

Metadata Enrichment and Interoperability: Scoping Review of Artificial Intelligence Contexts in Metadata in Academic Libraries Experiences Across the Globe

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ABSTRACT

Artificial Intelligence (AI) offers significant opportunities but requires librarian upskilling, responsible implementation, and ongoing evaluation of its impact on metadata ecosystems. This review (2015–2025) analyzes how AI is reshaping metadata creation, enrichment, interoperability, and access in academic libraries. Early research (2015–2019) focused on AI in digital library search engines and metadata extraction, while recent studies emphasize automation, GPT-based cataloguing, and interoperability frameworks. Key themes include automated metadata generation, metadata enrichment and structured archival description, and AI-driven discovery tools. Benefits cited are efficiency, scalability, and improved accuracy, though limitations include opacity of black-box models and inconsistency in outputs. Beyond technology, studies stress librarian readiness, metadata literacy, and AI competencies. Ethical and policy challenges—bias, transparency, and preservation standards (remain underexplored).

KEYWORDS: Automated Metadata Generation, Cataloguing, Metadata-Driven Discovery, Metadata Enrichment and Interoperability, GPT-based cataloguing, metadata generation, ChatGPT/CatGPT.

INTRODUCTION

AI-powered tools enhance interoperability by harmonizing disparate metadata schemas and connecting institutional repositories to a global discovery network. AI-powered tools can dynamically enrich and combine metadata, enabling more accurate searches, meaningful navigation, and personalized recommendations. Significantly, AI-powered discovery transforms metadata from a static record into an intelligent, adaptive layer that improves visibility, accessibility, and user experience in academic libraries.

Background and Overview of Included Studies

A total of 42 publications (2015–2025) met the inclusion criteria, covering a wide range of applications of artificial intelligence in metadata management in academic libraries. These studies come from diverse geographical regions, including Africa (e.g. Nigeria, Namibia, South Africa), Asia (e.g. India, Thailand, China), Europe (e.g. Norway, United Kingdom), and global perspectives. The collection included empirical case studies, conceptual analysis, bibliographic mapping, and systematic reviews. The earliest works (2015–2019) focused on AI-based metadata extraction in digital library search engines. It is observed that the recent studies (2023–2025) have documented practical AI deployments, along with librarian readiness, and ethics-oriented frameworks.

Limitations of the Evidence Base

While the reviewed literature (scoping review) spans multiple regions and approaches, it remains uneven in depth and methodological rigour. Many studies are descriptive or conceptual rather than empirically evaluated in operational environments. Furthermore, grey literature and vendor white papers—often rich in implementation detail—were outside the inclusion scope but may contain valuable practice-based insights.

The literature was collected from Google scholar platform with the phrase “AI Contexts in Metadata in Academic Libraries” during the months of January till August 2025 to observe and include latest publications. The searched literature included various kinds of sources yet in the study the scholarly publications have been included.

Scoping Review of AI Contexts in Metadata in Academic Libraries

1. Introduction

AI is increasingly transforming metadata creation, management, and interoperability in academic libraries. The reviewed literature (n = 42, 2015–2025) covers applications ranging from automated cataloguing to AI-assisted archival description, with diverse geographical and technological perspectives. Academic libraries are increasingly adopting artificial intelligence (AI) to improve metadata creation, management, discovery, and interoperability. This review maps existing research between 2015 and 2025, highlighting contexts, challenges, librarian competencies, and future research gaps.

2. Scope and Objectives

Scope: Identify AI applications in metadata processes (creation, enrichment, interoperability, discovery) within academic library contexts.

Objectives:

1. Map technological approaches (ML, NLP, neural networks, GPT).
2. Understand librarian readiness and competencies.
3. Explore ethical, policy, and implementation issues.

3. Thematic Categories

A. Automated Metadata Generation and Cataloguing

- Core Focus: Many studies (e.g., Barman 2024; Yang et al. 2025; Brzustowicz 2023; Lund & Wang 2023) examine AI for automating descriptive metadata, subject tagging, and classification.
- Technologies: Machine learning (Barman 2024), AI-powered cataloging tools (Mahmud 2024), GPT-based language models (Roy & Chanda 2024).
- Benefits: Efficiency gains, improved accuracy, scalability for large collections.
- Limitations: Black-box AI models (Bøyum & Khosrowjerdi 2025), inconsistencies in automated metadata.

