

Rise of Linked Data beyond Boundaries: A Systematic Review

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ABSTRACT

Linked data (LD) has emerged as a significant technology in libraries and information centers, and has the potential to transform the way information is accessed and organized. The aim of the study is to explore linked data initiatives in libraries and information centers along with motivating factors, challenges and future directions of linked data within the libraries. A systematic literature review (2017-2023) was conducted to achieve the objectives of the study. Data were collected from different scholarly databases by using PRISMA guidelines. The finding shows significant advancements in libraries because of implementation of linked data technologies into practice such as the transition from traditional cataloging methods to more interconnected data structures, improvements in metadata interoperability and resource discovery. After successful implementations of LD initiatives (i.e. BIBFRAME, Europeana Data Model, and DPLA) in some libraries, libraries are still facing many challenges. It includes lack of equipment and financial resources, the need for professional expertise, training programs, licensing constraints, and complexities in data integration. The systematic review reveals that most LD

initiatives and projects have taken place in developed countries, and after all these years, developing countries are still lagging behind. Overall, result depicts a bright future of Linked data in libraries and information centers, as these initiatives significantly enhancing discovery, access, and user experience.

Keywords: Libraries; Benefits; Challenges; Linked Data; Semantic Web; Metadata; Data Integration; Resource Discovery; BIBFRAME

Introduction

The rise of Linked Data beyond traditional boundaries has been significantly influenced by the advancements in Semantic Web technologies, which enable the interlinking of structured data sets across diverse domains. This expansion is evident in several fields, such as geographical data, cultural heritage, digital libraries, and education. For the last fifty years, libraries structured their data by one specific format that is MARC (MACHine Readable Cataloging) which transformed the traditional catalog card into a machine-readable record. But, in recent years, library professionals have been criticizing the limited potential of MARC, and calling for a new format for describing, organizing and maintaining information that has continuously risen louder (Julia Unterstraber, 2023). Previous research has suggested that linked data (LD) offer a solution for these issues (Cagnazzo, 2017, Pennington and Cagnazzo, 2019). Linked Data refers as a set of best practices for publishing and connecting structured data on the Web (Bizer, Heath, & Berners-Lee, 2023), it emerged as a transformative technology in libraries and information centers, revolutionizing the way information is accessed and organized. The Semantic Web and the Linked Data initiatives are a growing movement for libraries and information centers to make their existing data available in a machine-readable format. Thus, libraries and information centers are highly encouraged to publish, share and interlink their data publicly. As libraries are preparing to shift away from machine-readable cataloging (MARC) to a linked data framework, new convergences in the metadata production activities of libraries' technical services units, special collections, and digital libraries are becoming possible. Therefore, literature show that integrating linked data principles into libraries has significant advancements. It has become an integral part of the everyday work practices of many of the participants which is in line with the goal of the traditional library to move towards a completely linked data system. LD has evolved as a mature technology with a lightweight realization of the Semantic Web, as well as a way of facilitating knowledge reorganization and discovery (Cuijuan, Wei & Lei, 2018).

Linked Data gained acceptance in libraries and information centres to make data accessible on the Web through LD technology, because of the potential benefits of LD. It provides the opportunity for libraries to collect, link, share and make their data machines readable. It makes documents available on the Web by linking in the form of CSV, HTML or XML (Ali and Warraich, 2018). There is no longer a need to input data in a manual format; it identifies the fields and input them automatically (Pennington, 2019). As a result, human workload gets lesser. The challenges of producing and publishing Linked Data are relatively well documented, and include conceptual, technological and legal issues; a prevalence of unstructured and not easily

disambiguated data, proprietary license constraints, a lack of financial and skilled human resources, low-levels of awareness within the profession, and lack of infrastructure, including tools, standards and best practices (Pennington, 2017; Hawkins, 2022). Barriers to the adoption of linked data are conceptual as well as technical. The aim of the research reported in this article is to provide a systematic review of the literature on linked data in libraries worldwide. The review explores the adoption of linked data in libraries, recent developments, and challenges in the implementation of linked data initiatives from 2017 to 2023. This will fulfill the literature gap and provide comprehensive picture of library linked data implementations and associated challenges. Based on these results, it makes recommendations for improving best practices in linked data implementation and suggests future research.

