Extended Abstract

Exploring the Adoption of Sustainable Smart Library and Information Systems using: AI/ML-Based Applications

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Degree for which submitted: Doctor of Philosophy

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Abstract

This thesis examines the transformation of Library and Information Science (LIS) in response to rapid digitalization, sustainability concerns, and the integration of advanced technologies such as Artificial Intelligence (AI) and Machine Learning (ML). Libraries, once limited to physical spaces, have evolved into dynamic, user-centered digital systems that provide access to information anytime and anywhere. Alongside this shift, sustainability has emerged as a critical concern, emphasizing long-term access, efficient resource use, and inclusive services. These developments have led to the emergence of the Sustainable Smart Digital Library (SSDL), which integrates intelligent technologies with sustainability to create adaptive and future-ready library ecosystems.

To understand this transformation, the study first analyses research trends in sustainable e-libraries, representing the early stage of digital development. Using 2,837 Scopus-indexed articles (1961–2024), topic modeling identifies key themes such as digital literacy, information access, semantic search, and e-library services, while highlighting gaps in community engagement, open systems, and multimedia processing. Building on this, the study extends to Sustainable Smart Digital Library (SSDL) ecosystems using 3,378 articles (1961–2025). Applying Latent Dirichlet Allocation (LDA), fifteen major themes are identified, including digital library usage, semantic networks, and sustainable development, while gaps remain in digital infrastructure, resource access, and library management systems. This progression reflects a clear shift toward intelligent, data-driven, and sustainable library systems. From a user perspective, the study examines students' library usage in real academic settings. The findings reveal a hybrid usage pattern, where students rely on both physical and digital resources. Libraries remain essential for focused study, particularly during examinations, while digital resources support flexible and remote learning. However, challenges such as limited seating, poor internet connectivity, lack of charging facilities, and restricted access to resources affect user experience, indicating the need for improved infrastructure and services.In addition, the study explores the transformation of LIS education through survey data from 368 participants analyzed using machine learning techniques. Validation methods, including 50–50, 66–34, 80–20 splits, and 10-fold cross-validation, resulted in a maximum accuracy of 84.98%. The findings highlight that technology-based learning, practical training, and interdisciplinary approaches are key factors for job readiness. However, a gap between theoretical knowledge and practical skills persists, emphasizing the need for curriculum reform and the development of technically skilled "Algorithmic Librarians."

Overall, the study provides a comprehensive framework linking research evolution, user behavior, and educational transformation to explain the shift from e-libraries to Sustainable Smart Digital Library (SSDL) ecosystems. It concludes that future libraries must be intelligent, adaptive, and inclusive, integrating technology and sustainability to support both academic advancement and broader goals such as digital inclusion and sustainable development.

Keywords: Library Transformation; Sustainable Smart Digital Library (SSDL); Artificial Intelligence; Machine Learning; Digital Libraries; Sustainability; Library and Information Science (LIS); Topic Modelling; Explainable AI (XAI).

Chapter 1: Introduction to transformation in library systems

Libraries have always been the key to education, research, and sharing of knowledge. Previously, they were regarded as being a physical space where books, journals and other printed materials were kept and retrieved. Individuals frequented libraries either to read, borrow or to do academic research. The role of libraries however has changed in the past years. The advent of digital technologies has pushed libraries past the physical collections. They nowadays offer access to e-books, internet-based journals, digital databases, and other services based on technology. It is now possible to get information anywhere and anytime. This revolution has not only revolutionized the way libraries are run, but also the way users relate with the libraries. Meanwhile, the concept of sustainability has become a significant issue in the library profession. Sustainability also encompasses long term access to information, digital preservation and services that are accessible to all users, in libraries as well as in the environment. Libraries should make sure that their systems are effective, available and can adjust to the future changes. The emergence of technologies like Artificial Intelligence (AI), Machine Learning (ML), and Data Science can be discussed as another significant issue affecting libraries. These technologies are transforming the way information is handled, analysed and presented. They are also establishing new possibilities of enhancing library services which include intelligent search systems, automated cataloguing and personalized user recommendations. These changes have also affected LIS education. The old courses do not suffice to equip students with modern library jobs. Technology, data and digital system skills have become the requirement of students. This has given rise to concept of the so-called Algorithmic Librarian, a professional, who will integrate traditional knowledge of libraries with the new technical skills. This thesis will seek to comprehend these transformations on different grounds. It analyses the trends in research on sustainable e-libraries, researches on the transformation of LIS education and how students apply library services in practice. Integrating the approaches of topic modelling, survey analysis, and machine learning, the work offers both theoretical and practical understanding.