B. Metadata Enrichment and Interoperability

- AI’s ability to improve metadata interoperability (Hazarika 2025), extract citation contexts (Wu et al. 2015), and enrich digital repositories (Michalak 2023).
- AI-assisted archival metadata platforms (Rim et al. 2025) facilitate structured data extraction.

C. AI for Metadata-Driven Discovery

- Enhanced search and retrieval through AI-enriched metadata (Shamsitdinova et al. 2024; Nova et al. 2025).
- AI in research discovery tools (CiteSeerX: Wu et al. 2015).

D. Librarian Readiness and Competencies

- Studies highlight the need for metadata literacy and AI competency (Cox 2023; Paiste & Siago 2024; Kalbande et al. 2024).
- Gaps in skills for AI-driven metadata management (Mabawonku & Buraimo 2025).

E. Ethical, Policy and Implementation Issues

- Responsible AI in metadata (Mannheimer et al. 2024; Michalak 2023).
- Concerns about bias, transparency, and preservation metadata standards (Oyedokun 2025).

4. Chronological Trends

- Early Work (2015–2019): AI in digital library search engines (Wu et al. 2015) established technical groundwork for metadata extraction.
- Middle Phase (2020–2022): Limited focus, mainly conceptual discussions of AI in libraries.
- Recent Surge (2023–2025): Explosion of applied studies, practical AI metadata tools, and regional case studies.

5. Geographic Spread

- Africa: Namibia (Titus 2024), Nigeria (Mabawonku & Buraimo 2025), South Africa (Zondi et al. 2024).
- Asia: India (Kalbande et al. 2024; Hazarika 2025), Thailand (Meesad & Mingkhwan 2024).
- Europe: Norway (Bøyum & Khosrowjerdi 2025), UK (Cox 2023).
- Global/General: Systematic and bibliometric reviews (Kulkanjanapiban et al. 2025).

6. Identified Gaps

1. Evaluation Metrics: Few studies measure accuracy, recall, or precision of AI metadata tools.
2. Long-Term Sustainability: Limited research on metadata maintenance and AI model retraining.
3. Multilingual Metadata: Scarce work on AI for non-English metadata processing.
4. User-Centered Design: Lack of participatory design involving end users in AI metadata systems.

The literature shows a clear shift from conceptual exploration to practical AI implementation for metadata in academic libraries. While automation offers efficiency and scalability, success hinges on librarian competencies, ethical safeguards, and interoperability standards.

Evidence Table

Author(s)	Year	AI Context	Metadata Function / Finding
Oyighan, Ukubeyinje, David-West, & Oladokun	2024	Metadata Management	Examines opportunities, and emerging trends of AI in metadata management
Knonth	2023	Machine	Use of AI/ML in open research as well as metadata for

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		Learning in Libraries	libraries/archives
Titus	2024	Adoption	AI adoption to improve metadata services .
Sabol	2025	Intelligent Catalogs	Envisioning the AI-driven intelligent catalogs
Meesad & Mingkhwan	2024	Smart Libraries	AI- smart libraries having the metadata automation
Devi, Mohanapriya, & Sarumathy	2024	AI + Mathematics	Various AI methods applied to metadata
Barman	2024	Automated Cataloging	ML-driven cataloging and metadata generation
Mabawonku & Buraimo	2025	Librarian Readiness	Librarians preparedness
Ikwuanusi et al.	2022	Resource Allocation	AI optimizes resource allocation, and leading and linking to metadata efficiency
Mannheimer et al.	2024	Responsible AI	Ethical metadata practices in libraries
Cox	2023	Competencies	AI reduces manual metadata creation
Yang, Fu, Amin, & Kang	2025	Modern AI	Broad impact of AI on metadata management
Roy & Chanda	2024	Automation	AI automates cataloging and metadata generation
Zondi et al.	2024	Review	AI analysis into large-scale scientific metadata collections
Kulkanjanapiban, Silwattananusarn, & Lambovska	2025	Bibliometric Review	Identification of metadata automation
Rim et al.	2025	Archival Metadata	AI-assisted archival metadata generation
Shamsitdinova et al.	2024	Search & Discovery	Metadata enrichment
Paiste & Siago	2024	Competencies	Metadata extraction
Bairagi & Lihitkar	2025	Research Workflows	AI improves metadata to enhance academic resource availability
Bevara et al.	2025	AI Beyond ChatGPT	Discusses advanced models for cataloging and metadata
Nova et al.	2025	Data-Driven Libraries	Application of neural networks used for metadata extraction
Mahmud	2024	Automation	AI-driven cataloging and classification of metadata
Veerakannan	2025	Access & Retrieval	Metadata-driven access to knowledge
Bayramli	2024	Research Tools	AI metadata support
Hazarika	2025	Metadata	AI for metadata interoperability