In the realm of geographical data, organizations like the Ordnance Survey of Great Britain are leveraging semantic web technologies to enhance their role as geographical information providers. By encoding topological relationships between geographic entities in RDF formats, they facilitate the linking of datasets with other information sources on the web, thereby extending the boundaries of traditional spatial queries (Goodwin et al., 2008). Cultural Heritage (CH) data provides another excellent example of linked data's rise. This data is inherently heterogeneous and multilingual, posing challenges to traditional data publication methods. The application of Linked Data principles has led to major national and international CH portals and open data repositories, such as Europeana and the Linked Open Data Cloud. These initiatives have greatly facilitated the interoperability and integration of distributed cultural content, thus allowing more dynamic sharing and reuse of cultural information (Hyvönen, 2012).

In digital libraries, linked data technologies have revolutionized how collections are accessed and utilized. These technologies have enabled digital collections to be machine-readable and more visible on the web, increasing user access to quality information from repositories such as the National Library of France, National Library of Spain, and the Library of Congress (Raza et al., 2019). The education sector also benefits from linked data, particularly in the area of technology-enhanced learning (TEL). Linked data is seen as the standard for data sharing on the web, enhancing interoperability among various educational resources and platforms. This integration supports a more seamless and enriched educational experience, encouraging the adoption of shared principles, datasets, and schemas (Dietze et al., 2013). Scholarly data has similarly benefited from the use of linked data. Efforts such as the Scholarly Data Project have addressed challenges in generating, representing, and maintaining linked datasets for academic conferences. By improving data models and supporting the growth of datasets beyond their original conferences, these initiatives enhance the accessibility and usability of scholarly information (Nuzzolese et al., 2016).

Overall, the rise of linked data beyond traditional boundaries is characterized by its ability to enhance data accessibility, interpretability, and interoperability across various domains. This evolution facilitates the overcoming of data silos and supports a more integrated approach to data management, providing significant benefits in sectors ranging from geography and cultural heritage to education and academic

research.

Research Questions

This study focused on the following questions:

What are the motivating factors to initiate linked data in libraries and information centers?

What are the challenges librarians and information professionals have to face while implementing linked data technologies in libraries and information centers?

What are the future approaches of these linked data initiatives in libraries and information centers?

Methodology

For the first phase, the relevant literature was collected through searching for the linked data use cases via the search engines following the Preferred Reporting Items for the Systematic Reviews and Meta Analyses (PRISMA) guidelines. The PRISMA 2020 statement includes new reporting guidance that reflects advances in methods to identify, select, appraise, and synthesize studies. (Page, M.J et.al. 2021).

“PRISMA is an evidence-based minimum set of items aimed at helping scientific authors to report a wide array of systematic reviews and meta-analyses. PRISMA focuses on ways in which authors can ensure a transparent and complete reporting of this type of research.”

Then, the collected literature relevant to this reported research was then analyzed with

Ranganathan's Five Facets (PMEST):

Personality: entity in question.

Matter: materials, substances, properties, etc.

Energy: operations, processes, activities, etc.

Space: geographic areas and features.

Time: periods, dates, seasons, etc.

These five facets can also be described as Who, What, How, Where, and When. Facet analysis was originated from Ranganathan's five fundamental facets, and these five facets (Lei Zhang, 2021). These facets helped in specifying inclusion and exclusion criteria.

Search Strategy

For searching the relevant literature, a comprehensive search strategy was devised. Reviewer repeatedly conducted searches to avoid biasness and to search comprehensively. Each search terms were devised on the basis of inclusion & exclusion criteria. Several keywords were formulated, such as: library linked data, initiatives and case study. These keywords were applied in the following manner:

(“library linked data” OR “information centres linked data” OR “library linked open data” OR “information centres linked open data”) and (“initiative” AND “case study”).

