Evaluating Open-Source Digital Library Systems: A Comparative Study

Yaghoub Norouzi[1] | **Nayere Jafarifar**[2*]

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Yaghoub Norouzi
Professor in Knowledge and Information Science, Department of Knowledge and Information Science, Faculty of Literature and Human Sciences, University of Qom, Iran.
E-mail: ynorouzi@gmail.com

Nayere Jafarifar
Corresponding Author, MSc in Knowledge and Information Science, Department of Knowledge and Information Science, Qom University of Medical Sciences, Qom, Iran.
E-mail: jafarinayere@gmail.com

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ABSTRACT

Digital Libraries (DLs) enable the development, organization, and administration of digital resources and collections while offering search, retrieval, and other information services through computer networks and electronic platforms. The efficient management of digital content in these libraries bolsters the knowledge economy and fosters an environment conducive to scientific advancements and innovations. Open source is increasingly viewed as a viable alternative to commercial digital library systems, largely due to dissatisfaction with their functionality. Additionally, budget constraints faced by libraries and the rising costs of software development and maintenance have further fueled this shift. Open-source digital library software offers free access alongside reliable functionality, making it an appealing option. Selecting high-quality software is a critical decision in designing a digital library, as it forms the foundation for delivering services. However, the wide range of available options can make the selection process challenging. The key issue lies in clearly defining the library's information requirements and its intended usage. To simplify the decision-making process, we evaluated six widely adopted open-source digital library systems including CDSware, DSpace, Fedora, Greenstone, Keystone, and EPrints. The assessment was based on a checklist comprising eight categories of key criteria. Among these, DSpace emerged as the top performer, followed by Fedora, Greenstone, CDSware, and EPrints. Conversely, Keystone was ranked as the lowest one due to inadequate support for several essential features outlined in the checklist. This study aims to assist decision-makers in selecting and implementing open-source digital library systems effectively in their institutions.

KEYWORDS

Content Management, Digital Library, Knowledge Economy, Open Source.

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Introduction

Digital Libraries (DLs) are integral to the knowledge economy, which is an economy primarily driven by the production, distribution, and use of knowledge and information rather than traditional industries like manufacturing. As the global economy shifts toward an increased reliance on intellectual capital and data-driven decision-making, DLs serve as critical hubs for storing, managing, and disseminating information (Ajani et al., 2024). DLs provide unprecedented access to a wealth of knowledge, including academic research, publications, datasets, and historical archives. This easy access supports knowledge dissemination, enabling individuals, businesses, and institutions to quickly find the information needed to innovate, solve problems, and make informed decisions. In a knowledge economy, access to relevant, up-to-date content can directly affect economic performance, productivity, and competitiveness (Das, 2008). The knowledge economy thrives on innovation, and research is its cornerstone. DLs support researchers by offering access to scientific journals, academic papers, technical reports, and data sets. Researchers can collaborate more easily, explore the existing works, and build on past findings, fostering the creation of new knowledge and technological advances. This leads to innovations in fields like technology, medicine, and environmental sustainability (Anyim, 2018). DLs support economic development by providing small businesses, startups, and Entrepreneurs access to valuable resources, market insights, and research reports that might otherwise be out of reach. For example, a small business might access market research to help make strategic decisions or obtain scientific literature to innovate and develop new products (Dent, 2007). The knowledge economy heavily depends on intellectual property rights, including patents, copyrights, and trademarks. DLs help protect and manage this IP by storing relevant legal documents and ensuring easy access to these records. This ensures the proper use and attribution of intellectual capital, which are essential for fostering innovation and maintaining a fair marketplace (Kahn & Wu, 2020; Kallinikou et al., 2009). DLs are not just passive repositories but dynamic, evolving resources that actively shape the knowledge economy. By improving access to information, supporting research, fostering collaboration, and enabling lifelong learning, DLs provide a foundation for the continuous growth and development of knowledge-based industries. As the global economy continues to evolve, DLs will remain central to ensuring that knowledge is accessible, preserved, and used effectively to drive progress (Patra, 2006; Zharinov, 2020).

Content management in DLs is crucial for the knowledge economy. DLs serve as repositories for vast amounts of information, research, and educational resources, all of which are fundamental to the growth and dissemination of knowledge. In the context of the knowledge economy, efficient content management ensures:

- Information Accessibility: Well-organized DLs make knowledge more accessible to a broader audience, enabling students, researchers, and professionals to find and use information quickly and effectively.
- Knowledge Preservation: Digital content management systems help preserve

valuable intellectual resources, ensuring that knowledge is not lost over time due to technological or physical degradation.