		Standards	
Mosha	2025	Accessibility	Automated metadata generation
Kalbande, Suradkar, Chavan, Verma, & Yuvaraj	2024	Integration	LIS professionals' perspectives in India
Green	2022	Application Profiles	Baseline study of metadata profiles
Hazarika & Konch	2025	LibraryGPT	AI+chat integration
BÃyum & Khosrowjerdi	2025	Perceptions	AI metadata functions
Molaudzi & Ngulube	2025	Innovations	AI in metadata innovations
Orubebe, Oloniruha, & Oladokun	2024	Adoption	AI adoption globally
Oyedokun	2025	Preservation	AI for preservation metadata standards
Dora, Zala, & Sa	2025	Content Analysis	Identifies metadata automation
Sacco, Norton, & Arms (Eds.)	2024	Impact Review	Metadata systems and AI tools in academic libraries
Michalak	2023	Policy & Ethics	Automation improved discoverability of metadata in repositories
Brzustowicz	2023	Cataloging	AI auto-generates cataloging/metadata (ChatGPT to CatGPT)
Cox	2024	Competencies	AI training/data contexts for metadata services
Wu et al.	2015	Digital Libraries	CiteSeerX metadata + citation context improves search/discovery
Lund & Wang	2023	GPT in Libraries	AI tools generate cataloging and metadata
Kalbande, Yuvaraj, Verma, A., Suradkar, & Chavan	2024	Integration	Cautious optimism; metadata automation emphasized
Miltenoff	2024	AI Literacy	Librarian leadership in metadata/AI adoption

Thematic Clusters: AI Contexts in Metadata in Academic Libraries

1. Automated Cataloging and Metadata Generation

Focus: AI/ML automating cataloging, classification, and descriptive metadata.

- Barman (2024) – ML-driven cataloging & metadata generation
- Rim et al. (2025) – AI-assisted archival metadata generation platform
- Mahmud (2024) – AI in cataloging and classification
- Roy & Chanda (2024) – AI role in automating cataloging/metadata
- Lund & Wang (2023) – GPT-based cataloging and metadata generation
- Brzustowicz (2023) – ChatGPT/CatGPT for cataloging and metadata creation
- Kalbande et al. (2024, Open Information Science) – Metadata automation in Indian academic libraries
- Dora, Zala, & Sa (2025) – Content analysis, metadata automation recurring theme

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1.1 Automated Metadata Generation and Cataloging

AI tools are applied to automate description, classification, and cataloging:

- Barman (2024) – machine learning for automated cataloging.
- Mahmud (2024) – cataloging and classification automation.
- Rim et al. (2025) – AI-assisted archival metadata generation.
- Brzustowicz (2023); Lund & Wang (2023) – ChatGPT and metadata creation.
- Dora et al. (2025); Kalbande et al. (2024) – Indian LIS professionals and metadata automation.
- Wu et al. (2015) – CiteSeerX as an early AI-powered metadata and citation system.

Observation: AI significantly reduces manual cataloging time and increases metadata scalability.

2. Metadata Management and Interoperability

Focus: AI in structuring, integrating, and managing metadata systems.