On the basis of the formulated search strategy and keywords, the search was conducted in different search engines, databases and digital libraries, such as Google Scholar, Scopus, IFLA digital repository, Emerald Insight, Science Direct, Springer

Link and so forth, including Semantic Web Journal.

Inclusion and Exclusion Criteria

The following inclusion and exclusion criteria were determined with the help of Ranganathan's five facets PMEST (Zhang, 2021) and discussion with the expert.

Inclusion criteria were as follows:

Studies with the terms LD or linked open data (Personality)

Articles, presentations or conference papers (material)

Studies focused on LD initiatives in libraries and information centres (Energy)

Only studies published between 2017 and 2023 (Time)

Only studies published in the English language;

Exclusion criteria were as follows:

Studies not relevant to linked data

Linked data studies not relevant to Library Information centres; and

Library linked data initiatives or case studies not describing motivating factors and challenges during the process.

Study selection and data extraction:

Figure 1 describes the identification and screening of eligible studies. Information was extracted from each eligible study in a specified form. Extracted information from each study consisted of author name(s), year of publication, country, motivating factors, challenges.

Results

After conducting a comprehensive search by using the search strategy on search engines and digital libraries and two core journals related to linked data technology, a total of 29,225 records were retrieved. After removing duplicates and scanning, 14,110 records were retrieved. From these selected full-text records, 10 records were selected that fulfill the inclusion criteria. The data extracted from the selected studies are presented in Table 1. The first column of the table shows the author(s) of the study, the second column is the country where the Linked data project was initiated, the third column indicates the year of publication, the fourth column presents motivating factors to initiate the linked data project, the fifth column shows the challenges during the linked data project implementation and sixth column shows the future approaches of these projects. The year of publication of selected studies ranged from 2017 to 2023. Four studies were published in 2017, two studies were published in 2018 and three studies were published in 2019, and only one study was published in 2021. LD projects were initiated in Finland, Canada, Cuba, Pennsylvania, Scotland, Shanghai, Sweden, the UK and the USA. All of the studies' methodologies consisted of a narrative review that highlighted the processes involved in implementing linked data, as well as their experiences, challenges, and future approaches.