- Collaboration and Innovation: A well-managed digital library facilitates collaboration across disciplines, industries, and borders by providing a central place for sharing and accessing diverse resources, thus fostering innovation.
- Efficient Use of Resources: Content management in DLs enables organizations to efficiently store, retrieve, and utilize data, reducing redundancy and improving productivity across sectors like education, business, and government.
- Economic Growth: By making high-quality information and research accessible, DLs contribute to the development of new ideas, products, and services, directly impacting the knowledge economy's growth (Du Plessis & Mabunda, 2016; Moahi, 2012; Paul, 2024; Srivastava et al., 2024; Stamou, 2017; Vijayakumar et al., 2024)

Therefore, content management in DLs plays a central role in ensuring the smooth flow of information and fostering innovation, which are vital to the functioning of a knowledge-driven economy. Meanwhile, using open source DLs is valuable in the knowledge-based economy. Open source DLs are typically free to use, reducing the financial burden on institutions. This is particularly advantageous for universities, libraries, and non-profit organizationsthat have limited budgets for proprietary systems (Kissa et al., 2024). Open source software allows institutions to modify and adapt the system to meet their specific needs. Customization is possible without relying on vendor-specific solutions or incurring high licensing fees. Open source projects are often supported by active communities of developers, scholars, and professionals. This fosters collaboration, encourages innovation, and provides a wide range of resources, such as forums, documentation, and user-driven development (Moradia et al., 2024). Open source code is open to inspection by anyone, which means that vulnerabilities can be identified and addressed quickly. This transparency also fosters trust, as users can verify that the system does not have hidden features or security risks (Ahammad et al., 2024). Open source DLs often adhere to widely accepted standards and protocols (e.g., OAI-PMH, MARC, Dublin Core), promoting easier integration with other platforms and systems. This can enhance resource discovery and sharing across institutions and regions (Hussein, 2017). Since open-source systems do not depend on the financial viability of a single vendor, they are less likely to become obsolete or unsupported over time. Institutions can continue using and evolving the software without worrying about licensing changes or corporate decisions (Ahammad et al., 2024). Open source DLs offer substantial cost savings over the long term compared to commercial solutions. The absence of licensing fees, lower initial setup costs, and more flexible customization options make open-source systems attractive, especially for institutions looking to minimize their total cost of ownership. However, these savings come with the need for more in-house technical expertise or reliance on third-party service providers for support (Ahammad et al., 2024).

Based on some research findings (e.g., Jabeen, 2024; Kampa & Kaushik, 2019; Khan &

Sheikh, 2022), evaluating open-source DLs content management is crucial in the knowledge-based economy. By leveraging the strengths of open-source technologies, organizations can contribute to a more open, collaborative, and innovative global knowledge infrastructure. Therefore, this article evaluates the content management in open source DLs' applications.

Literature Review

Vijayakumar et al. (2024) explored the role of Digital Libraries (DLs) in enhancing e-commerce growth by providing access to market research, best practices, and training resources, which are crucial for competitive advantages. They also examined the challenges that digital libraries face, such as funding constraints, digital divides, and technological advancements. By addressing these issues, Digital Libraries can continue to foster e-commerce development, contributing to the broader digital economy.

The study by Kampa and Kaushik (2019) investigated the adoption and utilization of open-source software (OSS) in libraries belonging to India's Institutions of National Importance (INIs) and examined its economic implications for these libraries. Furthermore, the research explored the business model associated with OSS. Through an online survey targeting library professionals in INIs, the study assessed the extent of OSS adoption, usage, and acceptance. To analyze the data, descriptive statistics and Pearson's chi-square test were employed.

The results showed that INI libraries utilize open-source software (OSS) for Integrated Library Systems (ILS) (18.4%), digital repositories (95.2%), and library websites (65.5%). The most widely used OSS solutions in these libraries are Koha, DSpace, Drupal, and Joomla! The findings suggested a strong positive correlation between the adoption and usage of OSS and factors such as favorable attitudes towards OSS and the presence of an OSS policy. Additionally, the study estimated that Indian university libraries could potentially save around ₹417 million by adopting open-source ILS platforms like Koha, Evergreen, NewGenLib, and ABCD.

