



Artificial Intelligence Guardians: Smart Digital Preservation in Academic Libraries

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Abstract

The growing volume of digital resources in academic libraries has intensified the need for sustainable preservation strategies. This study examined the extent of artificial intelligence (AI) application in digital preservation and its influence on the effectiveness of preservation strategies in academic libraries. A descriptive survey research design was adopted. The population comprised librarians and library personnel involved in digital preservation and information management across federal university libraries in Nigeria, from which a purposive sample of 31 respondents was drawn. Data were collected using a structured questionnaire. Descriptive statistics (mean and standard deviation) were used to answer the research questions, while Pearson correlation analysis was employed to test the relationship between AI application and digital preservation effectiveness at a 0.05 level of significance. The findings revealed a moderate level of AI application in digital preservation practices, with tools such as automated metadata generation and intelligent data management partially implemented. Digital preservation strategies were also found to be moderately effective. A significant positive relationship was established between AI application and preservation effectiveness, indicating that increased AI adoption enhances efficiency, accessibility, and sustainability of digital resources. However, major challenges identified include inadequate technical expertise, high cost of AI tools, infrastructural limitations, and lack of institutional policy support. The study recommends that academic libraries invest in AI-driven technologies, strengthen ICT infrastructure, and provide continuous training for librarians. It also emphasizes the need for institutional policies to guide the ethical and sustainable implementation of AI in library operations. This study provides empirical evidence on AI application and digital preservation effectiveness in academic libraries, contributing to the advancement of technology-driven preservation strategies in Library and Information Science.

Keywords: Artificial Intelligence, Digital Preservation, Academic Libraries, Machine Learning, Metadata Automation, Library and Information Science



Introduction

Libraries serve as the backbone of knowledge preservation and dissemination. The digital revolution has fundamentally transformed the way academic libraries acquire, organize, and disseminate knowledge. Traditional preservation methods that rely on physical storage and manual cataloguing have become inadequate for safeguarding the vast and ever-growing volumes of digital information. As libraries transition toward digital ecosystems, they face complex challenges such as data obsolescence, file format incompatibility, system failures, and security threats that endanger the long-term accessibility of scholarly materials (Oguche & Usman, 2022). To address these challenges, libraries increasingly turn to Artificial Intelligence (AI), a rapidly evolving field that simulates human cognitive processes to perform complex tasks such as learning, reasoning, and problem-solving (Russell & Norvig, 2021).

Artificial Intelligence (AI) refers to the ability of machines or computer systems to perform functions that typically require human intelligence, including perception, decision-making, and adaptation (Kaplan & Haenlein, 2019). AI systems are powered by algorithms that enable them to learn from data (machine learning), recognize patterns, and make autonomous predictions or classifications (Hassani et al., 2020). Within academic libraries, AI applications have diversified into various domains such as automated cataloguing, predictive analytics for resource management, intelligent search and retrieval systems, and digital preservation. AI offers innovative solutions to these challenges. AI encompasses systems that simulate human intelligence to perform tasks such as learning, reasoning, and problem-solving (Alam & Singh, 2023). It is being deployed to automate metadata creation, enhance digital curation, and predict file degradation patterns. Machine learning algorithms can identify and restore corrupted files, while natural language processing (NLP) assists in content classification and retrieval.

Digital preservation refers to the “series of managed activities necessary to ensure continued access to digital materials for as long as necessary” (Digital Preservation Coalition, 2019, p. 4). According to UNESCO (2020), it encompasses not just the storage of digital objects but also the technological, organizational, and managerial actions required to maintain their usability, authenticity, and integrity over time. In academic libraries, digital preservation ensures that digital asset such as institutional repositories, electronic journals, digitized manuscripts, and multimedia files remain accessible despite changes in hardware, software, or file formats. Digital



preservation encompasses the series of managed activities required to maintain access to digital materials over time, irrespective of the technological changes that may occur (Lavoie & Dempsey, 2021). The growing volume of born-digital and digitized content ranging from electronic theses and dissertations to institutional repositories demands advanced technological solutions that can guarantee sustainable preservation.