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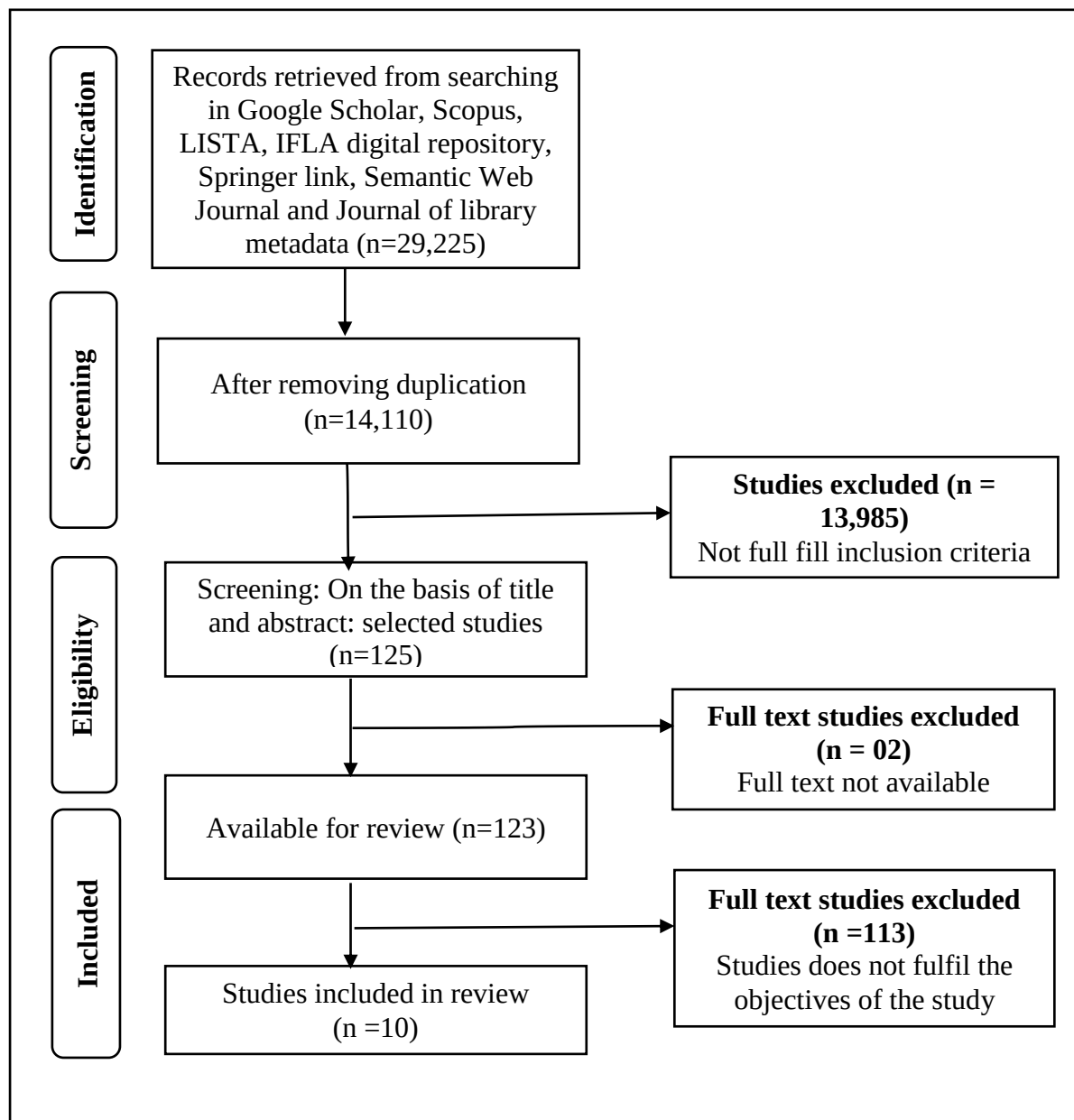
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Figure 1

Diagram of the search process



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Motivational Factors for Linked Data Initiatives in Libraries

Libraries are looking for the most effective ways of encoding and sharing their structured, machine-readable, reusable, and linked data on the Semantic Web. This approach brings the library community one step closer and put it in a larger context of technology development. There are several benefits and possibilities that can motivate information professionals to utilize linked data in libraries and information centers. The literature revealed some papers that refer to motivational factors in specific projects within the library context, which can be categorized chronologically as follows:

In 2017, Ballegoie et.al. provide a preliminary report on the work of Canadian Linked Data Initiative (CLDI) a collaboration between five of Canada's largest research libraries. In September 2015, the Canadian Linked Data Initiative (CLDI) was formed with the goal to shift away from machine-readable cataloging (MARC) to a linked data framework, it makes new convergences in the metadata production activities of libraries' technical services units, special collections, and digital libraries possible. One of the most immediate opportunities, that CLDI has provide, is the development of communal web that enable cross-country, cross-institutional collaboration. This knowledge-sharing across organizations has allowed participants to break out of their respective institutional bubbles, strengthening existing relationships while forging new ones, all the while sharing skillsets and documentation. The American Art Collaborative (AAC) also build and publish high quality linked data about their artwork and make it available on the Internet for researchers, educators, developers, and the general public. The purpose is to enhance the discoverability of data. They created a set of tools that allowed USC students to map the data without being experts in the ontology. They also publish common guidelines for best practices to assist members of the museum community to implement LOD (Craig et.al,2017). National

Challenges	Future Approaches
Issues of copyright of vocabularies	The availability of library
Resistance of using ontologies and	systems that can create, share,
linked Data in the first place	and search BIBFRAME
lack of knowledge of LD	linked data
	To adopt Schema.org model
	for publishing bibliographic
	Linked Data.
	Opening up bibliographic
	meta-data as Linked Open
	Data, including the national

