PRESERVING WISDOM: EXAMINING THE IMPORTANCE AND DEEP LEARNING ENABLED DIGITAL PRESERVATION OF ENDOWMENT LIBRARIES

PRESERVANDO A SABEDORIA: EXAMINANDO A IMPORTÂNCIA E O APRENDIZADO PROFUNDO PERMITIDO PELA PRESERVAÇÃO DIGITAL DE BIBLIOTECAS DE DOAÇÕES

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Abstract

This study investigates why endowed libraries are essential and important for our academic journey. These libraries get financial support from endowments to expand and function with an excellent way. These endowment libraries are important because they help pay for school, promote education, learning, and keep educational assets safe for the future. They might be able to concentrate on collecting, growing, and keeping their collections with the help of reliable sources, without having to worry about money all the time. This study looks at both old and new endowment libraries and talks about how they help to protect historical records, culturally related artefacts, and rare important manuscripts, as well as how they help maintain digitally safe information. These projects employ Deep Learning (DL) to link valuable artefacts to digital safeguard preservation, which protects them for future generations. Endowment libraries also provide a lot of educational and teaching materials that help schools, the public domain, and other groups. They help scholarly academic research by giving out different grants, fellowships, and special, rare collections and so on. This helps people to learn and gain knowledge, come up with new ideas skills, and develop leaning phase. It's also important to confirm that everyone can meet the library's holistic way, since they often have programs and learning events that highly encourage to enhances our knowledge, lifelong learning for

Resumo

Este estudo investiga por que as bibliotecas dotadas são essenciais e importantes para nossa jornada acadêmica. Essas bibliotecas recebem apoio financeiro de doações para se expandirem e funcionarem de maneira excelente. Essas bibliotecas dotadas são importantes porque ajudam a pagar pela escola, promovem a educação, o aprendizado e mantêm os ativos educacionais seguros para o futuro. Elas podem se concentrar em coletar, aumentar e manter suas coleções com a ajuda de fontes confiáveis, sem ter que se preocupar com dinheiro o tempo todo.

Este estudo analisa bibliotecas antigas e novas financiadas por doações e discute como elas ajudam a proteger registros históricos, artefatos culturais e manuscritos raros e importantes, bem como ajudam a manter informações digitalmente seguras. Esses projetos empregam Deep Learning (DL) para vincular artefatos valiosos à preservação digital, protegendo-os para as gerações futuras. As bibliotecas financiadas por doações também fornecem muitos materiais educacionais e didáticos que ajudam escolas, o domínio público e outros grupos. Elas ajudam na pesquisa acadêmica, concedendo diferentes bolsas, subsídios e coleções especiais e raras, entre outros. Isso ajuda as pessoas a aprender e adquirir conhecimento, ter novas ideias e habilidades e desenvolver a fase de aprendizagem. Também é importante confirmar que todos possam atender

continuous education programs. These libraries still have a lot of challenges to cope with, like not having enough money and attempting to keep up with a digital technological world that changes rapidly. They need to keep doing what they've always done, but they also need to articulate the latest tools to keep up with everything. This study investigated how to cope with several obesities' challenges, such as obtaining financial assets from multiple areas and transforming cultural information into digital formats. This study finally establishes the relevance of endowed libraries in safeguarding culture and advancing learning in education. It makes a resilient case for keeping them up to date and adding to them, showing how necessary essential they are as sources of information and cultural heritage in a world that is changing rapidly. The work outlines a method to assess, evaluate and execute the proposed deep learning architecture, model linking it to practical applications in digital evaluation and preservation.

Keywords: Endowment Libraries. Preservation of Cultural Heritage. Digital Preservation. Deep Learning. Academic Research Support. Educational Resources. Library Sustainability.

à abordagem holística da biblioteca, uma vez que elas costumam ter programas e eventos de aprendizagem que incentivam muito o aprimoramento do nosso conhecimento e a aprendizagem ao longo da vida para programas de educação continuada. Essas bibliotecas ainda têm muitos desafios a enfrentar, como não ter dinheiro suficiente e tentar acompanhar um mundo tecnológico digital que muda rapidamente. Elas precisam continuar fazendo o que sempre fizeram, mas também precisam articular as ferramentas mais recentes para acompanhar tudo. Este estudo investigou como lidar com vários desafios, como obter ativos financeiros de várias áreas e transformar informações culturais em formatos digitais. Este estudo finalmente estabelece a relevância das bibliotecas dotadas na salvaguarda da cultura e no avanço da aprendizagem na educação. Ele apresenta um argumento resiliente para mantê-las atualizadas e ampliá-las, mostrando como elas são essenciais como fontes de informação e patrimônio cultural em um mundo que está mudando rapidamente. O trabalho descreve um método para avaliar, analisar e executar a arquitetura de aprendizado profundo proposta, modelando-a e vinculando-a a aplicações práticas em avaliação e preservação digital.
Palavras-chave: Bibliotecas dotadas. Preservação do patrimônio cultural. Preservação digital. Aprendizado profundo. Apoio à pesquisa acadêmica. Recursos educacionais. Sustentabilidade da biblioteca.

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1 INTRODUCTION

Over a two decades, people have known that libraries have places where cultural heritage, information, and learning are kept safe and grow. They have large collections of subjects ranging from language to literature & from rare manuscripts to the modern digital arena. They have important places to store knowledge in terms of hard form, acquire knowledge, and keep culture alive (Hare *et al*.,2018). Endowment libraries differ from other types of academic scholarly libraries in that because they are unique in nature. People, institutions, and organisations give funds to these institutions, which have

invested to generate revenue. The money that comes in helps with acquisitions, evaluation, and long-term sustainability (Casella & Adank, 2023; Hirschler, 2019). Endowment libraries can be found in public institutions, private organisations, or universities (Dondi *et al*.,2022; Bermiss *et al*.,2017). They have been around since ancient times, when affluent patrons gave a sort of land or financial help to keep collections of manuscripts and books safe (Behrens, 2018; Steven, 2014). They have often been connected to schools and churches, and they show how essential it is for society to keep knowledge and culture alive for coming generations.

The primarily objectives of this research is to assess, evaluate the complex issues of endowment libraries in this society, fully culturally based, reflecting their historical importance, operational enhancements, and relevance challenges over here. We develop that, despite their seemingly broad nature, these basic elements made up a cohesive framework essential for the development of creations of sustainable and high technology-driven relevance. Historical and functional insights elucidate the enduring importance and cultural significance of endowed libraries. The roles challenges section discusses the challenges faced and encourages new ideas with skills-based learning. The suggested deep learning (DL) framework has a proactive essential way to make sure that things are long-term safe and straightforward to access in the digital and technological age (Sharma, 2019; Harvey & Mahard, 2020).