Despite these promising developments, the integration of AI in library operations particularly in developing regions, faces significant challenges. Limited funding, lack of technical expertise, infrastructural gaps, and ethical concerns regarding data privacy which hinder effective adoption (Ezeani, 2021; Ogunleye, 2023). Moreover, many libraries lack institutional frameworks or policies guiding the ethical and sustainable deployment of AI technologies. These constraints create disparities in technological advancement between libraries in developed and developing nations. Therefore, this study seeks to examine the relationship between AI applications and digital preservation strategies in academic libraries. It aims to explore how AI adoption influences the efficiency, sustainability, and accessibility of digital resources, as well as the challenges that affect its implementation. By analyzing AI-driven preservation models, the study contributes to a deeper understanding of how technology can support the long-term management and protection of digital scholarly assets.

Statement of the Problem

The rapid growth of digital information in academic libraries has intensified the need for effective digital preservation strategies to ensure long-term access and sustainability of scholarly resources. Although Artificial Intelligence (AI) has been identified as a viable solution for enhancing digital preservation through automation, predictive analysis, and intelligent data management, its adoption in many academic libraries particularly in developing regions, remains limited. This raises concerns about the ability of libraries to effectively manage increasing volumes of digital content using traditional or semi-automated methods. Moreover, there is insufficient empirical evidence on the extent to which AI has been integrated into digital preservation practices and whether such integration significantly improves preservation effectiveness. While existing literature highlights the potential benefits of AI, it remains unclear



how its application influences the efficiency, accessibility, and sustainability of digital resources in real-world library settings.

In addition, several challenges including inadequate funding, limited technical expertise, weak ICT infrastructure, and absence of clear policy frameworks, continue to hinder the effective implementation of AI in academic libraries. These constraints not only slow down adoption but also limit the realization of AI's full potential in digital preservation. Therefore, there is a need to examine the extent of AI adoption, its influence on the effectiveness of digital preservation strategies, and the challenges affecting its application in academic libraries.

Research Questions

1. What is the extent of Artificial Intelligence adoption in digital preservation practices in academic libraries?
2. How does the use of Artificial Intelligence influence the effectiveness of digital preservation strategies?
3. What are the major challenges hindering the application of Artificial Intelligence in digital preservation in academic libraries?

Review of Related Literature

Artificial Intelligence in Libraries

Artificial Intelligence (AI) adoption in libraries has emerged as a transformative trend reshaping information management, user services, and digital preservation. AI, as defined by Russell and Norvig (2021), refers to the simulation of human intelligence processes by machines, enabling them to learn, reason, and make decisions. Within library settings, AI technologies such as machine learning (ML), natural language processing (NLP), and intelligent automation are increasingly utilized to support cataloguing, information retrieval, recommendation systems, and preservation workflows (Rathore & Sharma, 2023). Globally, several studies have demonstrated a steady increase in the integration of AI applications in libraries. According to Khan and Bhatti (2022), AI tools enhance library efficiency by automating repetitive tasks such as metadata creation, plagiarism detection, and resource classification. Similarly, IFLA (2023) reported that AI adoption in libraries facilitates predictive analytics for digital preservation, enabling early



identification of at-risk files and improving long-term accessibility. Studies by OCLC Research (2022) further highlight the growing interest in AI-assisted metadata workflows, emphasizing their role in improving accuracy and scalability in preservation management.

In the African context, AI adoption in libraries remains in its nascent stage due to infrastructural and skill-related constraints. Ezeani and Ugwu (2022) observed that Nigerian academic libraries exhibit a positive attitude toward technological innovations but face barriers such as limited funding, lack of technical expertise, and poor awareness of AI capabilities. Despite these challenges, empirical evidence from Makori (2021) suggests that library professionals recognize the potential of AI to enhance digital preservation, particularly through intelligent file format migration and automated data validation. Overall, the literature underscores that while AI presents immense opportunities for libraries to optimize digital preservation, the extent of its adoption depends largely on institutional readiness, funding availability, and staff competence. Hence, continuous professional development and strategic investment are critical to realizing the full potential of AI-driven digital preservation in academic libraries.

