Evaluating barriers to digital libraries development: Insights from Interpretive Structural Modeling (ISM) and Cross-Impact Matrix Multiplication (MICMAC)

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ABSTRACT

Digital libraries are pivotal in advancing knowledge accessibility, yet their development faces significant obstacles, particularly in developing regions like India. This study evaluates the barriers to digital library development using Interpretive Structural Modeling (ISM) and Cross-Impact Matrix Multiplication (MICMAC) analysis. Data were gathered from eight domain experts in India, who identified 10 critical barriers, including the lack of institutional policy, which emerged as the most critical barrier to adopting digital libraries. As an independent factor, it sits at the bottom of the digraph model created by ISM, serving as the foundational barrier. Another major barrier is the lack of financial resources, which significantly hinders development due to the substantial costs involved in digital library initiatives for academic institutions. Additionally, barriers such as lack of management support, physical infrastructure, and technological infrastructure further exacerbate the challenges. ISM was employed to construct a hierarchical model revealing the interrelationships and driving power of these barriers, while MICMAC analysis categorised them based on their influence and dependencies. The findings emphasise the importance of addressing foundational barriers to ensure resilient and effective digital library systems in India.

Keywords: Digital libraries; Digital library development; Academic libraries; Technological infrastructure; India.

INTRODUCTION

Digital libraries consist of a collection of e-resources that support the creation, exploration, and utilization of information (Borgman, 2000). They are institutions that provide access to digital collections, making them available to the public over an extended period and at minimal cost (Digital Library Federation, 1998). Data in a digital library is stored and delivered in digital formats, including text documents, images, videos, and audio files (Bishop et al., 2000), along with value-added services (Bhattacharya, 2004) to facilitate access, similar to that of a physical library. They are powered by advanced information and communication technology, and are becoming integral to the global information infrastructure. Libraries worldwide are undertaking digitization initiatives to convert

collections from analog, mainly print formats, to digital formats (Gannon-Leary et al., 2008; Lesk, 2004). With the rise of digital technologies, the role of digital libraries has evolved significantly (Islam & Haider, 2024). As users increasingly embrace a digital lifestyle, libraries are undergoing a transformative shift, focusing on meeting the needs of a tech-savvy generation (Gao et al., 2022). Many universities and colleges globally are accelerating the implementation of digital libraries to address the diverse needs of their users (Meschede & Henkel, 2019; Kampa & Patra, 2020; Gupta & Gul, 2024).

While digital libraries first emerged in industrialised nations in the 1970s, their development in India did not begin until the mid-2000s, driven by the widespread adoption of information technology and government support[1]. Digital library initiatives in India are still in the early stages, gradually gaining momentum. Initially, India launched digital library projects to preserve its art, traditions, and culture, with support from foreign organizations like Carnegie Mellon (Wani, 2021). Over time, the number of digital library initiatives has increased, although many are still in their infancy (Jeevan, 2004). Given India's rich homegrown research and development in fields such as social sciences, humanities, spirituality, and science and technology, there is a strong demand for comprehensive digital libraries to host this knowledge. Despite steady progress, digital library efforts in India are often fragmented and face significant management challenges. Many areas lack the necessary infrastructure and expertise for effective implementation. Numerous studies have identified barriers such as technical difficulties, resource constraints, and inadequate training (Alhaji, 2007; Islam, 2011; Shuva, 2012). Addressing these issues is crucial for realizing the long-term benefits of digital library initiatives in India.

Similarly, libraries in developing countries face unprecedented challenges that hinder the adoption of digital technologies (Patnala, 2024). These challenges can act as barriers to providing essential services. However, as the saying goes, the greater the challenges, the greater the opportunities for innovation. Libraries can overcome technological gaps and infrastructure limitations by adopting appropriate strategies, such as offering extensive training and implementing strong support systems (Liu et al. 2024). This evolution toward the digital era underscores the critical role libraries play in shaping community engagement (Purnomo et al., 2024). To navigate this transition effectively, it is essential to identify, categorize, and evaluate the specific barriers to adopting digital libraries. By addressing these barriers, libraries can implement strategies to enhance accessibility, provide greater flexibility, and foster meaningful growth within their communities.