Garzarelli et al. (2008) leveraged classical economic theories on the division of labor and institutional analysis to examine the comparative costs and benefits of open-source software (OSS) and proprietary software development. They contended that OSS, with its unique licensing model, facilitates market expansion more effectively than proprietary alternatives by encouraging voluntary contributions from a diverse pool of participants. This collective effort results in a division of labor described as 'redundant economies'. By continuously generating, reusing, and sharing knowledge, these redundant economies produce increasing returns, which are crucial for fostering the economic growth.

As a result, there has been a growing interest in the development of open-source software for DLs, with developers from various locations and organizations collaborating to share codes and enhance programs. From an economist's perspective, the behavior of individual programmers and commercial entities involved in open-source DL projects is of significant importance. Background checks showed while there has been significant

research on digital libraries and content management in general, the specific application of open-source solutions in this area seems underexplored.

There is a lack of research that specifically evaluates the role of open-source DL software in content management for the knowledge economy. By focusing on this gap, the article could contribute new insights into the advantages and challenges these open-source platforms present for managing knowledge.

Methodology

DLs play an essential role in creating, organizing, and managing digital content and collections, offering users tools for search, retrieval, and a range of information services through electronic platforms and computer networks. Technological advancements in DL systems have transformed the way people access and interact with information, redefining libraries as entities beyond physical spaces.

In recent years, open-source software has emerged as a viable alternative to commercial digital library systems, largely due to functionality concerns and the financial constraints faced by many libraries. Budget reductions, coupled with the rising costs of software development and maintenance, have made open-source DL software an increasingly attractive option. These platforms offer free access while maintaining robust functionality, contributing to their growing popularity.

A critical step in designing a digital library is selecting the appropriate software platform to deliver services effectively. With a wide array of options available, this decision can be complex. The key issue lies in clearly identifying the type of information the library will manage and its intended use.

To support this decision-making process, this study compares six widely used digital library systems that are implemented globally. DSpace[1], developed by the MIT Libraries and Hewlett-Packard Labs, is distributed under the BSD open-source license. Fedora[2], a collaboration between Cornell University and the University of Virginia Library, is released under the Educational Community License. Greenstone[3], developed by the University of Waikato, is distributed under the GNU General Public License. Keystone[4], developed by Index Data, is also licensed under the GNU General Public License. EPrints[5], created by the University of Southampton, is an open-source system for managing digital repositories. CDSware[6], developed by CERN, the European Organization for Nuclear Research, CDSware is used for document server software in one of the world's largest particle physics laboratories.

The six digital library systems were systematically assessed based on their content management features, as outlined in the subsequent sections (Table 1). The weighting of

1. DSpace Federation: Available at http://www.dspace.org/.
2. Fedora Project. Available at http://www.fedora.info/
3. Greenstone Digital Library Software. Available at http://www.greenstone.org/
4. Keystone DLS. Available at http://www.indexdata.dk/keystone/
5. EPrints for Digital Repositories. Available at http://www.eprints.org/
6. CDSware developed the CERN document server software. Available at http://cdsware.cern.ch

evaluation criteria was adapted from the method proposed by Dawood et al. (2021), who utilizes the Fuzzy Delphi technique. This technique traditionally involves a committee assigning weights to criteria anonymously, using questionnaires. For this study, the approach was modified by enlisting a panel of 10 individuals, all trained in information science and knowledgeable about Digital Library (DL) concepts, to independently assign weights to each category and its associated items.

Subsequently, the six selected DL software systems were evaluated using a comprehensive checklist. The evaluation was conducted by the same 10-member panel during a separate session, where they collaboratively scored the software. If disagreements arose regarding whether the software met specific criteria, a simple majority vote was used to resolve the issue. In cases of a tie, the matter was clarified by reaching out to the software developers via email or consulting additional resources.

Table 1.
Verbal Phrases for Confirming the Evaluation Indicators

Linguistic Variable	Fuzzy equivalents	Inverse Fuzzy Equivalents
Not important	1-1-1	1-1-1
Very low importance	3-2-1	0.5-1-0.333
Low importance	4-3-2	0.5-0.333-0.25
Relatively low importance	5-4-3	0.333-0.25-0.2
Somewhat essential	6-5-4	0.25-0.2-0.166
A little essential	7-6-5	0.2-0.16 -0.142
Somewhat necessary	8-7-6	0.166-0.142-0.125
Essential to a great extent	9-8-7	0.142-125.0-0.111
Completely necessary	9-9-9	0.111 -0.111 -0.111

(Source: Researcher's Findings)

Research Elaborations

The criteria for the initial selection of DLsoftware were as follows:

1. *Availability for free download and installation*: The software must be available for download and installation at no cost under an open-source license to facilitate evaluation.
2. *Widespread use*: The software should be relatively well-known and commonly used. This was inferred from the number of installations, especially in reputable institutions such as universities.
3. *Platform compatibility*: The software must be supported on either Linux or Windows, as these are widely used platforms.