Digital Preservation Strategies

Hedstrom (1998) was among the first scholars to emphasize that digital preservation is both a technological and policy-oriented process that involves long-term planning, standardization, and resource allocation. Beagrie (2019) adds that preservation must address both bit-level and logical preservation: bit-level focuses on maintaining the physical bits of data, while logical preservation involves maintaining the usability and interpretability of digital content over time. Digital preservation strategies encompass policies, actions, and technologies aimed at ensuring continued access to digital materials over time (Higgins, 2008). Core strategies include migration, emulation, metadata creation, and replication. With AI integration, these processes can be automated to improve scalability and precision.

In the context of digital preservation, AI technologies can also play crucial roles in metadata extraction (of library catalog card), anomaly detection, file format recognition, and digital curation (like curation of digital artworks including animation, visual media or computer aided design, e-books and written documents). (Alam & Singh, 2023). For instance, machine learning algorithms can automatically detect corrupt files or outdated formats, while natural language



processing (NLP) tools can improve metadata accuracy by interpreting document contents and generating descriptive tags. Deep learning models can also forecast the likelihood of hardware failure or data degradation, enabling proactive preservation measures. According to Kraska (2022), AI-driven preservation tools can enhance both the efficiency and reliability of archiving systems by reducing human error and automating repetitive processes. Furthermore, AI-based automation allows libraries to handle big data and complex digital collections more effectively. Through intelligent indexing and clustering, AI enhances retrieval precision and ensures long-term accessibility of scholarly resources (Chowdhury, 2020). This transformation supports the global movement toward smart libraries, where technologies such as AI, the Internet of Things (IoT), and data analytics converge to create adaptive, user-centered information environments (Kaur & Verma, 2022).

Challenges Hindering Artificial Intelligence Application in Academic Libraries

Although Artificial Intelligence (AI) has shown great potential to revolutionize academic library operations, its implementation faces numerous challenges that hinder widespread adoption, especially in developing regions. One of the most prominent barriers is the lack of technical expertise among library staff. According to Khan and Bhatti (2022), many librarians lack the computational and data science skills necessary to operate AI tools effectively, leading to resistance and underutilization. Similarly, Ezeani and Ugwu (2022) emphasize that most Nigerian academic libraries lack trained professionals who can integrate AI systems into existing digital preservation workflows. Another major challenge is inadequate funding and infrastructural deficits. Implementing

AI solutions requires significant investment in software, hardware, and network infrastructure (Makori, 2021). However, many institutions in developing countries struggle with limited budgets, making it difficult to acquire and maintain AI tools (Oduwole & Ekong, 2023). This financial limitation directly affects the sustainability and scalability of AI-driven initiatives. Ethical and data governance issues also present a major concern. AI systems used in libraries handles sensitive user data and digital heritage responsibly; however, the absence of clear ethical guidelines and privacy frameworks can deter adoption. Additionally, organizational resistance to change further compounds the problem. Staff members accustomed to traditional library



processes may perceive AI as a threat to their roles rather than an enhancement (Rathore & Sharma, 2023).

Finally, the lack of supportive policies and collaboration between stakeholders hinders integration. As observed by IFLA (2023), without national and institutional frameworks promoting AI adoption in library services, isolated initiatives often fail to achieve long-term impact. Collectively, these challenges underscore the need for a strategic approach, combining training, policy support, and investment to enable the effective application of AI in academic library systems. However, success depends on institutional readiness and resource allocation. However, successful implementation of these AI-driven strategies depends on institutional readiness, technological infrastructure, and librarian competence. As emphasized by Oguiche and Usman (2022), without adequate training and investment, the potential of AI in ensuring digital continuity cannot be fully realized.