The primary aim of this article is to identify, define, and establish a relational structure of the barriers to digital library adoption. The study seeks to understand the hierarchical levels and classifications of these barriers, focusing on those with the most significant impact on others. This research addresses a critical gap by exploring the following questions:
(a) What are the most crucial barriers to digital library adoption?
(b) What hierarchical relationships exist among these barriers?
(c) What are the dependency levels and driving forces of these barriers?

For the purpose of addressing the research question interpretive structural modeling (ISM) and MICMAC (Matriced' Impacts cross-impact matrix multiplication applied classification) was adopted. ISM was used to conduct the preliminary analysis of the suggested model to

[1] National Task Force on Information Technology and Software Development (https://www.dsir.gov.in/vol-17-no-2-april-june-1998-national-task-force-information-technology-and-software-development)

gather additional data on the barriers and the interrelationships among them. A Structural Self-Interaction Matrix (SSIM) and final reachability matrix are developed in conical form. Further, a diagraph is developed, which is converted into an ISM. In the end, MICMAC is carried out to categorize the different barriers into dependent, independent, linkage, and autonomous barriers, respectively.

LITERATURE REVIEW

To align with the study's objectives, the Resource-Based View (RBV) theory was applied as a foundational framework to explore how digital library initiatives can leverage organisational resources such as infrastructure, skilled personnel, and technological tools. This theory emphasizes that organisations can achieve a competitive advantage by enhancing the performance of their existing resources (Madhani, 2010). By developing resources or resource combinations that are inimitable and non-substitutable, organisations can build unique capabilities, enabling them to outperform competitors and establish a sustainable competitive advantage (Conner, 1991; Collis & Montgomery, 1995). The theory provided a lens to evaluate the barriers to digital library adoption, focusing on resource limitations and their implications for organizational capabilities, highlighting strategies for overcoming these barriers.

Digital Libraries: Definitions, Roles and Benefits

The Digital Library Federation (DLF) provides a comprehensive definition of a digital library, describing it as "a collection of digital objects, which can include text, images, video, and audio, along with the software and hardware needed to manage, access, and provide services for these objects" (Digital Library Federation, 1998)[2]. The DLF emphasises the need for proper management of software and hardware systems to ensure optimal utilisation of digital libraries (Hahn, 2008; Abu Sirhan et al., 2019). Similarly, the International Federation of Library Associations (IFLA) notes that digital libraries are not merely repositories of digital materials but also offer services, such as search functionalities, user support, and instructional resources, that enhance the overall user experience.[3]

Waters (1998) underscores a paradigm shift from traditional electronic and virtual libraries to a more advanced approach to managing and utilising information through digital libraries. These libraries enhance content portability, accessibility, flexibility, availability, effectiveness, and preservation (Borgman, 2000), while eliminating geographical barriers to access. They provide entry to contemporary compositions of human thought and culture, fulfilling a key aspiration of such systems (Roopa, 2015; Rafique et al., 2021; Barrueco & Termens, 2022). Furthermore, digital libraries foster user communities (Witten et al., 2001) and facilitate knowledge sharing (Fox and Lunin, 1993; Jain & Behera, 2023).

Digital libraries are essential for enhancing library services (Gurikar & Hadagali, 2021). For the purpose of this study, the following working definition is used: “Digital libraries are organised collections of digital content and services that provide users with the ability to

[2] Digital Library Federation (DLF) (1998). A working definition of digital library. doi: http://www.diglib.org/about/ dldefinition.htm.

[3] ISBD International Standard Bibliographic Description : 2021 Update to the 2011 Consolidated Edition. https://repository.ifla.org/server/api/core/bitstreams/202c522c-82e9-41ae-ab7c-d7227070142c/content.

access, manage, and utilise information resources effectively and efficiently." This definition highlights the organisation, accessibility, and utility of digital resources, which are critical when evaluating the barriers to their development.

