

“A Life Cycle Sustainability Assessment of AI adoption in Libraries”

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Abstracts

Artificial Intelligence (AI) integration in libraries has changed the traditional information service into offering improved services in library activities such as: cataloguing, metadata administration, smart search, digital reference, and collection building. However, AI implementation offers advanced features in regard to environmental, economical, and social sustainability. This paper applies to a Life Cycle Sustainability Assessment (LCSA) framework to talk about AI systems during their life-cycle not only during the acquisition, deployment, and day-to-day operations but also during the maintenance and the decommissioning. The assessment takes into account AI infrastructural environmental performance, economic sustainability in the long term, and social outcomes of equity of access, privacy of users, and ethics information operations, and concentrates on the overall execution of AI in library ecosystems.

Its findings indicate that AI implementation in libraries can lead to a significant efficiency gain and more positive user experiences, although the implementation should be carefully controlled to minimize the energy use, resource consumption, and the probability of algorithmic bias. By incorporating LCSA into the operation and planning of libraries, the institutions can achieve the balance between the innovation of the technologies and the long-term sustainable management of knowledge, sustainable stewardship of the resources and long-run operational viability. The paper concludes that the sustainability approach that is based on lifecycle is required to ensure that libraries might use AI opportunities without sacrifices to develop green information space as well as equitable and future-ready.

Keywords:-Artificial Intelligence (AI), Libraries, Life Cycle Sustainability Assessment (LCSA), Digital Library Services, Sustainable Information Management, Green Library Technology, AI Ethics in Libraries

Introduction

This is because the growing role of Artificial Intelligence (AI) in libraries has transformed the conventional information services into smarter, data-driven space. It is a comprehensive

approach to studying the environmental, economic, and social impacts of AI implementation in the life cycle of the library technologies- the implementation of systems and data infrastructure and their following lifecycle maintenance and a successive technological update. The use of novel AI applications in automated cataloguing, intelligent information search, digital reference service and predictive collection management in modern library ecosystems has heightened efficiency and interaction between the operations and the users. However, the assessment of the sustainability will include the observation of the consequences of these systems on the use of resources, cyber infrastructure, and institutional long-term resilience in the library setting.

The life cycle sustainability perspective can be applied in academic and research libraries to enable librarians and information professionals to examine the overall consequences of adopting AI-based library management systems, discovery platforms, and digital repositories. The assessment will cover the energy consumed during data processing, the lifecycle expenses of AI infrastructure, ethical practices of information, and the changing role of the librarian in the knowledge organization and service delivery of AI. Libraries can tactfully embrace the use of AI technologies without losing their responsibility to the information resources under their care and ensure sustainability of the institution by aligning the concepts of sustainability with the practices of library science, including metadata management, collection development, information literacy support, and digital preservation.

Literature Review

1. Review of the AI Applications in Library Operations and Services.

A scoping review on generative AI in library operations indicates that the AI technologies employed to serve libraries are chat bots, expert systems, robots, RFID, natural language processing, and machine learning algorithms. These technologies are useful in the cataloguing, classification, virtual reference services, information retrieval, and collection management. The research also adds that AI enhances efficiency in frequent activities such as inventory control, stocktaking, and weeding, which saves the expenses and time of operating. Nevertheless, the authors note that libraries should consider the long-term technological and infrastructural impacts of using AI tools to make the delivery of information services viable.

Deep Seek AI's transformative impact on libraries—enhancing accessibility, improving resource management, and fostering a more personalized and efficient user experience—position it as a key player in the future of library services. (*Suryawanshi 2025*)

2. Responsible AI Practices in Libraries and Archives A Review.

The studies of responsible AI practices in libraries explore ethical, social, and governance factors of AI adoption. Much of the literature on this topic highlights areas of concern, including algorithm bias, transparency, privacy preservation and data management in library information systems. Libraries that implement AI technologies should make sure that automated systems are compatible with such professional values as intellectual freedom, equal access to information and privacy of users. It has been proposed in the study that AI integration in digital libraries and archival systems should be guided by responsible AI models to ensure the ethical sustainability and accountability of institutions.

3. Survey on academic library adoption of AI.

A systematic review of the use of AI in academic libraries reveals that AI is used in many applications such as automated metadata creation, recommender systems, intelligent discovery platforms, and even AI-based user service. The research points out that the major difficulties that libraries encounter include lack of technological knowledge, funds, and technological sustainability. It also emphasizes the importance of strategic planning and policy formulation in order to make sure that the implementation of AI will contribute to the long-term institutional objective and sustainable practices in library management.