Craig et.al.	USA	2017	To create and publish a LOD, drawn from the 14 museum, and made it available on the internet for researchers, educators, developers, and the general public Publish good practices guidelines to help the broader museum community to implement LOD.	The main challenge for museums is that the defacto standard ontology is complex and museums lack expertise in semantic web	To explore techniques to simplify the task of publishing LD so, other museums can easily join the AAC
Xia Cuijuan, Liu Wei, & Zhang Lei	Shanghai	2018	To integrate and maintain Digital Humanities data by constructing associations between datasets to enhance the sharing and reuse of data. To improve the accessibility of DH resources and facilitate the exploration and discovery of new knowledge through enhanced data linking	The need to develop tools to handle these tasks efficiently, such as the "Geographical Name Glossary" for place name disambiguation and "Crowdsourcing" functions to involve the broader community in data processing	Need to enhance the user experience by expanding the platform's capabilities to continue publishing different types of data, such as vocabularies, controlled names, and data sets To provide various data consumption interfaces for developers
David Wilcox	NA	2018	As a linked data server, Fedora focus on RDF triples to create semantic links between resources, it allows resources to be semantically linked both within the repository and on the broader web	Resource Constraints Interoperability Issues	To make data findable, accessible, interoperable, and reusable

Rasmussen Pennington & Cagnazzo	Scotland	2019	Opening Scotland's library content to the world	Lack of resources /time /staff	To collaborate towards design
			To augment the visibility and discoverability of library data	Licensing constraints, as well as difficulties with obtaining management buy-in for linked data initiatives	and adoption of a common model
			To overcome linguistic barriers to support interoperability	Lack of agreement on standards	to facilitate data integration
				Lack of tools / guidelines	Improve communication between system providers and information professionals
Andrew Weidner, Anne M. Washington & Xiping Liu	USA	2019	To improve the quality of the descriptive metadata in the UH Digital Library's collections	Limited standards to follow when establishing complex local heading	To make data available on a webpage or GitHub repository
			To align legacy metadata with external controlled vocabularies	It is time-consuming to develop the vocabulary infrastructure	to explore additional dissemination mechanisms
			to share & reuse data effectively across domains within semantic web	Significant amount of manual work	dissemination mechanisms
				Lack of management interface for creating and editing terms in a web browser	for Cedar data
Pedro Urria Gonzalez	Cuba	2019	To integrate printed catalog data into an open library space	Limited internet access,	To make the bibliographic data available on open and linked internet locations
			To make a cross-matched online space, by indexing these data in JSON-LD	Lack of equipment and financial resources	

Author	Country	Year	Motivational Factors	Challenges	Future Approaches
Gary Price	Pennsylvania	2021	To enhance the discoverability and accessibility of resources the project aims to make resources easier to find both within Penn's systems and through external search tools. simplifying the cataloging process, enabling better metadata sharing, and supporting advanced metadata-driven research	Challenge is to navigate the hybrid environment Complexity in developing workflow tools, and systems that efficiently support linked data creation and management	Expanding the use of hybrid linked data environments that combine traditional metadata with linked data enhancements developing a modular and interoperable framework that integrates linked data into existing library systems

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Library of Finland also build a Linked Data that makes bibliographic data more accessible and interoperable instead of adding yet another incompatible data model to the current mix (Hyvonen, 2017). The initiative aims to create living lab prototypes of centralized national Linked Data services for open science. The dataset containing about 40 million of RDF triples and based on schema.org and BIBFRAME, and it was extracted from MARC bibliographic records. The dataset contains a wide range of materials, including books, maps, journals and digitized documents. The services enable publication and utilization of datasets for data-intensive Digital Humanities (DH) research and application in structured, standardized Semantic Web formats via open interfaces, such as SPARQL endpoints. Unterstraber (2017) states that National Library of Sweden also working on improving cataloging-workflows by transforming the LIBRIS-data from MARC21 to BIBFRAME. This LD technology enhanced manual and automated work flows for the cataloging tool in LIBRIS. He states that linked data not only impacting library practice in the digital sphere, but it also provides the pillars for future technological developments, like the use of AI, to build upon and takes on an active role in further spreading the ‘ideal’ of sharing, reusing and opening up information resources on the internet.