Methodology

This study adopted a descriptive survey research design to examine the application of Artificial Intelligence (AI) in digital preservation strategies within academic libraries. The design was considered appropriate as it enabled the systematic collection and analysis of data based on the opinions and experiences of library professionals. The population comprised librarians and library personnel involved in digital preservation and information management activities across Federal University libraries in Nigeria, from which a purposive sample of 31 respondents was selected to ensure that participants possessed relevant knowledge and experience in AI applications. Data were collected using a structured questionnaire designed to capture information on AI adoption, effectiveness of digital preservation strategies, and associated challenges. The instrument was validated for clarity and relevance, and responses were analyzed using descriptive statistics, including mean and standard deviation, to address the research questions, while Pearson correlation analysis was employed to determine the relationship between AI adoption and the effectiveness of digital preservation strategies.

Results

Data Analysis and Findings

Total Responses: 31



Paired Cases for Correlation: 30

Overall Mean (AI Adoption): 2.952

Overall Mean (Effectiveness): 3.039

Pearson Correlation (r): 0.527 (p = 0.0027)

Research Question 1: What is the extent of AI adoption in digital preservation practices in academic libraries?

Table 1: Mean and Standard Deviation Scores of AI adoption

Items	N	Mean	SD	Interpretation
1. Our library currently uses AI or machine learning tools for digital preservation activities.	31	2.806	1.401	Moderate (>2.5 and <3.5)
2. AI tools are used in our library for metadata creation and organization of digital files.	31	3.032	1.402	Moderate (>2.5 and <3.5)
3. AI helps automate or speed up preservation-related tasks in our library.	31	2.935	1.366	Moderate (>2.5 and <3.5)
4. Staff in our library are aware of AI technologies for digital preservation.	31	3.032	1.332	Moderate (>2.5 and <3.5)

The four items measuring adoption (current AI use, metadata use, task automation, staff awareness) produced mean scores between 2.806 and 3.032 (on a 5-point scale). The overall adoption composite mean was 2.952, which falls in the moderate range. From the findings of the sample, academic libraries have begun to adopt AI tools particularly for metadata creation and awareness but adoption is not yet widespread or mature. The item “AI tools are used for metadata creation” showed the highest mean (~3.03), suggesting metadata-related use-cases are the most common early applications. Conversely, the overall moderate score suggests many institutions remain at pilot or early deployment stages rather than full integration.



Research Question 2: How does the use of AI influence the effectiveness of digital preservation strategies?

Table 2: Mean and Standard Deviation Scores of AI Effectiveness

Items	N	Mean	SD	Interpretation
5. Our library has a clear digital preservation policy or plan.	30	2.9	1.221	Moderate (>2.5 and <3.5)
6. AI has improved how we manage and preserve our digital collections.	29	3.138	1.224	Moderate (>2.5 and <3.5)
7. Our current preservation strategies ensure long-term access to digital resources.	29	3.103	1.269	Moderate (>2.5 and <3.5)

Effectiveness items (existence of a preservation policy, perceived AI improvement to management, and assurance of long-term access) averaged 3.039, a moderate score indicating participants perceive some benefit from AI to preservation effectiveness. Importantly, the Pearson correlation ($r = 0.527$, $p = 0.0027$) between the AI adoption composite and effectiveness composite shows a moderate, statistically significant positive association. This suggests that respondents who reported higher AI adoption also tended to report better effectiveness in digital preservation strategies. While correlation does not prove causation, the finding supports the idea that greater AI adoption is associated with improved perceptions of preservation practice effectiveness. The results indicated a moderate but positive perception of AI's effectiveness in improving digital preservation (overall mean = 3.04).

Research Question 3: What are the major challenges hindering the application of AI in digital preservation in academic libraries?