The technological modern era has main primarily focus points on digital data-based technology that has growing high speed, and rational and traditional institutions has under a lot of financial constraints endowment libraries need to do two basic things: preserved cultural artefacts and keep up with latest digital based technologies (Hidayati *et al*.,2020; Tamayo *et al*., 2020). They major focus on research, developing learning, and places where people can work with a high spirit and together, and develop new technological-based ideas with skills and developments (Saied *et al*., 2018; Gul & Bano, 2019; Ouni *et al*., 2017). This study provides a comprehensive, detailed view for reassessing digital preservation methodologies in endowment-related libraries, integrating historical-based context, practical applications, emerging new challenges, and a digital technological library-enabled structure. This research study not only presents the conceptual model framework but also articulates digital-based methodologies for validating and applying the practical framework, thereby ensuring its feasibility and practical relevance of the technologies.
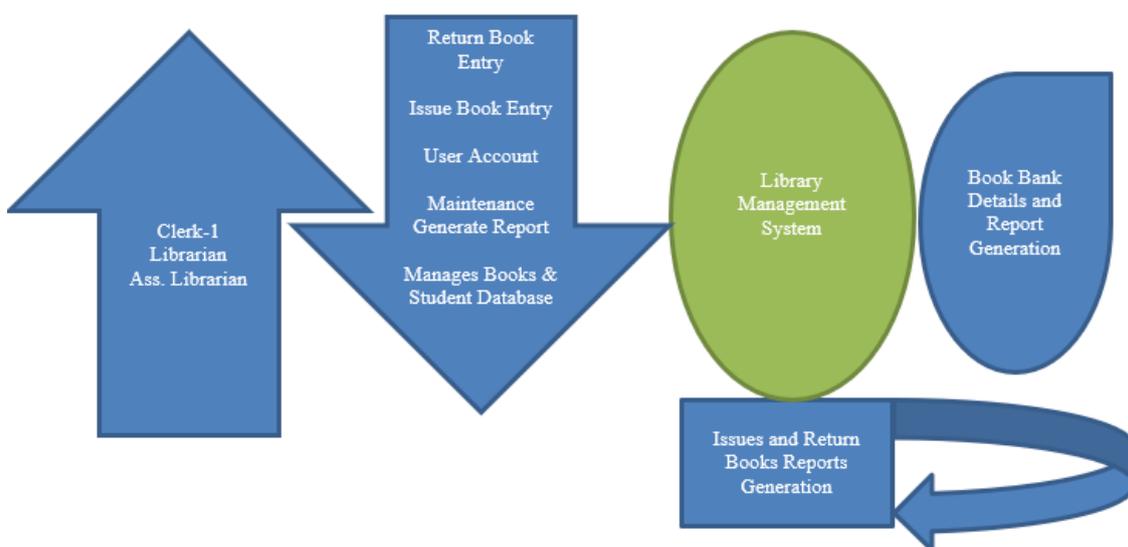
This study provides a comprehensive evaluation of the history, functions, and future projections of endowment libraries, including their historical background and evolution.

- The most important thing that libraries do is keep knowledge and cultural legacy.
- How they affect education and learning for life.
- Making room for research and academic work.
- Plans for long-term success and financial models.
- Examples of well-known endowment libraries.
- What people say about them and the problems they must deal with
- What could happen in the future and what they might do.

To understand the importance of endowment libraries because they support in distinguishing their worth in a swiftly changing world. Educational and cultural institutions struggle with reduced funding and shifting priorities; however, endowment libraries offer a way forward for resilience and sustainability. By examining their successes and struggles, this paper discusses how to maintain and expand these essential institutions in a rapidly changing world. Figure 1 shows the pictorial representation of the general library management system.

Figure 1

Conventional Library Management System

2 HISTORICAL CONTEXT OF ENDOWMENT LIBRARIES

The concept of endowment libraries has a complex and multifaceted history that spans cultures and centuries. Research growth provides a structure of valuable insights into their developing roles and lasting effect on societal developments (Dondi *et al*.,2022; Bermiss *et al*.,2017) Focus delves into the real origins, essential milestones, and the origin of endowment libraries. The opinion of endowed libraries could be traced back to ancient societies, where all individuals and scholars funded the creation of libraries to preserve information in digital-based technologies for cultural and knowledge people (Ouni *et al*., 2017).

2.1 University endowment library: case study

Higher academic libraries are often connected to colleges and universities and institutions, which use long-term endowments to ensure they are financially stable for the long term. These libraries basically have large collections of resources in terms of scholarly content, like manuscripts and so on. They also provide accessibility to transform the digital resources for research, teaching, and learning purposes. Their two prime concerns are to help with both academic research and learning, and to protect cultural heritage, rare materials that are essential to historical representations. Endowments give these libraries structure for financial independence, which lets them make their content, new books, digitise old ones, and work with other libraries on projects.

One of the old libraries named "Alexandria", which was primarily opened in Egypt in the 3rd century BCE, is a well-known and excellent example of an early library; we cannot ensure it was an endowment library (Joo *et al*., 2018). It was made up of the Ptolemaic dynasty, which revealed support for libraries with these stigmata of leaning. Monastic libraries became prominent in medieval Europe, frequently receiving funds with endowments from clergy and nobles that allowed them to accumulate essential collections of religious and scholarly works to be passed down to upcoming generations. These libraries played a necessary role in preserving traditional values of text during the Middle Ages (Waheed *et al*., 2017). There are several examples that have shown how endowment libraries were important to society's development and scholarly work, supported by generous endowments from benefactors (Kutu & Olajide, 2018). Over time,

the roles, nature, and purpose of endowment libraries have evolved in many roles for scholarly and curated related content. The Renaissance, the founding of university libraries, marked a significant example of this shift. These libraries were highly funded by wealthy individuals or through institutional endowments, with the purpose of supporting the many important events that show the importance and the burgeoning scholarly events in Europe (Yang & Shieh, 2019; Stokić *et al*.,2019). In 1602, Sir Thomas Bodley founded the Bodleian Library at Oxford University. By his own funds and through soliciting further endowments, Bodley endowed the library, establishing a model for future libraries. In the early 20th century, United States manufacturers and benefactors played a pivotal role in the development of public libraries (Neves, 2019; Gharieb, 2021). Andrew Carnegie funded and ensured that over 2,500 libraries worldwide have endowments to maintain their operations, providing financing for their construction through the Carnegie Library Initiative. This project established a standard for public endowment libraries and opened access to information (Khalid, 2019). Numerous endowment libraries stand out for their historical implication and impact. The Bodleian Library is the oldest and most influential, and its endowment has allowed it to grow into one of the world's most excellent libraries, containing holdings in every subject of study (Choi & Harper, 2020). In the US, the New York Public Library was founded in 1895 and was created through the merger of two private libraries and supported by endowments from John Jacob and Samuel J. The Library of Congress was set up in 1800. The United States Congress officially supported this research library (Konya, 2017). Also, it is the biggest Library in the world, with huge collections and digitalisation projects supported by big donations and federal money. These libraries do not have enough money to build large collections, make information available to the public, and help with scholarly research, but they have been continuously trying to do so. (Lee & Noh, 2021). The fact that many of these libraries are still around and making a difference in society today is proof of their lasting legacy. In conclusion, the history of endowment libraries shows a path of growth and change, guided by the benefactor's foresight and society's changing needs (Cheng *et al*.,2020). They have always kept information and culture safe for future generations, from ancient collections to modern digital archives.