Artificial Intelligence (AI) has the potential to completely transform library operations and services. Libraries can increase productivity, optimize resource allocation, and improve user experience by utilizing AI tools and technology. (*Mane & suryawanshi 2024*)

4. Review on Environmental Artificial Intelligence in Public Libraries.

The scientific study of environmental AI in the libraries has shown that AI technologies can be used to facilitate sustainability efforts in libraries ecosystems. The systems that are based on AI can optimize energy use, resource distribution, and environmental surveillance in library

buildings. The survey of the public libraries identified that despite the awareness of the significant importance of sustainability by many of the library staffs, the number of institutions that implemented AI-driven environmental management system is lower. The analysis concludes that the libraries can hugely decrease their carbon footprint by implementing AI in building management, environmental education programs, and community engagement programs.

5. Daniel, Ittenheimer, Braune, and Amaral Review on Sustainable AI and Green AI Research.

A thematic analysis of the current sustainable AI research points to the key themes such as responsible AI governance, energy-efficient computing, and AI-enabled sustainable development. The paper lays stress on the idea that sustainable AI is about focusing on the environmental and socio-economic effects. In the framework of digital institutions such as libraries, AI systems should be controlled to reduce the energy costs of computation and the efficient use of resources without decreasing the efficiency of the service. Another important finding of the research is the necessity to incorporate the principles of sustainability into the process of developing and deploying AI solutions.

6. Survey on AI and Sustainability Evaluation Models.

The role of AI in the accomplishment of environmental, economic, and social sustainability objectives is identified in a systematic literature review about AI and sustainability. The research states that AI technologies promote sustainable development by following data-based decision making, predictive analytics, and resources optimization. The review, however, also notes that AI systems themselves consume a lot of computing power and infrastructure, which might also raise the amount of energy used. Thus, the sustainability assessment models like life cycle assessment (LCA) are needed to assess the total environmental impact of the AI technologies.

7. Surveillance on Artificial Intelligence Lifecycle.

The studies of the lifecycle implications of AI emphasize that environmental effects take place at multiple levels such as hardware manufacturing, training models, deployment, and active use of the models. Research indicates that the majority of studies are primarily concerned with

energy consumption when AI is being computed, and less concern larger lifecycle questions like material resource use, water usage, and the effects of hardware manufacturing. The authors suggest using a lifecycle approach to assess the sustainability of AI in order to capture the totality of the environmental footprint of AI technologies that have been deployed in the digital infrastructure, such as libraries.

8. Green AI Lifecycle Models Review.

The literature review of Green AI suggests a systematic lifecycle model of AI systems comprising of steps like design, development, deployment, operation and reuse. In the study, the authors state that the sustainability considerations must be added throughout the AI lifecycle, such as using energy-efficient algorithms, optimizing the use of hardware, and responsible data management.

This lifecycle-oriented model is a helpful tool to apply to libraries that adopt AI-based information systems and allow them to assess and reduce environmental effects without disrupting the effectiveness of services.

9. Survey on the environmental effects of Generative AI.

A scoping review of generative AI sustainability examines a carbon footprint of both AI system training and inference processes. The paper suggests that although training huge AI models can be an energy-intensive process, their constant use by users at deployment as well leads to a significant environmental footprint. The study demonstrates the necessity of standard measurement systems and lifecycle monitoring systems to determine the sustainability of AI technologies used in online services, libraries among them.

10. The review on AI to Sustainable Systems and Circular Economy.

The bibliometric and systematic review of AI applications in sustainable systems indicates that AI is important in supporting resource optimization, waste reduction, and the practices of a circular economy. The study implies that analytics based on AI can enhance the management of resources and the decision-making procedure in numerous industries. The same principles can be utilized in digital resource management, collection development, and infrastructure optimization in library settings, which can be used as part of more sustainable information ecosystems.

Discussion

Life cycle Sustainability Assessment (LCSA) is a holistic approach taken to measure the environmental, economical and social impacts of a technology or system throughout the life cycle of the technology, both during acquisition and implementation and during the operation and subsequent decommissioning. LCSA when used in the context of libraries places emphasis on AI systems including digital cataloguing systems, recommendation systems, automated reference services, smart discovery platforms and collection management software.