This study aims primarily to determine the major trends, gaps, and future directions in LIS. It attempts to provide answers to three key questions:

1. What are the key research trends and gaps in sustainable e-libraries to Sustainable Smart Digital Library (SSDL) ecosystems?

2.What is being transformed in LIS education, and how can it be reformed to better prepare students?

3.What is the current situation with libraries and what are the problems of students using them?

Chapter 2: Transformation from E-Library to Smart Sustainable Library-key dimensions

Chapter 2 brings together two closely related ideas, sustainable e-library and Sustainable Smart Digital Library (SSDL) ecosystems, to provide a complete understanding of how digital library research has evolved and where it is heading. The discussion begins with sustainable e-library

because it represents the foundational stage of digital transformation in libraries. This part focuses on how libraries moved from physical systems to digital environments while trying to ensure long-term access, resource efficiency, and basic sustainability. Using topic modeling on Scopus data, the study identifies how research in sustainable e-libraries has developed over time, what themes have been widely explored, and which gaps still remain. The dataset initially included 3,223 articles (1961–2024), later refined to 2,837 records with abstracts. The findings show strong emphasis on areas such as digital literacy, e-library services, semantic search, and technology use, while areas like community engagement, open collection systems, and multimedia processing remain underexplored. This stage is important because it establishes the research base and highlights the gradual shift toward more advanced digital practices. Building on this foundation, the chapter then moves to the concept of Sustainable Smart Digital Library (SSDL) ecosystems, which represents the next stage of evolution. While sustainable e-libraries focus mainly on digital access and basic sustainability, SSDL expands this idea by integrating smart technologies, data-driven systems, and inclusive design. For this part, a larger dataset of 3,704 articles (1961–2025) was collected, and after filtering by title, abstract, keywords, and language, 3,378 English-language articles were analysed. Using Latent Dirichlet Allocation (LDA), the study identifies 15 major research themes, including digital library usage, digital literacy training, semantic networks, and sustainable development. At the same time, it highlights less-explored areas such as digital resource access, library management systems, and sustainable digital infrastructure. This shows that while the field is growing rapidly, certain practical and inclusive aspects still need attention.

The reason for including both sustainable e-library and SSDL ecosystems in this research is to show a clear progression of knowledge. Sustainable e-library provides the historical and conceptual base, helping to understand how digital systems and sustainability were first combined. In contrast, SSDL ecosystems reflect the current and future direction, where technologies like artificial intelligence, machine learning, cloud computing, and IoT are deeply integrated with sustainability goals. In simple terms, the first concept explains where the field started, and the second explains where it is going. Without the first, the second lacks context; without the second, the study remains incomplete and outdated. Together, these two perspectives create a comprehensive framework for understanding digital library transformation. The combined analysis not only maps past and present research trends but also identifies future priorities such as improving digital access, strengthening infrastructure, promoting inclusivity, and adopting intelligent technologies. This integrated approach makes the study more meaningful, as it connects traditional sustainability efforts with modern smart systems, ultimately supporting the development of digital libraries that are not only technologically advanced but also environmentally responsible and socially inclusive.