Based on these criteria, six digital library software packages were selected for evaluation: CERN Document Server (CDSware), DSpace, Fedora, Greenstone, Keystone, and EPrints.

The following are the primary content management features expected in modern integrated DL software:

1. *Object model*: This pertains to the internal structure of digital objects, which integrate metadata and digital content within the DL system. Unique identifiers for each object and its components are vital for ensuring long-term preservation and accessibility.

2. *Collections and relationship management*: This includes metadata for describing collections, defining sub-collections, and using templates to determine the format of digital objects or how collections are presented. It also encompasses establishing relationships between various types of objects.
3. *Metadata and content storage*: This feature addresses storage functionality and preservation concerns. The DL system should support both standardized and customized metadata sets while managing diverse digital content formats.
4. *Search and navigation*: This involves mechanisms for indexing and searching metadata. The system should provide indexing capabilities not only for a limited range of metadata but also for specific metadata fields to enhance the search functionality.
5. *Object management tools*: These tools include interfaces and processes for managing metadata and digital content, enabling users to insert, update, or delete records effectively.
6. *End-user interfaces*: These interfaces provide users with seamless access to the digital library, its collections, and digital objects, ensuring a user-friendly experience.
7. *Access control mechanisms*: This includes user and group management, as well as authentication and authorization methods. The system should provide granular access and update controls across various levels, including the digital library, collections, individual objects, and content.
8. *Multilingual support*: The software must support multiple languages across its user interface, metadata, and digital content. Proper character encoding is essential to ensure full functionality in multilingual environments (Kamdar, 2019; Mandal, 2018; Rahman & Islam, 2020).

The defining features of effective open-source DL software were identified through a review of the literature. Key categories of content management features were first outlined and subsequently broken down into their supporting components. To evaluate these features comprehensively, a checklist was created encompassing all identified content management attributes. The outcomes of the Fuzzy Delphi panel are summarized in Table 2.

Table 2.
Fuzzy Delphi Panel Results

Indicator	Definite Average	Confirmation Status
Search and browse	8.8	Approved
User interfaces	8.8	Approved
Metadata and digital content storage	8.7	Approved
Object management	8.5	Approved
Access control	8.2	Approved
Object model	7.8	Approved
Multiple languages support	7.7	Approved
Collection support and relations	7.4	Approved

(Source: Researcher's Findings)

In this study, the threshold number was considered to be 7 (Wu & Fang, 2011). Based on the findings in Table 2, it was determined that after analyzing the data from the Fuzzy Delphi questionnaire and in two stages, a total of 8 indicators was confirmed and selected to evaluate content management in open source DL.

The checklist was applied to evaluate six widely used open-source DL software packages—CDSware, DSpace, Fedora, Greenstone, Keystone, and EPrints. This assessment aimed to determine their suitability for DL projects, as guided by the insights of the Fuzzy Delphi Panel members.

Each of the six DL systems was evaluated across the eight categories mentioned earlier. Based on the analysis of these categories, the DL systems were graded for each characteristic, with the scores ranging from **1** (the lowest) to **5** (the highest). This grading system helped to provide a clear comparison of the systems based on their features and suitability for the project.

Next, the Simple Additive Weighting (S.A.W.) method was used. In this method, the scores obtained from the evaluation of each software in each indicator were multiplied by the weighted average determined in the Fuzzy Delphi Evaluation List for each indicator, and based on the results, the open access software of the studied digital library was compared with each other in terms of their content management status.

Findings

In this section, we present our findings regarding the six selected DL software packages considering 8 basic content management features:

Table 3.
Evaluation Results for 8 Basic Content Management Features

	DSpace	Fedora	Greenstone	Keystone	EPrints	CDSware
Search and Browse	• The system automatically indexes the core metadata set (qualified DC) using a relational database. • It also indexes additional metadata sets using the Lucene API (Apache Lucene). • Lucene enables field-specific search, stemming, and the exclusion of stop words. • Searches can be limited to specific collections or communities. • By default, browsing options are available for title, author, and date fields.	• The default indexing system accommodates both the DC metadata set and the system metadata of digital objects. • Indexing and search functions are managed through relational databases like MySQL, Oracle, or PostgreSQL. • Searches can be performed across all indexed fields, with the flexibility to apply constraints combining multiple fields. • A generic search interface is available using search engines like Lucene or Zebra. • Relationships between digital objects are indexed and searchable via the Fedora resource index. • The system does not provide a browsing mechanism by default.	• Indexing is supported for text documents and specific metadata fields. • The search function allows queries to target specific sections within a document or the entire document. • Stemming and case-sensitive searches are enabled. • Open-source tools are used to handle large data volumes for indexing and searching operations. • Catalogs can be browsed and organized by specific fields using a hierarchical structure.	• Indexing is available for designated document types across the entire metadata set. • Free-text search functionality is provided. • No browsing mechanism is available.	• All metadata fields are supported with MySQL as the database and full-text indexing are available for selected fields. • Users can perform both combined fielded searches and free-text searches. • Browsing is enabled using specific fields.	• Supports full-text search and allows searching across all metadata fields. • The CDSware system utilizes its proprietary indexing technology and a search engine tailored for large data repositories. • Indexing and searching are handled through a relational database, such as MySQL.

	DSpace	Fedora	Greenstone	Keystone	EPrints	CDSware
User Interfaces	• A default web user interface is provided, allowing users to browse collections, view the qualified Dublin Core (DC) metadata of items, and access their bitstreams. • Navigation within an item is supported through its structural metadata. • A search interface is included by default, enabling users to perform keyword searches.	• The web interface provides a search environment for users. • By default, digital objects are displayed with system metadata and their associated datastreams. • The presentation or manipulation of datastreams is determined by the behavior of digital objects. • Developers have the ability to create custom web services and associate them with digital objects as behaviors. • Dublin Core (DC) metadata is included as default behaviors.	• The default web user interface enables users to browse and search collections, as well as navigate through hierarchical objects using a table of contents. • The display of documents or search results can vary based on the specified XSLTs.	• The presentation of the document is controlled by an XSLT stylesheet customized for its document type. • The main web user interface is structured in a portal-like format, enabling users to browse the document directory and search within the digital library.	• The web user interface allows browsing by specific metadata fields. • Browsing can be hierarchical, especially for subject fields. • The search environment enables users to refine their queries by using multiple fields and selecting values from predefined lists.	• CDSware allows users to store repository content in personal files within the system. • Each collection can have its own dedicated interface. • Multilingual support is provided for the interfaces.
Metadata and Digital Content Storage	• The qualified DC metadata is maintained in a relational database, such as PostgreSQL or Oracle. • Other metadata collections and digital content are stored as bitstreams on the file system. • Each bitstream is linked to a particular format. • A support level is assigned to each bitstream format, which indicates the level of preservation for the corresponding file format.	• Metadata and digital content are handled as data streams within the digital object. • Data streams can be stored in three different ways: (a) within the digital object XML file, (b) as managed content on the file system, or (c) from an external source. • Multiple metadata sets can be used at the same time. • Basic technical metadata, such as MIME type, file size, and checksums, are stored for each data stream to ensure content preservation. • Versioning is available for specific data streams, allowing users to access previous versions of the data stream instances.	• Documents and resources are stored on the file system. • Metadata is user-defined and embedded within documents using an internal XML format.	• Each item keeps its metadata in an XML file. • The metadata is not restricted to a particular standard but is specified using a custom XML schema for each type of document. • The digital content is stored within a directory system that contains the XML files.	• The user defines the metadata fields. • The data object, including metadata, is stored in a MySQL database, while the documents themselves are kept on the file system.	• Metadata fields can be added or removed as needed. Accepted content is updated and indexed in real-time. The data object, including metadata, is stored in a MySQL database.
Object Management	• Items are created through the Web submission interface or by using the batch item importer, which uploads XML metadata documents and associated content files. • A workflow process may be triggered in both cases, depending on the collection's configuration. • The workflow can be customized with one to three steps, allowing different users or groups to participate in the item submission process. • Collections and communities are created via the Web user interface.	• Digital objects can be created using the administrator client or the batch import utility, which supports XML files in METS or FOXML format. • Metadata can be added or edited through a text editor within the administrator client. • The same client is also used for adding or removing digital content (data streams).	• New collections and the documents within them are created using the Greenstone librarian interface or the command-line building program.	• Keystone's content management system offers a web interface for document editing. • It allows designated users to manage both the content of documents and the file structure.	• A default web user interface is available for creating and editing objects. • Authority records are utilized to assist in completing specific fields, such as authors, titles, etc. • Objects can also be imported from text files in various formats, including METS, DC, MODS, BibTeX, and EndNote.	CDSware supports multiple collections within the system. The collected data is always converted into MARC XML format, ensuring compatibility with OAI. Additionally, it allows for format conversions, such as from MARC XML to MARC21 or Dublin Core (DC), among others.