As a use case and start point, based on linked data technology, a genealogy knowledge service platform was implemented by the Shanghai Library for providing knowledge discovery and open data services to integrate and maintain Digital Humanities (DH) data. It constructs association between datasets to enhance the sharing and reuse of data. The adoption of linked data improves the accessibility of DH resources and facilitate the exploration and discovery of new knowledge through enhanced data linking (Cuijuan, Wei, & Lei, 2018). Fedora, the Flexible, Extensible, Digital Object Repository Architecture, is open source repository software that stores, preserves, and provides access to digital content. This flexibility is primarily based on linked data. Fedora uses Resource Description Framework (RDF) triples to create semantic links on the broader web (Wilcox, 2018).

Weidner, Washington & Liu, 2019 stated that, The University of Houston (UH) Libraries has been working on Linked Data for more than 5 years, since 2013, to improve the quality of the descriptive metadata in the UH Digital Library’s collections. Towards the end they developed Cedar an open source controlled vocabulary management system for use throughout the UH Libraries and the wider linked data ecosystem on the Web. Linked Data align legacy metadata with external controlled vocabularies to share and reuse LOD effectively across domains within semantic web. The vision of National Digital Library of Cuba was to integrate printed catalog data into an open library space, and the significantly, a cross-matched online space. These data were indexed in JSON-LD. The conversion of bibliographic data of printed catalog in Linked Data enhances the searching and discovery capabilities (Gonzalez, 2019).

The Penn Libraries adopted linked data initiatives to enhance the discoverability and accessibility of resources. The project aims to make resources easier to find both within Penn's systems and through external search tools (Price, 2021). The primary goal of adopting LD is to making library resources more easily cataloged and making it simpler to share and exchange metadata.

Challenges to Implementing Linked Data in Libraries

LD adoption still faces many challenges such as lack of human resources, finances, expertise, and implementation guidelines. These challenges are enlisted as conceptual, technical and legal challenges (Hawkins, 2022).

Conceptual Challenges

Craig et.al., 2017 stated that it is challenging to integrate data all in different formats, it is essential for libraries to agree on a universal model, in order to reduce the complexity of data integration. Lack of common standards, methods and practices leads to another problem (Pennington, Cagnazzo, 2018). Metadata Unit encountered similar challenges in determining which standards to follow when establishing complex local headings. Another challenge includes the conversion of existing metadata (MARC) to BIBFRAME, this is not only time consuming but also a complicated process (Wang & Yang, 2018, Weidner, 2019). Linguistic barrier is also a challenge in data visibility and discoverability (Pennington & Cagnazzo, 2019). One of the core problem and obstacle in the adoption of linked data technology is the lack of skills and expertise among librarians and information professionals (Unterstraber, 2017, Pennington & Cagnazzo, 2018). Librarians' commitment to change is also a hindrance moving from traditional system to discovery system (Craig et.al., 2017). The top barrier in both surveys of OCLC 2015, 2018 was the steep learning curve for staff. Smith, 2018 as well as Unterstraber, 2023 also identified the steep learning curve as an ongoing challenge for many libraries starting their own projects.

Technical Challenges

The technical challenges associated with the adoption of Linked Data is, the conversion of legacy data into linked data structure, a transition from the flat data structure of the library domain MARC21 format to the open RDF entity-based model was problematic (Deliot et.al.,2018). Lack of infrastructure, technical resources i.e. tools and skills is also a barrier in adoption of LD (Pennington & Cagnazzo, 2017). Assigning URIs to bibliographic entities as text strings imposed by the tools, so the selection of an appropriate LD tool is a challenge. Another challenge is to navigate the complexity in developing workflow tools, and systems that efficiently support linked data creation and management (Price, 2021) .