Table I gives a summary of the history of the endowment libraries. Figure 2 shows how endowment libraries are set up. But in the context of AI, digital preservation strategies are still not well understood. Recent research indicates encouraging
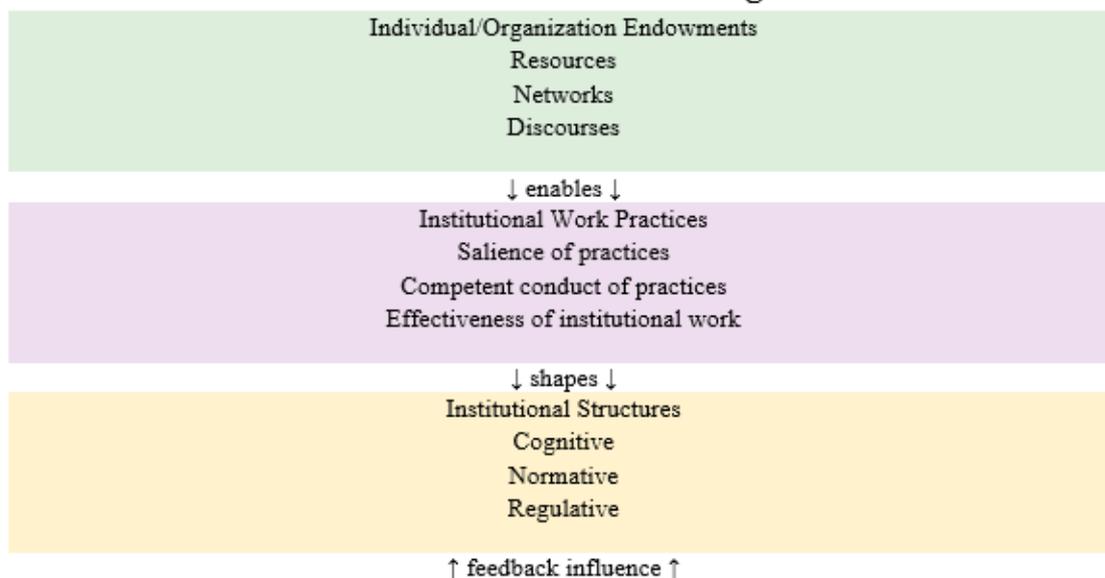
applications of deep learning in this field. Transformer-based OCR has enhanced recognition accuracy for historical manuscripts (Smith & Zhao, 2022), CNN-driven restoration pipelines improve degraded images (Rossi & Bianchi, 2023), and BERT-based models automate metadata extraction for digital libraries (Chen *et al.*, 2021; Gupta *et al.*, 2024). Autoencoder-based anomaly detection has also been utilised to maintain data integrity in extensive digitisation efforts (Khan, & Ahmed, 2021).

2.2 Application of the DL framework

The proposed deep learning framework can be directly applied to strengthen digital preservation efforts in such libraries. For example, digitized manuscripts and rare texts can be processed using transformer-based OCR models (Smith & Zhao, 2022) to accurately recognize historical scripts, thereby reducing the need for manual transcription. (Rossi & Bianchi, 2023) can enhance the image quality of degraded documents, while autoencoder-driven anomaly detection CNN-based restoration techniques (Khan, & Ahmed, 2021) provide and ensure the high integrity of digital-based technological files by flagging unsupported issues, such as corrupted or low-quality scans. Moreover, metadata integration and high enrichment could be automated using BERT-based NLP models techniques. (Chen *et al.*, 2021; Gupta *et al.*, 2024). Lessening metadata of cataloguing time and improving forward discoverability. By injecting and implementing this technological workflow, the University Endowment Library could access and validate the feasibility of the technological framework, presenting how Digital library tools can preserve heritage and rare collections while simultaneously enhancing access for scholars and real-time users as well.

Table 1

Historical Context of Endowment Libraries

Library Name	Founding Date	Key Benefactors	Notable Contributions
Abbey of Saint Gall	8th century	Monastic orders, European nobles	Religious texts and the preservation of classical texts during the Middle Ages.
Carnegie Libraries	Late 19th - Early 20th centuries	Andrew Carnegie	Democratized access to information over 2500 libraries worldwide.
Library of Alexandria	3rd century BCE	Ptolemaic Dynasty	A major centre of learning in the ancient world conserved vast information.
New York Public Library (NYPL)	1895	Samuel J. Tilden, John Jacob Astor, others	A significant research and cultural resource, a comprehensive public library system.
Bibliothèque Sainte-Geneviève	(1851).	French government, private donors	A vast collection of manuscripts and books for public access.
Library of Congress	1800	US federal government, private endowments	The world's largest Library for extensive collections and digitization projects.
Bodleian Library, Oxford	1602	Sir Thomas Bodley, Oxford University	Model for future university libraries and extensive academic collections.

Figure 2

Structure of Endowment Libraries

Institutional Framework Diagram

Individual/Organization Endowments
Resources
Networks
Discourses

↓ enables ↓

Institutional Work Practices
Salience of practices
Competent conduct of practices
Effectiveness of institutional work

↓ shapes ↓

Institutional Structures
Cognitive
Normative
Regulative

↑ feedback influence ↑

3 ROLE OF ENDOWMENT LIBRARIES IN KNOWLEDGE PRESERVATION

Endowment libraries are essential for preserving and making information accessible for future generations. Several aspects of these roles are explored in this section, which includes digitization efforts, cultural preservation activities, and archival functions (Joo *et al*., 2018). The most important role of these endowment libraries is to preserve historical documents, important materials, and rare books safely. Moreover, these libraries ensure the continuity and morality of important works that might otherwise be lost or deteriorate over time through their archive role **(Stokić*et al*., 2019).**

- *Historical documents and manuscripts:* These endowed libraries can store important historical documents and manuscripts. These are completely protected by using a special method. For example, the Bodleian Library holds real manuscripts by famous authors and historical figures, and they provide resources for historians and scholars **(Stenstrom *et al*., 2019)**

- *Special collections*: Several endowment libraries have special collections that focus on themes and types of materials. Their collections need careful curation and protection efforts. For instance, the public Library in New York has extensive special collections that include rare first editions of famous books as well as the archives of well-known authors.

In the digital era, endowment libraries have increasingly turned to digitization as a means of preservation. The technique not only helps to preserve the physical state of delicate items but also makes them more available to a broader audience.