	DSpace	Fedora	Greenstone	Keystone	EPrints	CDSware
Access Control	• Supports users with different levels of access rights. • Authentication is managed through user passwords or the Lightweight Directory Access Protocol (LDAP). • Access control permissions are configured for each item, specifying the actions users are allowed to perform.	• Supports users and groups with authorized access to specific digital objects through XACML policies. Authentication is provided via LDAP or for specific IP addresses.	• A user is assigned to one of two predefined groups: administrator or collection builder. The administrator group has the rights to create and delete users, while the collection builder group is responsible for building and updating collections. End users have access to all collections and documents.	• A basic access control system is supported, allowing the definition of administrators and standard users, each with specific access rights to designated parts of the document structure.	• Registered users can create and edit objects by logging in with their username and password.	• CDSware recognizes multiple resources within the system. Users have the option to select their own passwords and are provided with password reminder features.
Object Model	• The fundamental unit is an item, which encompasses both metadata and digital content. It employs Qualified Dublin Core for metadata. The internal structure of an item is determined by its structural metadata. Each item is assigned a globally unique identifier using the CNRI handle system, and persistent identifiers are also applied to the bitstreams linked to each item.	• The primary entity is the digital object, structured according to the Fedora Object XML, which follows the METS standard. This digital object consists of both metadata and digital content, with each being managed as data streams. Additionally, the digital object contains links to its associated behaviors. Data streams are uniquely identified by a combination of the digital object's persistent identifier and the DataStream identifier.	• The primary entity is the document, represented in XML format. Documents are associated with one or more other entities. Each document is assigned a unique identifier, though persistent identifiers for the resources are not supported.	• The core entity is the document, with its internal structure defined by a user-specified XML schema. The directory organization of the documents mirrors the structure of the objects.	• The fundamental entity is the data object, which consists of a record that includes metadata. This data object can be linked to one or more documents (files), and each data object is assigned a unique identifier.	• CDSware includes a versioning system to manage updated or enhanced versions of registered objects. Additionally, it offers a function for managing and correcting submitted objects. Like other software in this category, CDSware emphasizes allowing creators to submit digital objects themselves.
Multiple Languages Support	• Employs Unicode character encoding. • Supports multiple languages in both metadata fields and digital content.	• Utilizes Unicode character encoding. • Supports multiple languages within the metadata fields and digital content.	• Employs Unicode character encoding. • Supports multiple languages in both metadata fields and digital content. • Offers pre-translated multilingual interfaces ready for use in various languages.	• Utilizes Unicode character encoding. • Supports multiple languages in metadata fields and digital contents. • Provides an XML attribute in metadata fields to specify the language of the field value.	• Employs Unicode character encoding. • Supports multiple languages within metadata fields and digital contents. • Includes an XML attribute in metadata fields to specify the language used for each field value.	• Unicode support enables the use of nearly all languages. • Document formats can be defined as short or detailed HTML, XML DC, and XML MARC21.
Collections and Relations Support	• Allows the creation of collections of items and communities that contain multiple collections. • An item can be part of several collections, but it has only one primary collection. • Default values for metadata fields can be set within a collection. • The collection's descriptive metadata includes the title and description. • There is no support for establishing relationships between different items.	• Fedora supports collections via the RELSEXT DataStream, which includes a fundamental relationship ontology. • This DataStream utilizes the Resource Description Framework (RDF) to express relationships between digital objects (W3C). • However, Fedora lacks a built-in mechanism to manage or manipulate these relationships.	• A collection specifies a set of attributes that define its functionality. • These attributes encompass capabilities such as indexing, searching, browsing, supported file formats, conversion plugins, and import entry points for digital content. • A hierarchical structure is supported for text documents, including elements like chapters, sections, and paragraphs. • Specific sections within a text document are marked using special XML tags. • XLinks within a document can be used to create links to other documents or resources.	• Collections are not explicitly defined but are implied by the hierarchical organization of the documents. • The XML schema for the documents outlines shared characteristics for documents of a particular type. Relationships between documents are not formally defined, but can be indicated by using URLs in specific metadata fields.	• Collections are not explicitly considered. • Data objects are categorized based on specific fields like subject, year, or title. • Relationships between documents are not formally defined, except by using URLs in specific metadata fields.	• CDSware enables repository administrators to pre-set specific values for metadata fields, making data entry more efficient. • Collections are organized using a hierarchical structure. • Metadata and full-text information are kept separate. Metadata only contains the necessary information to access the full-text source using the OpenURL Protocol.