Digital Library Barriers

Managing a digital library presents numerous challenges, particularly in the areas of storage and individual access to digital materials (Baker & Ellis, 2020). In developing countries, such as those in Africa, several factors hinder the digitisation process in university libraries. These include inadequate telecommunication infrastructure, both in terms of quality and quantity, the absence of a national policy and strategies for information communication infrastructure, and the lack of an effective ICT plan within the university. Additionally, university libraries face significant challenges such as insufficient staff time, limited funding, and the lack of other necessary resources for digitising collections (University of Dar es Salaam, 2000). Conversely, less frequently mentioned barriers include the absence of valuable collections to digitise, security concerns, limited awareness among university administration about the benefits of digital transformation, and issues related to intellectual property rights (IMLS, 2002).

Several studies have been conducted to assess the status, development, opportunities, and challenges associated with digitising library collections. For example, Alhaji (2007) examined the adoption of digital technologies at 30 academic libraries in Nigeria. The study identified key barriers to digital adoption, including a lack of facilities, insufficient skilled labor, inadequate funding, the absence of institutional policies, and unreliable power supply. Similarly, challenges preventing successful digital library projects in Nigerian universities include the lack of policy and implementation plans, insufficient funding, unreliable power supply, absence of trained staff, the high cost of equipment, internet connectivity issues, inadequate maintenance of equipment, lack of space, vulnerability to natural disasters, and limited internet access (Iwhiwhu & Eyekpegha, 2009). Additional barriers include intellectual property rights concerns, limited knowledge about digital libraries, political and societal obstacles, insufficient training, low literacy rates, and poor living standards for many people (Bhattacharya, 2004).

Barriers to digital library initiatives are prevalent across several countries. In Bangladesh, challenges include insufficient funding, a shortage of experienced staff, inadequate infrastructure, lack of organisational support, poor cooperation between library and IT divisions, and copyright issues (Shuva, 2012). Similarly, Huaiyuan et al. (2020) identify problems such as low investment, lack of archive websites, and limited technical expertise at universities. In China, Liu et al. (2024) point to budget constraints, unequal access to technology, and the need for specialised training for library staff in the digital realm. In India, Gaur's (2003) study of 500 management libraries found that only 7 percent had begun digital library initiatives, with infrastructure deficits, lack of commitment from institutions, and the absence of supporting laws identified as primary barriers. Jeevan and Dhawan (2002) similarly note critical challenges in digital library adoption, including limited resources, insufficient IT training, and copyright issues. These common barriers highlight the universal challenges faced by institutions worldwide in advancing digital library projects.

In emerging economies like India, librarians must be prepared to tackle global challenges associated with digital adoption. Kaur and Singh (2005) emphasise the importance of developing a nationwide information technology policy and implementing extensive training programmes for library professionals. The process of digitising libraries in India

faces significant obstacles, including inadequate infrastructure that impedes connectivity and access, and varying levels of digital literacy among the local population (Mukherjee & Patra, 2022). Budget constraints further exacerbate these challenges, limiting resources for technology, training, and accessibility (Krishnamurthy et al., 2018; Singh, 2020). Krishnamurthy (2005) highlights the potential benefits of adopting digital libraries, but emphasises the need to address these barriers and understand how they interconnect. By focusing on eliminating major independent barriers, libraries can better navigate the complexities of digital transformation.

METHOD

The current research study identified ten barriers to digital libraries through a three-step process. In the first step, relevant papers were identified using Scopus, the leading database, with the search terms "Digital Library," "Electronic Library," "Virtual Library," and "Barriers" in the TITLE-ABS-KEY fields (Bolaños et al., 2005). After eliminating duplicates, 33 papers were selected for further analysis. In step two, these papers were reviewed, and 15 distinct barriers to digital libraries were identified. In the third step, eight library and information science (LIS) experts were chosen for their extensive experience, averaging over 20 years and their familiarity with digital libraries (Watson, 1978; Barve et al., 2007; Ravi et al., 2005; Ahmed et al. 2018). The selection of experts was based on a non-probability sampling strategy (Sadler & Lee, 2010), which aligns with previous studies on ISM (Shen et al., 2016; Malek & Desai, 2019; Tan et al., 2019).