- *Digital archives:* By developing digital duplicates of their collections, these libraries protect the original products from harm. The Library of Congress was the leader, and they have comprehensive digital items which make millions of products obtainable online, such as government documents and ancient newspapers (Bladek, 2019)

- *Enhanced accessibility:* Nowadays, these digital collections are available anywhere. These are particularly important for unique products that are hard to access in their physical form. For researchers and the public, the Digital Public Library of America (DPLA) gathers digitized materials from various endowed libraries and offers a single access point.

Furthermore, the main aim of endowment libraries is to help preserve cultural heritage, including books, artworks, music, and other cultural products. This support helps sustain and celebrate diverse expressions.

- *Art and Artifacts:* There are many large libraries out there, such as the Getty Research Institute, which has a large amount of art and artifact collections, keeping these collections safe for public enjoyment and study. These collections encompass work from diverse time periods and numerous cultures. Therefore, it shows a broad view of human history and creativity (Sultan & Rafiq, 2021)

- *Music and Audio Archives:* These endowment libraries not only keep books safe, but they also keep music and audio recordings safe so that they don't get damaged. The British Library, for instance, has a large audio archive that contains oral histories and classical music transcriptions.

- *Cultural programs and Exhibits:* Most endowment libraries have exhibitions and cultural events to show off their collections and promote cultural heritage. These events give people a chance to learn more about different cultural traditions. The New York Public Library, for example, puts on exhibits about the Harlem Renaissance to show how much they care about preserving and teaching about different cultures.

Table 2

Role of Endowment Libraries for Knowledge Preservation

Library Name	Preservation Activity	Description	Outcome
British Library	Audio Documents Preservation	Digitizing and conserving music and oral history recordings	Preservation and availability of a wide range of audio materials.
Digital Public Library of America (DPLA)	Accumulation of Digitized Materials	Providing centralized access to digital resources from several libraries	Increased public access to digital knowledge from many institutions.
Getty Research Institute	Art and Artifacts Conservation	Protecting artworks and historical artifacts	Preservation of cultural artifacts for research and public gratitude.
Bodleian Library, Oxford	Archival Preservation	Securing manuscripts and historical documents	Original manuscripts: long-term protection, accessible for study and research.
Library of Congress	Digitization Projects	Developing digital copies of resources	To reduce wear on physical copies, millions of items are now available online.
New York Public Library (NYPL)	Special Collections Management	Preserving rare books and literary documents	A vast amount of special collections is accessible to researchers and the public.

To maintain the security of books and documents for an extended period, endowment libraries utilize their financial resources. They utilize the funds to implement the latest preservation techniques and technologies, ensuring their collection endures longer. Table II provides the roles in the endowment libraries.

- *Conservation techniques:* Endowment libraries hire experts to protect and repair books and documents by using an advanced method. They employ techniques such as deacidification, rebinding, and climate-controlled storage. These methods help ensure the materials last longer (Nowrin *et al*., 2020).

- *Research and Development:* Endowment libraries invest in research to create a new method to preserve their collections by partnering with universities and research institutions. This helps libraries stay at the cutting edge of preservation science.

Almost all well-known endowment libraries show their commitment to preservation through specific initiatives.

- *Library of Congress:* called the largest Library in the world, its collection is extensive, but still, they have a severe problem of resource archiving and digitizing materials with advanced technology, though they have a large number of financial resources.

- *Bodleian Library:* offers a large level of online access to thousands of digitized technology-based resources with rapid technical transformation of resources, including rare and cultural materials and early printed books, which has demonstrated its dedication to preserving and making its collections accessible for real-time users.

- *British Library: This Library has the Endangered Archives program*, which aims to preserve and digitize records at risk of being destroyed. This represents the library's commitment to protecting knowledge/information globally.

4 EDUCATIONAL IMPACT OF ENDOWMENT LIBRARIES

Endowed cultural libraries have had a psychological impact on society, on education-based learning systems, and on helping schools and colleges. It also provides platforms where people access information and other related resources to encourage them to usage of learning these resources at an optimum level. This part goes into detail about

this financial contribution: The endowment libraries were essential and important for helping people to learn beyond the curriculum. Students, teachers, and researchers can find a lot of useful information and resources in these libraries.

Academic Resources: Current libraries not only provide the information and resources, but also provide a basic platform where users can access the information and resources in an easy way

Research Support: Endowment libraries have special and rare collections to help researchers with their advanced work. These libraries give scholars access to rare books and other materials that they can't find easily in other places. For example, the New York Public Library has a huge collection of rare books that are very useful for research.

Collaborative Spaces: These endowment libraries also have study rooms to learn separately, meeting rooms, and technology-based labs to help people work together. These spaces are meant to support several learning activities, from learning alone to working together on presentations and projects. Table III shows how endowment libraries affect education.

Table 2

Impact of Endowment Libraries in Education

Impact Area	Description	Example
Public Accessibility	Providing free access to books, community programs, and digital resources	NYPL offers free access to a wide range of educational materials.
Lifelong Learning	Encouraging education based on lifelong learning through adult education programs, workshops, and public lectures.	The British Library also offers public lectures and adult education programs.
Support for Schools and Universities	Supporting academic resources, collaborative spaces, and research facilities	The Bodleian Library helps Oxford University faculty and students with its enormous resources.
Community Outreach	Supporting local communities through educational programs and outreach campaigns	NYPL portable library and digital lending services provide materials to underprivileged areas.
Digital Learning Platforms	Offering online access to digitized educational resources	The Digital Public Library of America offers online access to a vast array of resources.

These endowment libraries are not only for students and researchers but also accessible to the public.

- *Free Access to Resources:* All collections in the endowment libraries are free to access. Allowing access to their resources ensures that all people profit from it.

For instance, the New York Public Library offers its vast collection of books, digital media, and resources to everyone at no cost.

- *Community Programs:* Endowment libraries regularly hold educational events for everyone. These education programs include literacy classes, computer training, and cultural events to help people acquire various skills and gain knowledge. For instance, the Library of Congress holds several events to inspire reading and learning among the public (Cox *et al*.,2019). By providing materials and opportunities, these endowment libraries offer continuous learning opportunities for all individuals after completing formal schooling.

- *Adult Education:* The information needs always arise when we are alive. Libraries provide a variety of different courses for adults, which provide the platform for adults, like language courses, job training workshops, and even lectures on various subjects, which are also led by them, so that they can also contribute to society with good spirits and improve their skills.

Large numbers of endowment libraries provide ads that reveal this educational success of outcomes with focused learning programs.

- *Bodleian Library:* This Library assists both students and staff with broad academic resources, group learning facilities, and particular research collections.

- *New York Public Library (NYPL):* This NYPL offers free access to a variety of resources, hosts community programs, and supports continuous education through its huge public services.

- *Library of Congress:* It provides many public programs and workshops by making its resources accessible to people of all ages and supporting continuous learning initiatives (Rubin, 2015).