(Source: Researcher's Findings)

In Table 3, the six open access DL systems are compared according to the characteristics outlined in the previous section. The level of support for each characteristic is discussed and specific considerations for each DL system are provided. The table displays the scores for each category across the six evaluated DL software systems.

Table 4.
Evaluation Results for Individual Categories

Characteristics	DSpace	Fedora	Greenstone	CDSware	EPrints	Keystone
Search and browse	35.2	26.4	35.2	35.2	35.2	17.6
User interfaces	35.2	17.6	35.2	35.2	35.2	35.2
Metadata and digital content storage	34.8	43.5	26.1	26.1	26.1	26.1
Object management	34	17	17	25.5	34	25.5
Access control	41	32.8	16.4	24.6	16.4	16.4
Object model	31.2	39	23.4	23.4	15.6	23.4
Multiple languages support	23.1	23.1	30.8	23.1	30.8	30.8
Collection support and relations	29.6	29.6	37	22.2	7.4	14.8
Total	264.1	229	221.1	215.3	200.7	189.8

(Source: Researcher's Findings)

Table 4 showed that DSpace was found to be the best performer followed by Fedora, Greenstone, CDSware, EPrints and Keystone. In contrast, Keystone was the worst performer due to its poor support for certain features deemed important in our checklist.

Discussion and Conclusion

It is challenging to recommend a single DL system as the most suitable one for all scenarios. Each system has its own strengths and weaknesses, as highlighted in the comparison above, which categorizes them based on fundamental characteristics and features. This comparison should only serve as a guide for organizations to determine whether one of these DL systems fits their needs for hosting digital collections. Typically, an organization's requirements vary based on factors such as the number of collections, the types of objects, the nature of the content, update frequency, content distribution, and time constraints for DL development. The following paragraphs offer guidance on selecting a DL system based on different organizational needs.

1. In a scenario where a university or institution needs a digital repository for research papers and dissertations from students and staff, DSpace would be the most appropriate digital library system. It naturally supports the organization of communities (e.g., university departments) and collections (e.g., research papers and dissertations), and its workflow management is vital for handling item submissions from individuals.

2. If an organization needs a single digital collection to publish content quickly and integrate the digital library's interface with a portal-like website, Keystone or EPrints would be the ideal choices. These systems allow separation of presentation and storage, are flexible in metadata standards, and offer simple web interfaces for submitting and displaying documents and metadata.

3. For an organization focused on digitizing collections from libraries, archives, and museums and managing them in one digital library system, Fedora is the best option. Its highly customizable and modular architecture suits organizations with the resources and time to tailor the system and develop additional modules. It supports preservation needs, multiple metadata standards, and a variety of digital content formats. Although it lacks user-friendly web interfaces or built-in functionalities, it is the best choice for managing diverse collections. CDSware is also a viable option for handling large repositories with various materials, such as museum object descriptions or classified documents.

4. When an organization wants to electronically publish books in a user-friendly and customizable digital library system, Greenstone is the most suitable choice. It supports hierarchical representation of books, including tables of contents, and enables full-text search within chapters.

In today's knowledge-driven economy, knowledge flows in new ways, leading to shifts in an organization's structure and function. Digital libraries, as organizations, often innovate in how they deliver information services to clients, leveraging information and communication technologies. The growth of technological applications is transforming how digital libraries serve their clients, with content management continuously redefining how DL collections are utilized.

This article made an attempt to explore the content management in six DL software systems including CDSware, DSpace, Fedora, Greenstone, Keystone, and EPrints. The research adopts a qualitative paradigm and a case study design, allowing for an in-depth analysis of the participants' perceptions and experiences while ensuring real-life situations are considered. A key finding from the study is the emphasis on the critical role of the content management in open-source DLs.

