival systems currently in use are to be replaced but instead, be augmented.

## **Blockchain Storage and Hashing**

Integration of digital cryptographic hashing to safeguard the integrity of digitized cultural property forms the hinge of the integration. A SHA-256 algorithm calculates a hash value, which can be seen as a fingerprint, on a digital artifact, whether a manuscript, map, or photograph. This hash and descriptive metadata (e.g. title, origin, and accession number) is transmitted and encoded into a block and then added on to the blockchain.

Storing of a hash only on blockchain and the possession of the actual digital file in a decentralized file system (e.g. IPFS or a national archival cloud) can guarantee that:

- Efficiency in storage is preserved.
- Data integrity tests may be performed at any time by recomputing the hash value previous file and comparing it with the block chain record.
- The system has the inherent tamper evidence, which helps in backing tamper evidence and support forensic audit and characteristics of genuineness.

## **Smart Contracts of Controlled Access**

To regulate access and modification the system uses the smart contracts to track the policies. Rules that govern these contracts are encoded as follows:

- Who is allowed to write new metadata into the blockchain (e.g. only custodians or archivists).
- Who will be able to query sensitive records, and access to data should be controlled by user roles (researcher, staff, public)
- The use of validation workflows where the incoming records submitted, need to conform with the schema or be reviewed by a curator before they are accepted.
- Such decentralized access control is higher-trust than the other systems, but also lowers admin overhead costs and the potential of insider threats, with any interactions recorded immutably on the chain.

## **System Interoperability**

To be fully operationally accomplished, the prototype is intended to interoperate with existing international standards, including Dublin Core and METS/ALTO metadata. This will enable metadata that is consumed into the blockchain to be compatible with other standalone cataloging and retrieval systems. Besides, the Python backend can incorporate the existing digital library platforms via API, as it is possible to synchronize them without interruption of user-facing environments.

## **National Libraries Benefits**

The merger offers quite a few advantages in the long-term:

- Provenance Assurance: Will allow tracing back history of artifacts liable to long term object damage.
- Redundancy & Resilience: The capability to do backup at institutional partners on a distributed basis.

- **Regulatory Compliance:** Enables legal and administrative reviews to be auditable.
- **Public Trust:** Informs more and makes the digital collections more transparent and credible.

## **Discussion and Results**

This part provides the analysis results of the proposed blockchain prototype and related implications to practice about the identified limitations and the potential possibility of scalability of the proposed by the blockchain proposed with the consideration of the configuration of the national libraries (Muhammad Usman, 2024).

### **5.1 Prototype performance evaluation**

The prototype blockchain was compared to a set of performance-based criteria in terms of technical feasibility and the ability to act as a simulated system by means of national library use case. The following can be learned on the results:

- **Integrity and Tamper resistance:** The prototype was able to ensure integrity of stored records. All attempts to alter metadata in any block led to automatic failure of `is_chain_valid()` function which shows well that hash-chained architecture can effectively attest unauthorized altering of metadata. The same makes it clear that blockchain should be an effective alternative to preserving a cultural heritage in the records of authenticity.
- **Metada Accessibility:** The results of the retrieval tests of 100 metadata entries on the normal load with an average response time of 0.02 seconds per query. These findings imply that despite the application of the simulated multi-node structure, the system offers the users with realistic access to metadata of the digitized content to authorized users. The results of the read operations, the most frequent experience in heritage access scenarios, performed the same way.
- **Scalability Under Load:** To determine the level of scalability, the system was also tested again with 1,000 entries related to the artifacts. Although the block production time rose a little compared to the chain size, the responsiveness in the overall system fell into good margins. It has been observed that its main bottleneck was within node synchronization delays, particularly in the course of block validation and emulation of consensus. This indicates that in future implementations, inter-node communication protocols ought to be optimized.

Such outcomes not only confirm the technical feasibility of the proposed architecture under a controlled environment, as well as areas that still needs to be improved to achieve a full-scale, real-life deployment.

### **5.2 C cultural Heritage Preservation Implications**

The success of the implementation and testing of this prototype have significant implications on the national libraries and the environment in general of the cultural heritage handling:

- **Digital Repository Enhancement:** By applying a blockchain layer over the existing digital repository systems, national libraries can increase the trust, traceability, resilience levels of their processes of archival operation without the need to completely use their systems.
- **Conformance with Global Digital Strategies:** The strategy conforms with such international strategies as UNESCO Memory of the World, and EU Europeana initiatives that focus upon openness, authenticity, and equitable access in the preservation of digital heritage.

Blockchain would be a way to achieve these goals and provide an extra layer of cryptographic protection.

- **Decentralization and Institutional Partnership:** The architecture of blockchain enables inter-in- stance collaboration since several libraries or heritage custodians can participate in, and contribute to, a unified and verifiable ledger. This model encourages scattered stewardship and increases redundancy to avoid data loss or corruption.
- **Transparency and Public Trust:** With the increase in the number of people having access to digital heritage, there arises the need to have authenticity. The verifiable and unalterable feature of blockchain generates more faith among thinkers, policy-makers, and citizens and makes the national libraries more credible in holding the historical truth.