- Oyighan et al. (2024) – Challenges and opportunities in AI metadata management
- Yang et al. (2025) – Modern AI in metadata management
- Hazarika (2025) – AI for metadata interoperability and standards
- Oyedokun (2025) – Preservation metadata standards in AI era
- Sabol (2025) – Intelligent catalogs and repositories
- Meesad & Mingkhwan (2024) – Smart library metadata automation
- Devi et al. (2024) – Advanced mathematics/AI applications in metadata
- Sacco, Norton, & Arms (2024) – Librarians devising AI-based metadata systems

2.1 Metadata Management, Standards and Interoperability

Studies highlight integration challenges and adherence to metadata frameworks:

- Oyighan et al. (2024) – challenges and opportunities in metadata management.
- Hazarika (2025) – metadata interoperability via AI.
- Oyedokun (2025) – preservation metadata standards.
- Green (2022) – metadata application profiles in U.S. academic libraries.
- Michalak (2023) – metadata discoverability in institutional repositories.

Observation: AI offers powerful tools, but standards compliance and interoperability remain unresolved.

3. Access, Discovery and Search Enhancement

Focus: AI leveraging metadata for improved retrieval and discoverability.

- Shamsitdinova et al. (2024) – AI enhances search via metadata enrichment
- Wu et al. (2015) – CiteSeerX metadata and citation context for discovery
- Nova et al. (2025) – Neural networks extracting metadata for BI in libraries
- Veerakannan (2025) – AI improves metadata-driven access to knowledge
- Zondi et al. (2024) – AI analyzes large scientific metadata collections
- Bairagi & Lihitkar (2025) – Metadata improves availability of academic resources

3.1 Search, Retrieval and Discoverability

AI-driven metadata enhances search precision and resource discoverability:

- Shamsitdinova et al. (2024) – AI in enhanced search.

- Wu et al. (2015) – AI-driven metadata citation context.
- Bairagi & Lihitkar (2025) – metadata improving availability of academic resources.
- Zondi et al. (2024) – metadata analysis for scientific collections.

Observation: Metadata enriched by AI improves retrieval efficiency and personalization.

4. Librarian Competencies and Readiness

Focus: Skills, readiness, and professional shifts linked to metadata work.

- Cox (2023) – AI reduces manual metadata creation; competencies needed
- Mabawonku & Buraimo (2025) – Librarians’ preparedness for AI metadata management
- Paiste & Siago (2024) – Metadata extraction enhances cataloging efficiency; librarian innovation
- Cox (2024) – Competencies: AI training processes and metadata creation
- Miltenoff (2024) – Librarians’ leadership in AI/metadata literacy
- Titus (2024) – Adoption of AI for metadata services in Namibia
- Kalbande et al. (2024, *Serials Librarian*) – Perspectives of LIS professionals on AI metadata

4.1 Librarian Competencies and Readiness

Adoption requires new skillsets and professional adaptation:

- Cox (2023, 2024) – competencies and evolving professional roles in metadata creation.
- Mabawonku & Buraimo (2025) – preparedness of librarians for AI-generated metadata.
- Paiste & Siago (2024) – AI competencies for cataloging.
- Sacco et al. (2024); Miltenoff (2024) – librarian training and AI literacy.
- Bøyum & Khosrowjerdi (2025) – ambivalent perceptions of AI’s role in libraries.

Observation: Librarians must be reskilled in AI-assisted metadata workflows.

5. Policy, Ethics and Perceptions

Focus: Responsible use, ethics, and librarian perceptions about AI metadata.

- Mannheimer et al. (2024) – Responsible AI in libraries/archives (metadata ethics)
- Michalak (2023) – Policy; automation improved metadata discoverability
- Bøyum & Khosrowjerdi (2025) – Norwegian librarians’ ambivalence toward AI metadata tools
- Orubebe et al. (2024) – Global adoption challenges/opportunities incl. metadata
- Knoth (2023) – AI/ML in open research metadata (policy context)
- Bayramli (2024) – Research tools; AI metadata in scholarly communications

6. Broader AI–Library Innovations with Metadata Dimensions

Focus: AI-driven systems where metadata plays a supportive or implicit role.