Chapter 3: Need of digital transformation for effective communication-use case Study habits at RGIPT

In this chapter, the studies the way students access library services at both examination and non-examination times, and their preferences in physical books or digital documents or both. The primary objective is to determine usage patterns, resource preferences, levels of digital awareness and the problems students encounter during the study. The survey is comprised of students across various programs, academic years and backgrounds and this will be helpful in

creating a realistic and general perspective of the way libraries are used in day-to-day academic life. This research will be based on an elaborate survey of the students which will focus on different factors including program of study, year, CGPA, frequency of library visits, duration of study, study location of choice and the kind of resources used. It also entails the awareness of the students about the digital tools and how they can be improved. In addition to numerical feedback, students also gave written feedback about practical aspects of the library such as availability of seating, Wi-Fi strength, charging stations, access to books, library hours, and whether they require quiet areas to study. Due to such a combination of structured information and individual feedback, the research is both quantitative and qualitative. The results are clear that the frequency of library use is higher during exams. Most students spend lengthy hours at the library and in most cases more than four hours a day and this is where they feel more comfortable studying. The physical library is still significant particularly to the people who need the use of the printed books, notes, and references. Meanwhile, the role of the digital resources has also gained importance. E-books, online videos, and academic databases are some of the resources that are commonly used by students to facilitate learning. It means that the majority of students now tend to pursue a mixed strategy, combining physical and digital resources with each other as opposed to the alternative. Regarding behaviour, students are likely to frequent the library during exams than when there is no exam. They appreciate the silence, ordered space, and both the offline and online resources. There are various sections of library that are used by many students based on their needs like self-study sections where students can study individually and reference sections where students can access particular materials. This indicates that the library is not only a bookstore but a valuable academic support network that enables students to remain focused and productive. Nonetheless, the research also shows that there are various challenges that influence the total library experience. Inadequate seating room, bad Wi-Fi connectedness, lack of power outlets, lack of books, and congested study rooms are the most prevalent problems reported by students. Moreover, the desire to have longer library hours, particularly during exams was raised by most students with some proposing 24 x 7 access. The improved access to digital resources like e-journals and e-books is also in demand. Some students also indicated that they require guidance or training in order to use online resources and this implies that digital awareness and information literacy is yet to be enhanced. On the whole, this chapter demonstrates that libraries continue to play a significant role in the academic life of students, but their existing facilities and services do not fully address the needs of the users. A physical and digital combination is evident in students relying on hybrid learning behaviour, as they clearly rely on both. To ensure that they can cope with these changes, libraries should advance infrastructure, increase digital access, and offer enhanced user support. Simply put, the library has remained of great value, but it has to develop in line with the current tendencies of studying and increasing student demands.

Chapter 4: Need of transformation in terms of study materials: studying contents use by large pool

This chapter describes how the fields of artificial intelligence, machine learning, and data science are transforming Library and Information Science (LIS) education. It also presents the concept of the so-called, Algorithmic Librarian, that is, a librarian who is educated not only in the skills of the traditional library but in the skills of modern technology as well. The point is that LIS education needs to be transformed in such a way that students will be prepared to work in digital libraries and information services in the future. The research gathered survey data of 368 respondents in educational institutions. The respondents were students, faculty, staff and library users. They expressed their opinions regarding such issues as AI, coding, digital tools, virtual reality, interdisciplinary learning, and future careers in libraries. The researchers used machine learning methods to study these responses and find the most important factors affecting curriculum change and job readiness. According to the results, the most significant aspect of contemporary LIS education is technology-based courses. Integrative AI, coding, and digital tools and library courses enable students to be professionally better equipped. Another gap that was identified in the study was the vision-reality gap. This implies that a good number of individuals are aware that the future technologies are significant, yet they lack the hands-on ability to apply them. Therefore, awareness is not sufficient but practical training is required. The analysis of data incorporated four testing techniques 50-50 split, 66-34 split, 80-20 split and 10 fold cross-validation. The model in these tests was good and provided good results. The highest accuracy was 84.98% in the 10-fold test. It is an indication that this model was robust in predicting the support of a curriculum to job readiness. This model also revealed that the strongest predictors were technical courses and future-oriented LIS learning. Conversely, other factors like gender, age, experience, etc. had minimal impact. The explainable AI component of the research assisted in demonstrating why the model predicted particular things. It simplified the results and made them more understandable. It revealed that there are students who might be good at comprehending the future technology, yet they do not possess the practical skills in such fields as AI tools, virtual reality, and digital library systems. Finally, the chapter presents the thesis that LIS education must no longer be taught in a traditional manner (it needs to have more digital, technical, and interdisciplinary learning). Training of the faculty, updating of the curriculum and collaboration with computer science and industry are also significant. This will assist in generating skilled and confident “Algorithmic Librarians who are ready for the modern workplace.