5 ENDOWMENT LIBRARIES AND RESEARCH SUPPORT

These libraries' goals are to focus on supporting research and development activities to promote cultural and heritage work access to specialized materials and provide scholarships to support the education system, as well as facilitating collaborations and networks. This section delves into these topics in depth. For researchers, these endowment libraries are a vital resource, as they possess vast and unique collections. Fig.3. illustrates the support of endowment libraries for research.

- *Specialized Resources:* Endowment libraries often hold rare books, manuscripts, and archives for deep research. For example, at Oxford University, the Bodleian Library has rare medieval manuscripts that are valuable for historical research.
- *Comprehensive Databases:* These endowment libraries sign up for many academic databases and journals, which provide access to researchers for the newest studies and publications. It helps the researchers to stay up to date with recent research discoveries.

These endowment libraries support researchers by providing them with funds to continue their current projects.

- *Research Grants:* Almost all endowment libraries offer scholarships and research projects by covering expenses such as travel and materials. For instance, the New York Public Library offers scholarships to researchers who need access to its special collections.
- *Fellowship Programs:* These libraries frequently provide collaborative programs that provide funding and access to their Library's resources for a limited time to the researchers. For instance, the Library of Congress has various collaborative programs to support research through its extensive collections (Rubin, 2015). Table IV defines the role of endowment libraries in research support.

5.1 V 1 Validation and implementation pathway

While the proposed deep learning (DL) framework provides a conceptual roadmap for digital preservation in endowment libraries, its value depends on feasibility and real-world applicability. To address this, we outline a validation and implementation pathway that demonstrates how the framework can be operationalized and tested in practice.

5.2 Pilot workflow design

The implementation begins with the digitization of library materials, including manuscripts, rare books, and audiovisual resources. To make sure they are all the same and of good quality, these digital objects are then pre-processed (for example, by improving the image, reducing noise, or normalising the format). The next step uses DL models that are made for certain preservation jobs:

Optical Character Recognition using convolutional neural networks (CNNs) or transformer-based vision models for text recognition in manuscripts.

Using natural language processing: Models like BERT or GPT-style architectures can automatically make descriptive metadata (like author, title, and subject headers) by taking metadata and putting it into categories.

Deep metric learning can find images that are similar or the same, making sure that each item stays unique.

Auto encoders can help you find scans that are broken or of low quality that need to be digitised.

The outputs go into a digital repository preservation system, where librarians easily find, modify, evaluate, and submit the metadata before it is added to the permanent repository system.

5.3 Benchmarking and evaluation

This methodology depends on the performance that is evaluated using metrics typically employed in digital preservation research, which has defined how endowment libraries play a key role for the development of society. Two important ways to evaluate how good OCR and text extraction are accuracy and word error rate. That can use precision, recall, and F1 scores to see how well Metadata categorization works. For image-based tasks, cosine similarity or mean average precision (mAP) can be used to measure how well similarity detection works. These measurements ensure that the framework is not only theoretical but also subject to validation against empirical outcomes.

5.4 Support for literature

Supporting literature review gives holistic view to provide significant evidence concerning the feasibility of these approaches. For example, transformers-based have made it much easier to read old documents (Smith *et al*., 2022). Deep learning techniques for augmenting metadata in cultural heritage collections have achieved optimal performance in automated cataloguing (Chen *et al*., 2023; Rossi & Bianchi, 2024). Similarly, autoencoder-based anomaly detection has been effectively employed in large-

scale digitisation projects to maintain data integrity (Ali *et al*., 2021). These studies collectively provide a holistic approach that the proposed framework can be substantiated by established and proven methodologies.

5.5 Future pilot testing

This study focuses to proposes a conceptual framework; an excellent next logical step involves pilot testing in collaboration with partner endowment libraries. A pilot project could select a subset of digitized manuscripts to implement the workflow described above, applying OCR and Metadata extraction models, and then comparing the DL-generated Metadata against manually created records. Such testing would not only validate the framework's technical feasibility but also identify practical challenges in deployment, such as computational cost, scalability, and librarian oversight.
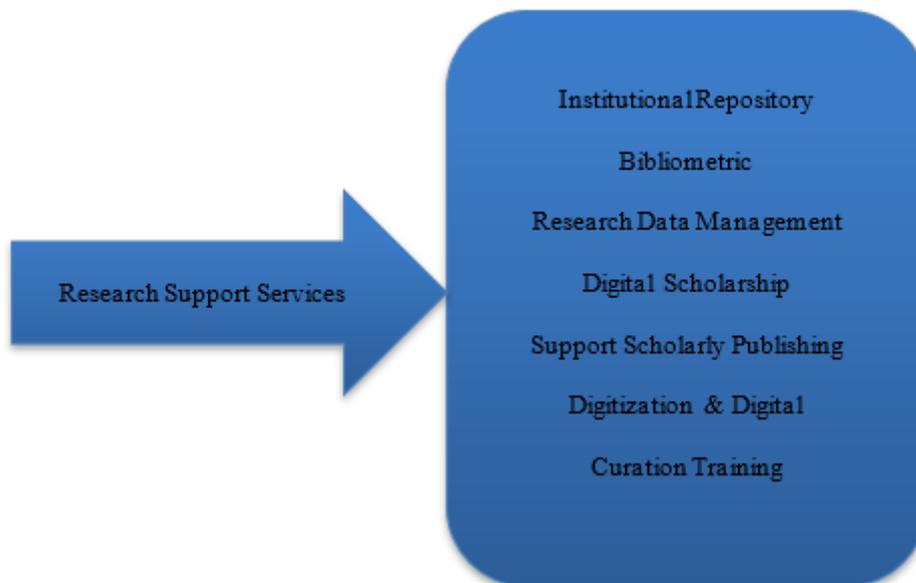
Figure 3

Research Support of Endowment Libraries

Figure 3

Research Support of Endowment Libraries Table IV

Role of Endowment Libraries in Research Support**Support Area**	Description	Example
Research Grants	Providing financial donations to support research projects	NYPL research fellowship for academics.
Research Collections	Offering access to particular materials, primary sources, and complex collections	The British Library has a wide range of historic documents and methodical journals.
Project Funding	Supports particular research projects affiliated with the library's qualities and objectives	Getty research organizations donate to art history research projects.
Fellowship Programs	Offering stipends, housing, and access to material research	Huntington Library's interaction program supports scholars in residence.
Scholarly Networks	Holding conferences, symposia, and workshops to create specialized networks	Getty research organizations host annual conferences for researchers worldwide.
Digital Collaborations	Developing online databases and platforms for remote data sharing and research	The Digital Public Library of America is a combination of digital collections from several libraries.
Institutional Partnerships	Grouping with many academies and research establishments for joint creativity	Bodleian Libraries partner with Oxford University subdivisions.

Endowment libraries encourage collaborations and networks between researchers, institutions, and academic and other public libraries.

- *Academic Partnerships:* These libraries frequently work with academies and research establishments on combined research projects and academic programs. Furthermore, this alliance can lead to significant developments in many fields of study.