- Molaudzi & Ngulube (2025) – AI innovations in public academic libraries (metadata use)
- Green (2022) – Metadata application profiles in academic libraries (baseline context)
- Bevara et al. (2025) – Beyond ChatGPT; advanced AI metadata implications
- Hazarika & Konch (2025) – LibraryGPT integration with metadata/chat systems
- Zondi et al. (2024) – Broader review of AI implementation in libraries (metadata analytics)
- Oyedokun (2025) – Emerging trends including preservation metadata
- Meesad & Mingkhwan (2024) – Smart digital library systems (metadata included)

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6.1 Broader AI Transformations Affecting Metadata

Studies exploring general AI adoption also emphasize metadata contexts:

- Sabol (2025); Meesad & Minghwan (2024) – smart digital libraries and intelligent catalogs.
- Mannheimer et al. (2024) – responsible AI practice.
- Knoth (2023) – machine learning for open research metadata.
- Nova et al. (2025) – neural networks for metadata extraction.
- Zondi et al. (2024) – AI for metadata-rich scientific collections.
- Kalbande et al. (2024, 2025) – LIS professionals in India on metadata and AI.

Observation: Metadata is central to nearly all AI-enabled transformations in academic libraries.

With this clustered map, the observations have made towards:

- Automation (who’s working on AI doing cataloging/classification)
- Management/Interoperability (AI structuring metadata systems)
- Access/Discovery (how metadata supports search/retrieval)
- Competencies/Readiness (human factors)
- Policy/Ethics (responsible/ethical metadata use)
- Broader Innovations (other AI-library overlaps that include metadata).

Chronological Coverage

- Early stage (2015–2019): Wu et al. (2015) – foundational work on AI and metadata.
- Growth (2020–2023): Metadata-focused AI adoption discussions emerge (Knoth, Cox, Michalak).
- Expansion (2024–2025): Surge in studies on automated metadata generation, librarian competencies, and interoperability challenges (Rim et al., Dora et al., Mabawonku & Buraimo).

Geographic Trends

- Africa: Emphasis on readiness, training, and infrastructural challenges in deploying AI metadata tools (Namibia, Nigeria, South Africa).
- Asia: Focus on multilingual metadata processing, repository interoperability, and national-scale library metadata frameworks (India, Thailand, China).
- Europe: Scholarly attention to ethics, bias, and governance in AI metadata workflows (Norway, UK).
- Global studies: Bibliometric analyses and systematic reviews (Kulkanjanapiban et al., 2025) mapping AI–metadata intersections.

S. No.	Duration	Description
1.	2015-2019	Foundational work on AI-assisted indexing and metadata extraction in scholarly search engines, often outside formal library systems.
2.	2020-2022	Conceptual discussions and early experimental deployments in metadata enrichment; limited empirical evaluations.
3.	2023-2025	Rapid expansion in real-world case studies, cross-regional analyses, and the integration of generative AI tools in cataloguing and metadata discovery.

Gaps in the Literature

Limited empirical case studies on large-scale AI metadata deployment in academic libraries. Ethical and responsible AI use in metadata creation is underexplored. Cross-cultural and developing-world perspectives remain relatively scarce (though Nigeria, India, Namibia are covered). Integration with linked open data and semantic web metadata standards needs more attention.

Insights

AI in academic library metadata is moving from experimental prototypes to mainstream implementations. Automated cataloging and metadata extraction are the most researched areas. Future work must focus on interoperability, librarian training, ethics, and large-scale pilots.

The major discernments from the literature:

1. Automated Metadata Creation and Cataloguing

Over one-third of the reviewed works examined AI's capacity to automate descriptive metadata generation, classification, and subject indexing.

- Technologies applied: Machine learning algorithms (Barman, 2024), neural networks (Yang et al., 2025), GPT-based large language models (Roy & Chanda, 2024), and AI-assisted cataloguing platforms (Mahmud, 2024).
- Reported benefits: Significant time savings in large-scale metadata generation; improved scalability in handling diverse collection types; potential to standardize classification schemes across repositories.
- Common challenges: Inconsistent subject term assignment across domains; dependence on "black box" AI decision-making with limited transparency (Bøyum & Khosrowjerdi, 2025).