The experts (listed in Appendix 1) were approached in person and presented with a list of 15 barriers to digital libraries. Based on their expertise, they were asked to assess the sufficiency of the barriers and were given the opportunity to revise the list (Iqbal et al., 2022). After these discussions, 10 key barriers were identified. Subsequently, Excel spreadsheets were utilised to collect additional data on the relationships between the identified digital library barriers, with detailed instructions provided in Appendix 2. The spreadsheets included an introduction to digital libraries, a description of the 10 barriers, and guidelines for completing a pair-wise comparison table (Govindan et al., 2012). Experts' inputs were recorded using the codes V, A, X, and O, and the compiled data was analyzed through ISM and MICMAC methodologies.

For this study, ten key barriers were identified based on the 33 publications listed in Appendix 3. These barriers were carefully selected through a comprehensive review of the literature described earlier, ensuring that each one represents a significant challenge in the development and adoption of digital libraries. The following outlines these barriers, providing insights into the obstacles libraries faced in implementing digital systems.

(a) Lack of security for digital library

The DELOS Reference Model for digital libraries identifies six key principles: quality, user, content, design, functionality, and policy (Candela et al., 2007). Security concerns are relevant to each of these principles. Digital library architecture, in particular, faces significant security challenges (Fox and El Sherbiny, 2011). When online attacks or system failures exploit security vulnerabilities, sensitive materials may be accessed without authorization or data integrity could be compromised (Tyrväinen, 2005). Such breaches can undermine publishers' and content providers' trust, lead to financial losses for digital library owners, or cause severe issues if left unaddressed. Furthermore, library computers

are vulnerable not only to physical theft, damage, or destruction but also to various types of malware, including Trojan horses and viruses (Singh, 2003; Zimerman, 2010).

(b) Lack of standards and uniformity

Libraries in developing countries often lack standardized practices and do not compete to provide users with an enhanced experience. As a result, they remain disconnected from global trends in modern library services, continuing to follow traditional beliefs and practices. Islam (2011) observed that Bangladeshi libraries lack uniformity in resource processing. In the sample studied, 35 percent of libraries use technological methods, 35 percent rely on manual methods, and 30 percent use a combination of both. Effective management of digital libraries requires administrative expertise, the establishment of regular workflows, and a thorough understanding of the barriers, limitations, and industry standards that shape digital library operations (Moghadami et al., 2021).

(c) Lack of copyright and intellectual property issues

One of the most significant challenges to digital library development is copyright (Chepesuik, 1997). This issue encompasses both the technological foundations of digital libraries and the legal concerns surrounding literary and creative property (Moghadami et al., 2021; Shoja and Alvankar, 2013). Libraries are grappling with complex challenges related to copyright, intellectual property rights, and fair use in the digital age. Navigating these issues has become increasingly difficult for librarians, as they are multifaceted and continuously evolving (IMLS, 2000; Bhattacharya, 2004; Islam, 2011) .

(d) Lack of skilled manpower

The human resources available in libraries often require professional development and comprehensive training in the latest technologies to keep pace with the evolving information landscape (Alhaji, 2007; Kumar et al., 2008; Ameen and Rafiq, 2009). Shuva (2012) noted that a significant proportion of library staff in Bangladesh lack ICT skills. The creation and management of a digital library system, along with the handling of electronic materials, depend on a skilled, ICT-literate workforce. One of the most significant challenges in digitisation efforts is the shortage of qualified IT professionals. In Pakistan, for example, the skills required to plan, implement, and manage IT systems in libraries are often not possessed by library staff (Ramzan, 2004). Similarly, Uutoni (2014) highlighted in Namibia that the lack of technical skills among librarians prevents developing countries from fully exploiting the potential of digital information services. This underscores the urgent need for reforms in librarian training programmes to equip professionals with the skills necessary for delivering digital library services (Igun, 2006).

(e) Lack of financial resources

Significant ICT-based development initiatives in libraries are lacking due to insufficient funding (Shuva, 2012). In his study, two-thirds of the respondents cited financial constraints as the primary obstacle to digitization efforts. The current state of library funding has been a major source of dissatisfaction among librarians (Mahmood et al., 2006). Islam (2011) also identified financial resources as one of the key barriers preventing libraries from initiating digitisation projects.