Table 3: Mean and Standard Deviation Scores of challenges hindering the application of AI

Items	N	Mean	SD	Interpretation
8. Our library management supports the integration of AI in preservation activities.	31	3.258	1.106	Moderate (>2.5 and <3.5)



9. Our staff have access to training or workshops on AI and digital preservation.	31	3.194	1.446	Moderate (>2.5 and <3.5)
10. Lack of technical skills is a major challenge to AI adoption in our library.	30	3.467	1.231	Moderate (>2.5 and <3.5)
11. The high cost of AI tools limits our ability to implement them.	30	3.4	1.227	Moderate (>2.5 and <3.5)

Items that measured institutional support and barriers showed the strongest concerns around lack of technical skills (mean ≈ 3.47) and high cost of AI tools (mean ≈ 3.40), both interpreted as moderate-to-high barriers. Management support and staff training items were slightly lower (management support mean ≈ 3.26 , staff training ≈ 3.19), indicating some managerial awareness but insufficient training opportunities. Open-ended responses corroborated these quantitative results: common free-text challenges reported included funding/finance, technical know-how/skills, and willingness to comply or organizational readiness. For benefits, common open-ended responses highlighted automation, improved metadata, and efficiency. Findings revealed that the lack of technical skills (Mean = 3.47) and high cost of AI tools (Mean = 3.40) were the most pressing constraints.

Discussion of Findings

The findings indicate that artificial intelligence (AI) technologies are gradually being introduced into library operations but have not yet been fully institutionalized. This aligns with the observations of Eze and Uzoagulu (2023), who found that most Nigerian academic libraries remain at the preliminary stages of AI integration, with applications largely limited to metadata generation and cataloguing. Similarly, Ifijeh and Osinulu (2021) emphasize that AI adoption in libraries across developing countries is constrained by infrastructural limitations and the slow



pace of innovation diffusion. The relatively higher adoption in metadata management observed in this study supports the argument by Musa and Onyancha (2022), who note that librarians perceive AI as most valuable when applied to repetitive and data-intensive tasks. Therefore, although AI adoption is emerging, it has not yet significantly transformed digital preservation practices across institutions.

Furthermore, respondents acknowledged that AI enhances the management and accessibility of digital collections, a finding consistent with Ezeani (2021), who reported that AI-based tools improve the efficiency and accuracy of preservation processes. More importantly, the study revealed a statistically significant positive correlation ($r = 0.527$, $p = 0.0027$) between AI adoption and digital preservation effectiveness, indicating that increased AI utilization is associated with improved preservation outcomes. This finding corroborates the works of Ngulube (2020) and Khan (2024), who highlighted that the integration of machine learning and automation facilitates proactive preservation strategies such as file format migration and metadata optimization. The result further reinforces the theoretical assumption that technological innovation plays a critical role in enhancing service delivery and operational efficiency in library management (Rogers, 2003).

Despite these benefits, significant challenges persist. The lack of technical expertise and the high cost of AI tools, identified as the most pressing constraints, mirror the findings of Okon and Ibenne (2022) and Oyelude (2021), who reported that funding limitations, inadequate infrastructure, and insufficient staff capacity remain major barriers to technological advancement in libraries. Although management support and training opportunities were rated at a moderate level, qualitative responses suggest that existing professional development initiatives are inadequate to meet the technical demands required for effective AI deployment. Respondents also highlighted persistent funding and policy gaps, supporting Igbinovia (2023), who observed that both national and institutional frameworks often lag behind emerging technologies, leaving libraries without clear strategic direction for AI adoption. While AI holds considerable potential for enhancing digital preservation in academic libraries, its full benefits remain largely unrealized due to structural, financial, and capacity-related constraints. Sustained investment in infrastructure, policy development, and continuous professional training is therefore essential to drive effective AI integration and achieve optimal digital preservation outcomes.