This evaluation in library science terminology does not only look at the functional value (e.g. of improved cataloguing accuracy, faster response to references, increased user experience) but also at the resource and infrastructure value, e.g. the energy consumption of server, the hardware life cycle, the network bandwidth and the cost of digital storage.

The final objective will be to find out how AI use correlates with sustainable practices of managing libraries, such as proper management of information resources and fair service provision.

Stages of Library Life Cycle Adoption of AI.

An LCSA library-oriented evaluates the use of AI at multiple library lifecycle phases:

1. Acquisition and Planning

- o Choice of AI tools to use in cataloguing, metadata generation, digital archives or reference services.
- o Evaluation of the preliminary expenses, compatibility with current Integrated Library Systems (ILS), and sustainability on the long run.

2. Deployment and Integration

- o Application of AI in library networks, databases, and online repositories.
- o Educating personnel on AI-aided cataloguing, indexing, and retrieving information as a part of user data privacy and institutional policies.

3. Operational Stage

- o Use of AI on a daily basis to optimize search results, suggest resources, automate repetitive tasks, and manage collections.
- o Observing energy consumption, system patches and server maintenance to be eco-friendly.

4. Maintenance and Upgrading

- o Software, hardware, and model retraining of AI algorithms periodically.
- o Evaluation of long-term expenditures and resource uses of library IT infrastructure.

5. End-of-Life/Decommissioning

- o Proper disposal or recycling of AI based hardware (servers, storage).
- o Digital data archiving and metadata preservation maintenance of digital preservation.

Libraries Sustainability Dimensions.

A. Environmental Sustainability.

- Critiques the energy usage of AI servers, carbon footprint of training AI models and e-waste due to hardware upgrades.
- Example: When AI is applied in digital cataloguing, it will save labor, but will consume more energy when the servers are not efficient.

B. Economic Sustainability

- Quantifies AI cost-efficiency in libraries during its life cycle.
- Examples: AI can save on the workforce expenses on routine jobs but needs to invest in employee education and software subscriptions.

C. Social Sustainability

- Assures user privacy, fair access, and information ethics in the implementation of AI.

- Case in point: AI-based recommender systems must not be biased to ensure that some groups of the users are not subjected to resource visibility.

Significance of LCSA in Library Situation.

Monitoring libraries with LCSA would make sure that AI implementation:

- Enables sound and effective information management.
- Lessens environmental influence by green IT activities and streamlined computer infrastructure.
- Enhances institutional sustainability, cost-benefit, technology, and library ethics.
- Offers evidence on library policy by enabling decision-makers to understand the trade-offs in the benefits of AI and sustainability.

Conclusion

Life Cycle Sustainability Assessment of AI adoption in library science is not a matter of implementing technology only, but using a comprehensive approach to assessing the acquisition, use, and retirement of AI systems. By aligning environmental, economic, and social aspects to the fundamental library activities, including the cataloguing, digital preservation, metadata, and users services, libraries can make sure that the adoption of AI can help in ensuring long-term operational efficiency, ethical stewardship, and sustainable information ecosystems.

The application of AI in libraries can change libraries into offering better services, such as automation in cataloguing, intelligent search and discovery, digital reference, etc. to collection management. However, in-depth Life Cycle Sustainability Assessment (LCSA) indicates that the benefits of AI must be balanced against the environmental, financial and social costs throughout the lifecycle of technology. Some of the considerations that libraries should make are energy consumption of AI servers, maintenance of digital infrastructures, staff training, ethical considerations, and fair access to information. Viewing AI systems as a cumulative whole, both purchasing, deploying, and maintaining the AI systems and using and dismantling AI, libraries can stand to be able to utilize AI in a way that will best maximize performance at the same time avoiding the ethos of sustainability.

Lastly, it is important to make LCSA a habit of library planning as part of the AI in order to sustain the sustainability of operation and management of information and knowledge within the long-term. It calls upon librarians and administrators to make knowledgeable decisions that would help in technological innovation to align themselves with environmental conservation besides fiscal prudence and social responsibility. By incorporating the idea of sustainability into every tier of the AI implementation, libraries will have a future of becoming wiser, more environmentally-friendly, and more just organizations, which will provide the future generation with the access to properly controlled, ethically checked, and technologically promoted sources of information.

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