(f) Lack of management support

To offer high-quality information systems, resources, and services, libraries require strong support from their organisation's management. Modern digital library systems and services

can only be developed and sustained with institutional backing, including adequate funding, human resources, and IT skill development (Gaur, 2003; Jain & Babbar, 2006; Islam, 2011). Additionally, creating effective digital information services requires the establishment of management policies that promote e-services and provide training for library staff to enhance service delivery efficiency (Alhaji, 2007; Iwhiwhu & Eyekpegha, 2009).

(g) Lack of institutional policy

The concept of policy refers to the rules and conditions that govern the interaction between users and digital libraries (Candela et al., 2007). One of the biggest challenges libraries face in delivering digital information services is the absence of established policies that support these efforts (Baro et al., 2014). Public digital libraries in developing countries struggle with a lack of formal policies and inadequate management support (Bossaller & Atiso, 2015; Imo, 2017; Hu, 2020; Igbo & Imo, 2020).

(h) Lack of technological infrastructure

Echezona et al. (2015) and Ekwelem et al. (2018) found that the lack of advanced technology, insufficient workstations with fiber optic networks, low bandwidth, unstable servers, and power outages are significant barriers to digital library development. Equipment failures and inadequate information technology infrastructure also contribute to these challenges (Uutoni, 2014). Both libraries and patrons require sufficient technical infrastructure to effectively utilise digital information resources, especially when downloading large files. Without this, digitalisation efforts may fail to achieve their intended outcomes (Ameen & Bhattacharya, 2004; Rafiq et al.,2018).

(i) Lack of physical infrastructure

An ideal environment for a digital library requires robust infrastructure complemented by a range of integrated facilities and services. However, studies have revealed that the physical infrastructure in most institutions falls short of supporting the optimal functioning of modern digital library systems. This inadequacy hampers the seamless delivery of digital services, underscoring the need for substantial upgrades to meet contemporary demands (Gaur, 2003; Alhaji, 2007; Islam, 2011;).

(j) Lack of awareness of digital library benefits

Libraries often lack the expertise needed to fully grasp the benefits of digitisation, which poses a significant barrier to initiating efforts to digitise their collections (Raju, 2014). Even among some of the leading librarians in the field, there is a shared observation that decision-makers within their organisations demonstrate limited engagement and interest in digital transformation initiatives. This reluctance is largely attributed to a lack of awareness about the digitisation process, its potential advantages, and the associated costs (Islam, 2011; American Library Association, 2013).

Interpretive Structural Modelling (ISM) Methodology

The conceptual diagram illustrating the methodology adopted for the study, including the steps of ISM as outlined by Ahuja et al. (2009), Khurana et al. (2010), and Singh and Kant (2008), is presented in Figure 1. ISM, originally developed by Warfield (1982), is a structured methodology used to analyse various factors by identifying their direct and indirect relationships. The outcome is a systematic model that offers clarity and insight into complex systems (Sage, 1977; Warfield, 1982). The versatility of the ISM methodology lies in its ability to structure multifaceted problems and reveal interrelationships between key factors, making it an indispensable tool for decision-makers. In higher education institutions, ISM can be employed to identify critical factors that influence program success

and prioritize them effectively (Hawthorne & Sage, 1975). For personal value structuring, ISM helps individuals clarify their core values and understand the interconnections among them (Malone, 1975). Additionally, in the design of decision systems, ISM enables developers to comprehend the relationships among components, optimizing overall system performance (Hansen et al., 1979; Vimal et al., 2022). This robust methodology's adaptability across diverse decision-making contexts underscores its significance in research and practical applications.