Conclusion

The increasing digitization of scholarly resources has fundamentally redefined the role of academic libraries, placing digital preservation at the center of sustainable information management. As libraries transition from traditional systems to complex digital ecosystems, the need for innovative, efficient, and scalable preservation strategies has become more urgent. This study was therefore necessary to address the growing concern over the limited integration of Artificial Intelligence (AI) in digital preservation practices, particularly within academic libraries in developing contexts, and to provide empirical evidence on its potential to enhance preservation outcomes. Overall, the study reveals a moderately progressive yet constrained landscape of AI application in digital preservation. Findings from both the literature and empirical analysis indicate that while AI technologies offer significant opportunities for improving metadata automation, data integrity, and long-term accessibility, their adoption remains at a moderate level. The study further establishes that digital preservation strategies in academic libraries are moderately effective, largely supported by conventional and semi-automated systems. Importantly, the results demonstrate a significant positive relationship between AI application and the effectiveness of digital preservation, confirming that increased AI integration enhances efficiency, accessibility, and sustainability of digital resources.

However, the study also identifies critical challenges including inadequate technical expertise, infrastructural limitations, high implementation costs, and the absence of clear policy frameworks which continue to hinder the full realization of AI-driven preservation systems. These findings align with existing literature that emphasizes the importance of institutional readiness, human capacity, and technological infrastructure in successful AI adoption. While AI holds substantial potential to transform digital preservation in academic libraries, its impact remains partially realized due to systemic and contextual constraints. Achieving sustainable and effective digital preservation will require a strategic combination of technological investment, capacity building, and policy support. By addressing these challenges, academic libraries can fully harness AI-driven innovations to ensure the long-term accessibility, integrity, and usability of digital scholarly resources.



Recommendations

1. Enhancement of AI Adoption in Digital Preservation

Given the finding that AI adoption in digital preservation remains moderate, academic libraries should move beyond partial implementation by strategically integrating AI tools into core preservation workflows. This includes adopting automated metadata generation systems, machine learning-based file monitoring, and intelligent archiving platforms. By doing so, libraries can bridge the identified gap in the limited extent of AI application in digital preservation practices.

2. Optimization of Digital Preservation Effectiveness through AI Integration

Since the study established that AI application positively influences the effectiveness of digital preservation strategies, libraries should fully leverage AI capabilities to improve efficiency, accessibility, and sustainability of digital resources. This can be achieved by embedding AI-driven solutions into existing preservation frameworks to enhance data integrity, retrieval accuracy, and long-term accessibility, thereby addressing the uncertainty regarding the actual impact of AI on preservation effectiveness.

3. Capacity Building and Technical Skill Development

In response to the identified challenges of limited technical expertise, academic libraries should implement continuous training and professional development programs focused on AI applications in digital preservation. Librarians should be equipped with skills in machine learning basics, metadata automation, and digital curation tools, ensuring that the knowledge gap highlighted in the study is effectively addressed.

4. Strengthening Infrastructure and Funding Support

To overcome infrastructural and financial constraints, institutions should prioritize investment in ICT infrastructure, including high-capacity storage systems, cloud-based preservation platforms, and AI-compatible technologies. Adequate funding mechanisms should be established to support the acquisition and maintenance of AI tools, thereby addressing the structural barriers identified in the study.

5. Development of Institutional Policies and Ethical Frameworks

Academic libraries should formulate clear policies guiding the adoption and use of AI in digital preservation, with emphasis on data privacy, security, and ethical considerations. Establishing



such frameworks will ensure responsible implementation and reduce uncertainties surrounding AI deployment, as highlighted in the study.

6. Promotion of Collaborative Partnerships

Libraries should seek collaborations with technology firms, research institutions, and funding agencies to facilitate knowledge sharing, technical support, and access to advanced AI solutions. Such partnerships will enhance institutional readiness and support the sustainable implementation of AI-driven preservation strategies.

7. Continuous Monitoring and Evaluation of AI Systems

To ensure long-term effectiveness, libraries should establish mechanisms for evaluating AI performance in digital preservation, using indicators such as accuracy, efficiency, and system reliability. Regular assessment will help refine implementation strategies and sustain improvements over time.

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