Chapter 5: Conclusion and Future Scope.

This study provides a clear understanding of how libraries are transforming in the digital age. It shows that libraries are moving from traditional physical spaces to smart, sustainable, and user-centered systems. The findings highlight three major areas of transformation: research trends, user behaviour, and education. Research analysis shows a shift from basic e-libraries to advanced Sustainable Smart Digital Library (SSDL) systems. The study of student behaviour reveals that users now rely on both physical and digital resources, but face challenges related to infrastructure and access. The analysis of LIS education shows that there is a need to improve practical and technical skills among students. The study concludes that future libraries must be more adaptive, technologically advanced, and inclusive. They should focus on improving digital infrastructure, enhancing user support, and integrating advanced technologies. At the same time, LIS education must be updated to include practical training and technical skills. In the future, more research can be done on the use of AI in library services, development of

sustainable digital systems, improvement of digital literacy, and creation of personalized user services. By addressing these areas, libraries can continue to support education, research, and knowledge sharing in an effective and sustainable way.

This research offers wider benefits beyond libraries. For society, smart libraries support equal access to information, reduce the digital divide, and encourage lifelong learning, especially in rural and low-resource communities. For academics and researchers, the findings contribute to improving LIS curriculum, developing modern courses, and preparing students for research and teaching in digital environments. For librarians and information professionals, the study highlights emerging career roles such as AI Librarian, Digital Resource Manager, Data Curator, and Smart Library System Operator, while encouraging continuous skill development to remain relevant in a changing job market. Overall, this research supports the development of modern, smart, and future-ready libraries that benefit society, education, and the professional LIS community together.

Research Publications:

1. Verma PK, Trivedi SK, Biswas S (2025), "Exploring trends and gaps in sustainable e-library research: a text mining analysis". Digital Library Perspectives, Vol. 41 No. 2 pp. 311–345, doi: https://doi.org/10.1108/DLP-07-2024-0110

2. Sustainable Smart Digital Library (SSDL) Ecosystems in the Digital Age: A Text Mining Analysis of Emerging Trends and Research Gaps by Verma PK, Trivedi SK, Biswas S; Information Discovery and Delivery _ IDD-06-2025-0141.R2 (Manuscript Accepted)

3. Prediction of Misinformation Impact on LIS Operational Performance: A Study Using Explainable Artificial Intelligence (XAI) by Verma PK, Trivedi SK, Biswas S; Information Discovery and Delivery_ IDD-04-2026-0129 (Manuscript Submitted)

4. The Algorithmic Librarian: Predicting Paradigmatic Changes in LIS Curriculum and Ecosystems Using Explainable Artificial Intelligence (XAI) by Verma PK, Trivedi SK, Biswas S; Information Discovery and Delivery_ IDD-04-2026-0130 (Manuscript Submitted)

5. Assessing Student Library Usage Patterns and Hybrid Resource Behaviour at Rajiv Gandhi Institute of Petroleum Technology (RGIPT), Amethi: A Comparative Study of Digital and Physical Library Use by Verma PK, Trivedi SK, Biswas S (Manuscript under process)

6. Trends and Patterns in Artificial Intelligence Research across BRICS Nations: A Scientometric Study (2006–2025) (Manuscript under process)