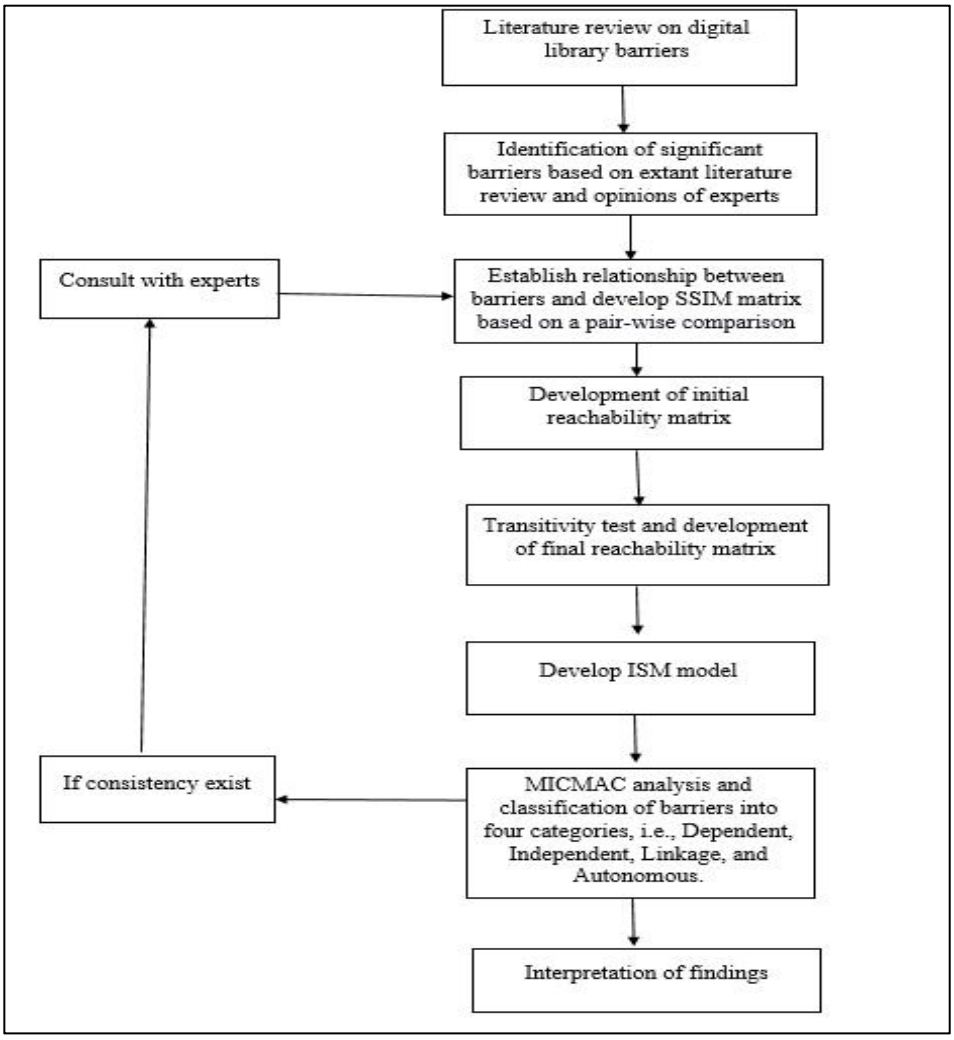

Figure 1: Conceptual Diagram Illustrating the Methodology Adopted for the Study

The ISM methodology has been widely applied to develop hierarchies, model critical success factors, and analyse supply chain and logistics systems (Sharma & Gupta, 1995). Its versatility and effectiveness make it an invaluable tool for both researchers and practitioners. By employing ISM, they can uncover insights into complex systems and pinpoint key drivers of success or failure. Majumdar and Sinha (2018) emphasise the importance of incorporating sustainability and environmental considerations into supply chain management. Tools like ISM are instrumental in identifying critical factors and relationships within the supply chain (Ravi et al., 2005; Schroeder et al., 2018) that either support sustainability initiatives or pose obstacles to progress (Chand et al., 2020). This capability positions ISM as a critical methodology for addressing multifaceted challenges, not only in modern supply chain management but also in the development and

optimization of digital libraries. By applying ISM, digital libraries can identify and prioritise key factors, such as infrastructure, user needs, and resource management, enabling them to address complex interdependencies and enhance their overall effectiveness.