Content management in DLs plays a crucial role in the knowledge economy by facilitating the organization, preservation, and accessibility of information. As knowledge becomes a primary driver of economic growth, the ability to manage vast quantities of digital content effectively ensures that valuable data, research, and intellectual capital are readily available to individuals, organizations, and governments. Here are a few reasons why content management is essential in this context:

- *Efficient Knowledge Sharing and Collaboration*: Digital libraries make it possible for individuals across the world to access research, academic papers, datasets, and other forms of knowledge. Effective content management ensures that this information is well-organized, searchable, and up-to-date, fostering collaboration and innovation in various fields.
- *Preservation of Intellectual Capital*: In the knowledge economy, intellectual property and research outputs are central to productivity and innovation. Digital libraries ensure that digital assets are preserved for future generations, reducing the risk of knowledge loss due to technological obsolescence or data corruption.
- *Support for Lifelong Learning and Skills Development*: Content management systems allow learners at all levels to access a vast repository of educational

resources, which is essential in an economy that requires continuous skill development. A well-managed digital library provides both structured learning materials and informal knowledge-sharing platforms.

- *Data Curation and Integration*: The knowledge economy often relies on the integration of vast amounts of data from diverse sources. Digital libraries with strong content management practices enable the curation and integration of datasets from various fields, supporting data-driven decision-making, research, and development.
- *Facilitating Innovation*: Access to well-managed, high-quality content allows researchers, entrepreneurs, and organizations to build upon the existing knowledge and create new products, services, and solutions. In this way, effective content management can directly contribute to the innovation and development of new industries.
- *Compliance and Security*: Proper content management ensures that the content within digital libraries is protected against unauthorized access and complies with legal and ethical standards, such as copyright laws and data protection regulations. This is vital in maintaining the integrity of digital knowledge resources.

In conclusion, content management in DLs plays a crucial role in supporting the knowledge economy by ensuring that knowledge is easily accessible, reliable, and secure. This facilitates learning, innovation, and sustainable economic growth. The goal of this study was to create a checklist for evaluating DL's content management systems. The checklist consists of eight key categories of object model, collections and relations support, metadata and digital content storage, search and browse, object management, user interfaces, access control, and multiple languages support. This checklist was applied to evaluate six open-source DL software packages (CDSware, DSpace, Fedora, Greenstone, Keystone, and EPrints). Based on the evaluation, DSpace emerged as the top performer, followed by Fedora, Greenstone, CDSware, EPrints, and Keystone. Keystone was considered as the worst due to its lack of support for important features in the checklist. The developed checklist is flexible, allowing users to add new categories to suit different DL needs.

Search Engine Optimization (SEO) is also vital in the knowledge economy, as it ensures that the information remains accessible, relevant, and visible to the right audience, promoting growth, engagement, and authority in a competitive digital environment. As shown in Table 4, DSpace and Greenstone were identified as the best performers in search and browse functionality and user interfaces. A case study by Formanek (2021) on worldwide repositories using DSpace demonstrated more than 59% improvement in SEO variables compared to a fresh installation. Additionally, Begum et al. (2012) found that the Digital Library Network in South Asia (DLNETSA), East West University, and BANBEIS enhanced their search and browse capabilities and user interfaces using Greenstone DL Software.

The research findings showed that Fedora was ranked as second in the evaluation checklist. However, according to Khan and Sheikh (2022), Fedora has not been used by any university libraries in Pakistan yet, and it is recommended that its use be explored by Pakistani library authorities.

Overall, the findings highlighted the importance of content management, user-friendly interfaces, usability, and efficient information search and retrieval. These insights can guide library professionals in making informed decisions about the successful implementation of open-source DL software in libraries and the improvement of library technologies.

It is important to note that selecting a specific open-source DL system is challenging because each system has its own advantages and disadvantages, as outlined in the comparison of their features. Organizations must use the comparison as a guideline to determine which system is best suited for their digital collections, considering factors such as the number of collections, types of objects, content nature, update frequency, distribution, and development timelines.

While open-source DL Software offers flexibility, cost savings, and customization options, it also comes with challenges such as security vulnerabilities, the need for extensive internal resources, potential technical limitations, and reliance on community support. Compared to commercial software, which typically offers professional support, regular updates, and comprehensive features, open-source DLS may require more effort to maintain, scale, and secure. Organizations must carefully evaluate these challenges against the benefits before committing to an open-source DLS solution, ensuring that they have the necessary resources and expertise to manage it effectively (David, et al., 2023; Khatami & Zaidman, 2024; Verma & Kumar, 2018).

In the end, it should be mentioned that the intersection of open source DLs with AI, Big Data, and Blockchain technology is shaping up to be a transformative force in content management. Future trends indicate that these technologies will drive more intelligent, scalable, and secure solutions for managing vast amounts of data and content. By making open source DLs more accessible and transparent, these trends promise to unlock new possibilities for digital library innovation (Panda & Kaur, 2023; Tella et al., 2022; Viji, 2025).

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