2. Metadata Enrichment and Interoperability

Several studies explored AI's role in improving metadata completeness, accuracy, and cross-platform compatibility.

- Examples: AI-powered enrichment for digital repositories (Michalak, 2023), crosswalk generation between metadata schemas (Hazarika, 2025), and automated citation context extraction (Wu et al., 2015).
- Interoperability focus: AI applied to harmonize metadata between institutional repositories, research data management systems, and archival platforms (Rim et al., 2025).

3. Metadata-Driven Discovery and Access

AI-enhanced metadata directly supports discovery services in academic libraries.

- Approaches: Semantic search enhancements using AI-tagged metadata (Nova et al., 2025); natural language processing for improved subject retrieval (Shamsitdinova et al., 2024); context-aware search personalization (Meesad & Mingkhwan, 2024).
- Implications: More intuitive search interfaces and improved retrieval accuracy, particularly for interdisciplinary research collections.

4. Librarian Readiness, Skills, and Training

A consistent sub-theme was the human capacity to manage AI-driven metadata systems.

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- Skills gaps: Limited familiarity with AI tools and metadata automation workflows (Mabawonku & Buraimo, 2025).
- Training needs: Professional development in metadata literacy and AI competency (Cox, 2023; Paiste & Siago, 2024; Kalbande et al., 2024).
- Organisational readiness: The importance of management buy-in, infrastructure investment, and staff retraining emerged as recurrent requirements.

5. Ethics, Governance, and Policy

Recent literature increasingly foregrounds the ethical dimensions of AI metadata applications.

- Concerns: Algorithmic bias, data privacy, transparency of automated decisions, and preservation metadata integrity (Mannheimer et al., 2024; Oyedokun, 2025).
- Governance models: Suggested approaches include human-in-the-loop verification, explainable AI modules, and adherence to international metadata standards.

Identified Gaps

1. Evaluation metrics: Very few studies report recall, precision, or F1-scores for AI metadata tools.
2. Long-term maintenance: Limited attention to model retraining, metadata drift, and sustainable AI system integration.
3. Multilingual metadata processing: Sparse work on AI for non-English or mixed-script metadata.
4. User-centred design: Minimal involvement of library patrons in the design or evaluation of AI-driven metadata systems.

Research Agenda

This scoping review surfaces clear gaps that define priorities for future research:

1. Benchmarking and Metrics: Very few studies report quantitative evaluation measures (precision, recall, F1-score) for AI-driven metadata tools. Future research should establish benchmarking protocols that can be applied across contexts.
2. Multilingual and Cross-Script Metadata Processing: Given the global nature of academic research, there is an urgent need to develop and evaluate AI systems capable of processing metadata in multiple languages and scripts, particularly for non-Latin alphabets.
3. Sustainability and Model Maintenance: Long-term AI metadata solutions must address model retraining, metadata drift, and the cost of maintaining proprietary AI systems. Comparative studies of open-source vs. commercial AI platforms could inform procurement strategies.
4. User-Centred Design: Current research is heavily librarian-focused, with limited exploration of how AI-enhanced metadata impacts end-user search behaviour, discovery satisfaction, or accessibility. Incorporating patron perspectives could guide more human-centred AI design.
5. Ethics by Design: There is potential for embedding ethical considerations directly into metadata generation workflows—bias detection algorithms, transparency dashboards, and explicit audit trails for automated decisions.

CONCLUSION

The scoping review highlights a rapid evolution in how AI is conceptualised and applied in academic library metadata workflows. Earlier works (2015–2019) were largely exploratory, focusing on metadata extraction and indexing tools often developed outside traditional library infrastructures. This is consistent with broader digital scholarship trends, where AI innovations first emerged in adjacent domains such as scholarly publishing and search engine optimisation before entering library contexts. From 2023 onwards, the integration of generative AI, advanced machine learning, and natural language processing into cataloguing and metadata enrichment mirrors global patterns in cultural heritage informatics, where automation is increasingly embedded in day-to-day operations (Harvey & Mahoney, 2023). This shift signals that AI in library metadata is transitioning from a “future possibility” to a “present operational reality.”

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