Legal Challenges

Linked data adoption faced not only technical challenges, but also issues of copyright of vocabularies and resistance of using ontologies in the first place (Hyvonen, 2020). There is lack of open licensing, permission is needed from database providers to link the data (Pennington & Cagnazzo, 2017). Cost of subscription is also a major challenge in library's plan to adopt linked data (Adeyemi & Omopupa, 2020).

Future Approaches of Linked Data

Fortier et.al., 2022, Price, 2021& Unterstraber, 2017 states that library staff need trainings to understand the basics of linked data. It is necessary to bridge the gap between theory and practice. Pennington & Cagnazzo, 2018 emphasize on Step-by-step implementation guidelines, so that small libraries can also adopt LD. Cuijuan,

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Wei, & Lei, 2018 add that their next steps will be to update platform to allow users and researchers to generate data more conveniently, upload their own documents, and share their research results. Unterstraber, 2017 states that Library of Sweden is also working on implementing linked data in their end-user systems. LD technologies are connecting library metadata to the open web in meaningful ways so that they make the data findable, accessible, interoperable, and reusable (Ballegooie, 2017, Wilcox, 2018). Libraries are working on the extensibility of future systems to find ways that can leverage the richness of metadata and increase both the volume and quality of linked data.

Discussion

Systematic review on Linked Data initiatives in libraries and information centers shows that there are variety of motivating factors and challenges to initiate a LD project. All identified papers highlight that the linked data has the potential to make library bibliographic metadata publishable, linkable and consumable on the Web. Linked data adoption in libraries has grown significantly. These developments support the conversion of library catalogs from MARC to linked data formats, improving metadata quality and interoperability. Craig et.al. provide three main thrusts of linked data project that are mapping the data to a common platform, then linking the data to other resources, and then using the results to allow users to explore the data. Data extracted from studies shows that libraries can offer more precise search results and enriched user experiences, by linking diverse datasets and vocabularies to LOD. The interoperability capabilities of linked data enable libraries to integrate diverse data, including external sources like cultural heritage repositories and scholarly databases (Craig et.al, 2017). Literature indicated a lot of approaches and methodologies, which certainly enables the possibility of cross-country and cross-institutional knowledge sharing (Ballegooie,2017). Use of machine learning and other AI techniques can further automate the production of libraries linked data. It can help in further advancements in knowledge organization and dissemination of data across libraries. These advancements aim to enhance data-driven decision-making and collaborative research in libraries. Librarians and information professional can play a vital role for libraries to adopt Linked data technologies. They just need to develop their skills and expertise in Linked Data and Semantic web. The findings highlight unexplored areas and provide a roadmap for further work.

Conclusion

A quote by Aristotle "The whole is greater than the sum of its parts" remind us of how much better things are together than as individual bits. Linked data is also following same formula to link diverse data on a single platform. This will help in data discoverability and accessibility. Linked data in libraries has become more than a major trend. Despite widespread interest and apparent advantages, only a limited number of institutions have managed to make their collection available as Linked Data. There are many libraries i.e. Nigeria, Greece are trying to adopt Linked data but facing different challeges (Okoroma, 2023). They claim that the ability for a library to transition from MARC to BIBFRAME depends upon both the library systems and people working. There is dire need of collaboration among libraries across

institutional borders to create standard protocols and manage the metadata creation activities of our technological service providers in order to adapt and succeed in this shift. In conclusion, collaborative efforts among libraries and the development of training programs is needed to enhance skills in linked data management.

Recommendations

Findings revealed that most of work has been done in developed countries and there is still very low level of adoption of this emerging technology in the developing countries, Libraries are at infancy stages of LD implementation. On the basis of the findings, researcher drawn following recommendations:

Librarians and information professional should be professionally trained together with IT staff for successful implementation of LD

Government or higher institutions need to sponsor and provide financial support to operate and manage the system

Conferences, seminars and workshops related to LD in Libraries and information centres should be conducted in developing countries to make the extensive awareness about this emerging technology

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