- *Research Communities:* Endowment libraries often organize seminars, workshops, and conferences to help research communities. These events permit researchers to present their work, exchange ideas, and expand their professional networks.

- *Interlibrary Loans and Resource Sharing:* These libraries contribute to loan programs by letting researchers access materials from other libraries. This sharing of resources expands the range of research materials available and improves research abilities (Duke & Cartwright, 2021).

Through a special initiative, these endowment libraries show their research support.

- *Bodleian Library:* This Library provides help to the research with its vast collections, collaborative programs, and partnerships with universities. These

resources offer researchers from various fields the opportunity to conduct in-depth studies (Gregory, 2019).

- *New York Public Libraries:* This NYPL helps researchers by providing special collections, events, and grants. Their fellowship programs support researchers with their important projects.

- *Library of Congress:* This Library helps research with its enormous collections, fellowship programs, and partnerships with other research institutions. It also provides a wide range of materials and professional assistance to researchers.

6 DEEP LEARNING FOR DIGITAL PRESERVATION

To enable digital preservation in the endowment libraries, this research proposes a deep learning enabled framework that is composed of three major components,

- Document Digitalization using Vision Transformers
- Semantic Metadata Extraction using BERT-based NER
- Integrity Monitoring using Variational Autoencoders'
- A. Document Digitalization using Vision Transformers:

Every scanned document image $d_j \in \mathbb{R}^{H \times W \times 3}$ is split into $P \times P$ Patches, linearly projected, and flattened as:

$$x_{(p)} = \text{Flatten}\big(d_j[p]\big), x_{(p)} \in \mathbb{R}^{P^2.C} \tag{1}$$

Every patch $_{(\ )}XP$ gets embedded and integrated with positional encoding as:

$$z_0 = \big[x_{(cls)}; x_{(1)}E; x_{(2)}E; \ldots ; x_{(N)}E\big] + E_{pos} \tag{2}$$

The embedded patches $z_0 \in \mathbb{R}^{(N+1) \times d^2}$ are provided to the L transformer encoder layers as:

$$z_l = \text{MSA}\big(\text{LN}(z_{l-1})\big) + z_{l-1}, z_l' = \text{MLP}\big(\text{LN}(z_l)\big) + z_l \tag{3}$$

From the above, the MSA is denoted by multi-head self-attention, and MLP denotes the multi-layer position-wise feed-forward network. The output from the [CLS] token $z_{cls}^{(L)}$ denotes the document visual embedding.

B. Semantic Metadata Extraction from BERT-based NER

To extract metadata from digitized document content, we utilize a BERT-enabled NER model. f_{NER} as:

$$T = \{t_1, t_2, \ldots, t_T\}, \ H = BERT(T) \tag{4}$$

$$y_t = Softmax(WH_t + b), y_t \in \mathbb{R}^{|L|} \tag{5}$$

From the above equation, the set of label types is denoted by L (i.e., place, title, date, and author, etc), the contextual token embedding for   The Token is denoted by H_t. By employing cross-entropy loss, the model gets trained as:

$$L_{NER} = -\sum_{t=1}^{T} \sum_{l=1}^{|L|} 1_{[y_t=l]} \log \hat{y}_t, l \tag{6}$$

C. Archival Integrity Monitoring from Variational Autoencoders

In order to ensure data integrity, the metadata representation gets encoded as $m_j \in \mathbb{R}^d$ to the latent distribution as:

$$z_j \sim q_\emptyset(z|m_j) = \aleph(\mu_j, \sigma_j^2), (\mu_j, \sigma_j) = f_{enc}(m_j) \tag{7}$$

By utilizing an encoder, the reconstruction is performed as $f_{dec}(z_j) = \hat{m}_j$. The VAE is effectively trained to diminish:

$$L_{VAE} = \mathbb{E}_{q_\emptyset(z|m)}[||m - \hat{m}||^2] + KL(q_\emptyset(z|m)||p(z)) \tag{8}$$

From the above equation, $p(z) = \aleph(0, I)$ denotes the prior. If the reconstruction loss exceeds the predefined threshold ϵ, ϵThe anomaly flag gets raised as:

$$\delta_j = \begin{cases} 1, \text{if } ||m - \hat{m}||^2 > \epsilon \\ 0, \qquad \text{Otherwise} \end{cases} \qquad (9)$$

To enable task optimization and training, the multi-task loss for the objective function is denoted as:

$$L_{total} = \beth_1 L_{NER} + \beth_2 L_{VAE} \qquad (10)$$

From the above equation, the reconstruction fidelity and balance metadata accuracy are denoted by $\beth_2$ and $\beth_1$, respectively.

7 CASE STUDIES ON ENDOWMENT LIBRARIES

Analyzing specific instances of endowment libraries demonstrates their significant roles and influences. This section highlights three notable endowment libraries, including the Library of Congress, the Bodleian Libraries, and the New York Public Library.

7.1 Library of Congress

This Library is one of the world's largest, located in Washington, D.C., and was established in 1800. It was funded by both the US government and the private endowments. The list of case studies in the endowment libraries is provided in Table V.

- *Funding and Endowment:* The Library of Congress was funded by both private and government donations, which helped to grow the library's extensive collections and several support programs.
- *Collections:* This Library has over 170 million items, which include books, manuscripts, recordings, photos, maps, and also covers numerous subjects and formats.
- *Research and Accessibility:* This Library also helps with research with its vast resources and digital projects. However, various available items are available online, which makes it easy for people to access their materials.

- *Public Programs:* It also provides essential programs, including lecture series, exhibitions, and educational and learning workshops.

Table 5

Various Case Studies available for Endowment Libraries

Library	Funding Sources	Key Collections	Notable Services	Impact
Getty Research Institute (GRI)	J. Paul Getty Trust endowment, donations, grants	Archives, digital resources, rare books, and photographs	Public programs, digital projects, and research help	Leading research in art history and cultural heritage protection.
New York Public Library (NYPL)	Public and private donations	Over 56 million products, special resources, including the theatre series, and the Schomburg Center	Educational programs, research divisions, and public access	Supports education and literacy, as well as community enrichment.
Bodleian Libraries	Academic donations, private funding, and bequests	Over 14 million printed products, early printed books, and medieval manuscripts	Digital initiatives, exhibitions, and academic help	Cultural preservation and academic resource.
Library of Congress	Federal appropriations, grants, and private funding	Over 172 million products, such as books, manuscripts, maps, and photographs	Digitization projects, public programs, and research support	Global access to knowledge, protection of national heritage.

7.2 Bodleian Libraries

This Library, located at the University of Oxford in England, was founded by Thomas Bodley in 1602.

- Funding and endowments: The University of Oxford, private donations, and endowments all helped pay for the Bodleian Libraries. These funds help them add to their huge collections and services (Moran & Morner, 2017).

- Collections of material: This Library has more than 13 million printed items, such as books, archival materials, and manuscripts.