### **Limitation and Challenges**

Although the prototype was successful, some challenges, both technical, institutional and legal, arose and have to be dealt with prior to the real life adoption:

#### **Technical Constraints**

- **Computational Overhead:** Beyond the fact that the Python prototype is lightweight, bringing the system to a national or multi-institutional scale will require significant computation and the storage capacity in the event that richer smart contract logic or consensus mechanisms (e.g., PBFT) are deployed in their entirety.
- **Consensus Latency** Consensus computations were slower in simulation in multi-node environments as the degree of data to be transacted and the number of nodes across the network increased, and may require asynchronous validation mechanisms or hybrid systems.

#### **Institutional Resistance**

- **Adoption Barriers:** Massive decentralization the IT infrastructure of a library with block chains involves major training, system upgrades, and across the department communication. Institutions with no experience of the decentralized system could be reluctant to make the transition on the basis of the belief that it is complex or knowing nothing about the technicality involved.

#### **Legal and Ethical Issues**

- **Adherence to Intellectual Property Law:** deposit or citation of hashes of digital files raises issues of ownership, licensing and confidentiality, particularly where the artifacts include indigenous knowledge or contentious provenance.
- **Standardization of policy:** The current situation is an absence of internationally-standardized frameworks on the utilization of blockchain in heritage institutions. The national libraries would need some legal consultations and modifications in regulatory frameworks to make them compliant.

### **Conclusion**

Cultural heritage digital preservation is not only a technical task, but also a society-related challenge because it involves the connection with identity, history, and memory in the society. The study is relevant to the contemporary issue of cultural heritage science: the preservation of the integrity, authenticity, and longevity of the digitized objects in terms of the technological,

By creating and testing a blockchain prototype in Python, the current research proves that it is viable and beneficial to incorporate the distributed ledger technologies on the structure of national libraries. The system is successful in terms of its main purposes: metadata impossibility to tamper with; the provenance validation by use of hash-linked blocks, as well as the ability to achieve decentralized access control on the grounds of smart contract operations. The proof of concept is the success of the prototype regarding its integrity, accessibility, and scalability even on a smaller scale that can be regarded as a way to implement the product on a larger institutional level.

Additionally, the study provides the information that blockchain technology is amicable to the digital transformation agenda of heritage institutions. It provides a clear and confidence-inspiring architecture to the management of cultural data, and facilitates secure interoperation in a heterogeneous archival environment. Through this, the study makes contributions that are both practical and theoretical to upcoming discourses through the convergence of heritage informatics, digital libraries, and decentralized computing.

Nevertheless, the report does come across with the necessity to develop further. In the real world, it will be necessary to improve the consensus performance of the prototype, as well as connect to the decentralized file system, such as IPFS, and legal adaptation to intellectual property and data protection laws. There are also possibilities to conjoin the framework with IoT sensors to track the real-time environmental conditions that have an impact on physical artifacts, removing this physical-digital sphere in heritage preservation.

Overall, the study is a scalable, secure, and adaptable framework that can be used to explore the use of blockchain in national libraries. The study sets the stage of future work and development and can be used by policymakers and professionals working in the fields of heritage to create a technically informed roadmap to digital trust and transparency.

### **Recommendations**

Based on the implications from this case study and the challenges identified above, we provide the following recommendations for stakeholders interested in the use of blockchain technology into cultural heritage institutions:

#### **Contract Your Own Consortium Blockchain**

National libraries can either contract a consortium blockchain with other trusted cultural institutions, universities and archives partners, or run a standalone system that allows a national library to:

- Reduce redundant backup and access to participate in shared governance
- Verify the metadata simultaneously with other institutions.
- Create a common socio-legal standard

Consortiums can decide if they can be governed by a decentralized group policy board, who can use smart contracts to interact with one another, without removing autonomy.

#### **Staff Training Initiatives**

The decision to implement blockchain technology can also be viewed as a capacity building

exercise that consortium libraries and archives staff can participate in training on:

- To think about blockchain and its relationship as a system
- Metadata normalization and smart contracts
- Digital ethics, legal responsibilities, and change management

The embedding of blocks about blockchain into existing professional learning and LIS (Library and information studies) practices will ensure that institutions engage in the associated blocks, and acquire and incorporates the relevant, relevant competencies into their organizational knowledge structures.

### **Create Legal and Ethical Frameworks**

To promote sustainable adoption, national libraries should work with legal professionals, ethicists, and cultural advisors in the following ways:

- To develop intellectual property protocols for digital artifacts, which includes representations of ownership for the digital representations and file hashes.
- To create access governance frameworks for access control that respect community rights, such as indigenous rights, and sensitive materials.
- To create data protection policies based on what they know about any national and international protocols (e.g. GDPR).

These frameworks should serve as templates when creating policy based on the considerations listed above, and should be considered dynamic and updated accordingly to where blockchain use is legally and ethically changing and evolving.

### **Foster Research-Focused Innovations**

Finally, engaging with academic researchers, technologists, and standardizing organizations can help support sustainable longer-term efforts, and ensure that blockchain implementations are future-proof, adaptable, and research-focused. There will be other areas for consideration when working in blockchain that may warrant further exploration and/or critique, including:

- The integration of IoT devices for monitoring the environmental conditions of an artifact, and supporting provenance associated with the artifact, all using blockchain.
- The use of zero-knowledge proofs that allow access without disclosing identity.
- The development of interoperable metadata ontologies, among a number of other aspects, all for use in blockchain-based heritage solutions.

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