- Help with research: The Bodleian libraries often have priceless resources for students and researchers. Their collection has both special collections and digital archives. It gives fellowships and research scholarships to help with academic work.

- sufficient spaces for working together: These libraries have excellent study rooms, technology labs, and reading rooms that make it easier for people to learn and do research together.

7.3 New York Public Library (NYPL)

Founded in 1895, the NYPL has one of the biggest public libraries in the US. This Library has huge collections and a lot of public programs, which enhance the quality of public domain information, and it gets millions of visitors every year.

Funding and Endowments: This Library gets money from both private and public sources, such as endowments. The city gives money, and people give money. These funds help to maintain the collection's growth and make services better in an excellent way.

The NYPL has more than 55 million items in its collections, such as books, DVDs, e-books, and special collections. Their collections are well known for how they have helped the humanities and social sciences.

Anyone can use the NYPL's collections and resources for free. It also has events, workshops, and programs for the community.

Research and Education: This Library also helps scholarly researchers by giving them access to its large collection of resources. They also had fun things for kids and adults to do.

7.4 Challenges and criticisms

AI provides a robust platform with excellent instruments for digital preservation; however, its execution encounters considerable obstacles that extend beyond mere technological feasibility. When AI algorithms make decisions about preservation without enough human oversight, it can raise ethical and privacy concerns because it may reinforce existing cultural narratives and push minority viewpoints to the side. Privacy is another concern because digital archives might have private information or things that aren't meant to be shared. The AI services usage on cloud basis, it's much handle too difficult to elaborate who owns living cultural data and importance of data, how safe it is, and how long it will be available. Also, the algorithms used in DL models can make them

biased. The instructed-on datasets that have too many examples of languages and formats that are commonly used in this model's level. This can make cultures and local scripts that aren't well-represented less visible. If these biases are not dealt with, they could change the historical record and future generations will become unaware what situation and cultural had been passed, which would make it harder for everyone to get to collections.

We need to use a variety of strategies to correct this method. First, human intervention is essential, it must involve librarians and archivists who need to oversee decision-making so that AI is used in a clear and more responsible way. Second, preservation projects should use AI techniques that highly protect privacy, like federated learning and differential privacy, to lower the risks that come with working with sensitive collections. Lastly, to make AI-driven preservation systems less biased and fairer, it's important to include regional local languages, scripts, and cultural heritage contexts in the training data.

To handle these complex issues we need to use a lot of different ways to resolve them. First, human librarians and archivists must continue to be the ones who make decisions about AI use, making sure that the process is open and accountable. Second, preservation content of the projects should use AI methods that protect privacy, like federated learning and differential privacy issues, to lower the risks of working with sensitive collections. Finally, it is important to have downward bias and make AI-driven preservation systems fairer by using a wider range of training data, including regional local languages, scripts, and cultural contexts.
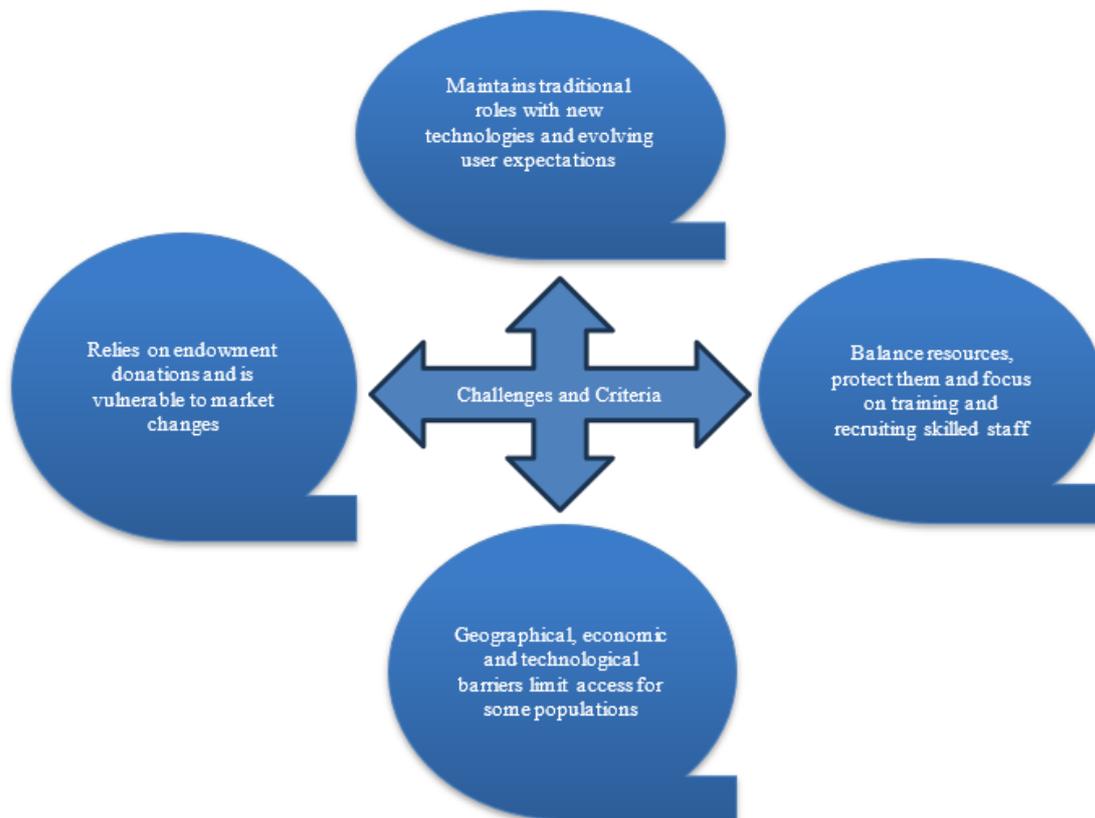
Endowment libraries have a variety of things about them, but they also have problems and get a lot of adverse publicity. This segment talks about the main challenges they faced, such as equity and access, money and stability, and the need for growth. Endowment libraries have a complication in making sure that everyone can use their resources (Senthilkumar, 2024). Figure 4 shows the problems and complaints that endowment libraries have to deal with.

- *Accessibility issues:* While endowment libraries provide free access, not every person can access their resources. Locations, transportation costs, and lack of internet access can limit their usefulness.
- *Inclusivity:* Some opponents believe endowment libraries should better serve diverse communities. This means offering materials in different languages and

formats and providing programs for several cultures and socioeconomic groups. Endowment libraries are primarily dependent on donations, government funding, and endowments for their resources. These supports can cause issues for various challenges.

Figure 4

*Challenges and Criticisms of Endowment Libraries **Economic Fluctuations***

- Fig.4. Challenges and Criticisms of Endowment Libraries *Economic Fluctuations:* These libraries might struggle during economic downturns. If these endowment donations decrease, they will struggle to preserve their services and collections.
- *Dependence on Donations:* If the Library depends on private funds, it may cause them trouble. If the funder's importance changes, the libraries might face funding shortages.
- *Resource Allocation:* Allocating limited funds is the most important and challenging process. Libraries must balance preserving their current collections

with acquiring new materials and investing in expertise. Table VI explains the challenges and criticisms faced by the endowment libraries.

Table 6

Challenges and Criticisms by the Endowment Libraries

Challenge Area	Description	Examples of Impact
Modernization and Innovation	Maintaining traditional roles with the need to accept new technologies and meet developing user expectations	Complexity of integrating AI and VR, struggle to change, and personalized services.
Operational Challenges	Balance and protection of resources, training, and recruitment of skilled staff members	Protecting rare items is very expensive, and there is difficulty in hiring experts.
Financial Stability	It mainly depends on endowment donations and vulnerability to market fluctuations.	Reduced endowment value during economic downturns, maintaining resource allocation.
Equity and Access	Due to geographical, economic, and technological barriers, access is limited for specific populations.	Control people, particularly those with lower incomes, and address the digital divide.

To remain relevant, every endowment library must adapt to changing technologies and user expectations.

- ***Digital Transformation:*** *As more people get information online, libraries will need to spend money on digital services. This requires a significant amount of money and advanced technology, which may put pressure on the finances.*

- ***Finding a balance between tradition and new ideas****: Libraries need to find a balance between their traditional roles and their desire to try new things. This can be challenging since some individuals may not like modifications that they believe contradict the library's primary objective.*

The following sections give extensive examples and case studies of specific libraries' shortcomings:

- ***Library of Congress:*** *This Library has a hard time digitising its extensive collections and making them available to everyone online. This helps it get more online access while keeping its physical assets.*

- ***Bodleian Libraries:*** *These libraries are having trouble since they do not have enough room, and it costs a lot to keep old structures in good shape. They invest in digital computer systems and provide services to meet current needs.*

- *New York Public Library (NYPL): The NYPL has money problems during economic downturns, so it has to seek new ways to get money and make things easier. It also works to make digital access and inclusion more widespread through several projects.*

7.4.1 Future prospects for endowment libraries

Endowment libraries have been established to address some of the challenges of the 21st century. This section discusses their future, with a focus on technology, their increasing importance, and their global perception. There are several ways that technology will have a significant impact on the future of endowed libraries:

- **Digital Collections:** These libraries continue to digitize their resources by gathering many books and manuscripts online. Additionally, it implies that everybody with online access can do their stuff.

- **Online Services:** These endowment libraries continuously add to their online services, which now include virtual support. Classes and e-books that you may read online. This allows users to utilise library services without having to visit the Library in person.

- **Advanced Catalogue Systems:** AI will make catalogue systems better by making it more straightforward for people to discover what they need by quickly organising and sifting through large amounts of data.
  Endowment libraries are becoming more than just lending books.

- **Community Hubs:** Libraries are becoming venues where people may have meetings, workshops, and other community events. This makes the libraries very vital places for all community events.

- *Educational Programs:* These libraries often provide educational programs for youngsters and older adults, which include literacy programs for kids, job training for adults, and learning opportunities for seniors. These programs aim to enhance skills and knowledge within the community.

- *Cultural Preservation:* Libraries help preserve cultural heritage by holding books, documents, digital media, art, and other cultural items. This ensures that human culture is preserved and documented for the next generations.

Globalization and international association will impact the future of endowment libraries.

- *International Collaboration:* Libraries all over the world were working together and sharing resources and expertise. It helps them to develop their services and influence many people (Miao, 2019).

- *Global Access:* By providing their resources online, these libraries can reach an international audience. Additionally, it is helpful for students and researchers in places with limited access to data.

- *Cultural Exchange:* The library encourages cultural exchange by exhibiting resources from different cultures. Many people learn and appreciate different cultures through exhibitions, online galleries, and cultural activities.

Some of the examples and case studies of Future Prospects for Endowment Libraries are provided below:

- *Library of Congress:* This Library mainly invests in cutting-edge technology to develop digital online access and digital catalogs. Additionally, it offers an extensive range of online resources and instructional initiatives.

- *Bodleian Libraries:* This Library enhances its digital collection by adding many materials online and expanding its role as a community hub by offering more events and activities.

- *New York Public Library (NYPL):* The primary aim of NYPL is to enhance its digital access and offer many internet services. It also maintains providing different ways to learn and serves as a cultural center.

8 CONCLUSION

This study investigates how endowed libraries can help and safeguard cultural heritage content alive and suggests a deep learning (DL) method to make digital preservation and access easier. The study offers a thorough strategy for preserving the important significance of endowment libraries in the digital era through the integration of historical context, analysis, assessment, contemporary complicated issues, and AI-driven solutions. Future endeavours should prioritize the validation and pilot testing of the framework, rather than merely conceptualising it. This involves using deep learning models for information extraction and finding excellent ways of information in digitised

collections. It also includes comparing the outcomes to those of manual cataloguing methods. A systematic utilization employing accuracy, memory, and precision will facilitate the assessment of the technique's effectiveness. There is also a strong need for collaborative projects that involve endowed libraries, universities, cultural heritage groups, and AI research centres. These sorts of partnerships are able to work together on the different datasets, domain knowledge, and computing knowledge needed for a strong implementation through these kinds of positive collaborations and working together. At the same time, research should investigate ethical privacy and responsible approaches that protect privacy, lower algorithmic bias, and include a variety of regional and local languages and cultural elements that are often left out.

Endowment libraries are essential in nature, an integrated part of our societal development and learning system that helps keep information safe and promotes learning and research development activities. They used to keep rare books, manuscripts, and cultural artefacts safe for future generations. Now, it focuses on a wider range of accessibility to materials and facilities. Digitising collections has made sure that information is safe and easily accessible for people in the future. These endowment libraries help scholars from schools, institutions, and the public by targeting patrons for educational events, encouraging people to keep learning, and giving people access to useful materials. They also help research by giving out unique, rare collections, fellowships, and financial aid, and by encouraging people to work together. The future of endowed libraries looks bright, even though they have to come up with several challenges like making sure everyone has equal access, keeping their finances stable, and keeping up with new technologies. They will be able to keep helping their communities thanks to advances in technology, more responsibility, and better cooperation around the world. These endowment libraries help make education fair for everyone without facing any obstacle, protect culture, and encourage new ideas. They stay relevant and advance ideas by using new technologies and focus more on services. Their long-term learning involves living beyond the physical collections of materials; they are primarily focused on teaching and learning, research, and preserving knowledge. It is necessary that they can change and adapt all the time. Considering, endowment libraries are safe to help the past live, enhance and improve the present, and highly motivate the future, which is an essential need for society and a large step forward for future generations. AI-driven preservation also has ethical privacy and bias-related risks that future research needs to investigate,

along with financial constraints and technological challenges. If you follow these steps, the suggested foundation can go from an idea to a reality. This will create a long-lasting, open, and tech-savvy way to keep knowledge in endowment libraries for future generations.

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