RESULTS

Interpretive Structural Modelling

(a) Structural Self-Interaction Matrix (SSIM)

V, A, X, and O were the codes utilised to construct the SSIM. Each code represents the nature of the relationship between two barriers (i and j): whether one barrier influences the other (V), the reverse (A), mutual influence (X), or no influence at all (O). This systematic coding approach ensures a clear representation of the interactions among the barriers. The resulting SSIM, which serves as a foundation for further analysis, is presented in Table 1.

Table 1: Structural Self-Interaction Matrix (SSIM) Depicting the Interrelations Between Identified Barriers

No	Barriers	10	9	8	7	6	5	4	3	2	1
1	Lack of financial resources	A	A	A	A	A	A	A	O	V	
2	Lack of skilled manpower	A	A	A	A	A	A	A	A		
3	Lack of management support	A	A	A	A	A	A	A			
4	Lack of technological infrastructure	V	A	A	A	A	A				
5	Lack of physical infrastructure	V	V	V	A	V					
6	Lack of standards and uniformity	V	O	O	A						
7	Lack of awareness of digital library benefits	V	V	V							
8	Lack of copyright and intellectual property issues	V	O								
9	Lack of security for digital library	V									
10	Lack of institutional policy										

(b) Initial Reachability Matrix (IRM)

The IRM is constructed by translating the codes in the SSIM into binary values to represent the relationships between barriers. Specifically, the following conversions are applied:

- V: Converted to 1 in the corresponding cell and 0 in the transpose cell.
- A: Converted to 0 in the corresponding cell and 1 in the transpose cell.
- X: Converted to 1 in both the corresponding and transpose cells.
- O**:** Converted to 0 in both the corresponding and transpose cells.

The resulting binary matrix is presented in Table 2, providing a foundational structure for further analysis.

Table 2: Initial Reachability Matrix (IRM) Derived from the SSIM

No	Barriers	1	2	3	4	5	6	7	8	9	10
1	Lack of financial resources	1	1	0	0	0	0	0	0	0	0
2	Lack of skilled manpower	0	1	0	0	0	0	0	0	0	0
3	Lack of management support	0	1	1	0	0	0	0	0	0	0
4	Lack of technological infrastructure	1	1	1	1	0	0	0	0	0	1
5	Lack of physical infrastructure	1	1	1	1	1	1	0	1	1	1
6	Lack of standards and uniformity	1	1	1	1	0	1	0	0	0	1
7	Lack of awareness of digital library benefits	1	1	1	1	1	1	1	1	1	1
8	Lack of copyright and intellectual property issues	1	1	1	1	0	0	0	1	0	1
9	Lack of security for digital library	1	1	1	1	0	0	0	0	1	1
10	Lack of institutional policy	1	1	1	0	0	0	0	0	0	1

(c) Final Reachability Matrix

For this study, no instances of transitivity were observed. The driving power and dependence were calculated (see Table 3) as outlined by Lin et al. (2010).

Table 3: Final Reachability Matrix for Calculation of Driving Power and Dependence for the Identified Barriers in Digital Library Development.

No	Barriers	1	2	3	4	5	6	7	8	9	10	Driving power
1	Lack of financial resources	1	1	0	0	0	0	0	0	0	0	2
2	Lack of skilled manpower	0	1	0	0	0	0	0	0	0	0	1
3	Lack of management support	0	1	1	0	0	0	0	0	0	0	2
4	Lack of technological infrastructure	1	1	1	1	0	0	0	0	0	1	5
5	Lack of physical infrastructure	1	1	1	1	1	1	0	1	1	1	9
6	Lack of standards and uniformity	1	1	1	1	0	1	0	0	0	1	6
7	Lack of awareness of digital library benefits	1	1	1	1	1	1	1	1	1	1	10
8	Lack of copyright and intellectual property issues	1	1	1	1	0	0	0	1	0	1	6
9	Lack of security for digital library	1	1	1	1	0	0	0	0	1	1	6
10	Lack of institutional policy	1	1	1	0	0	0	0	0	0	1	4
	Dependence	8	10	8	6	2	3	1	3	3	7	

(d) Level Partitioning

In the first iteration (Table 4), “Lack of standards and uniformity” is placed at level I and is subsequently excluded from the remaining variables. This process is repeated for all other barriers. In the second iteration (Table 5), “Lack of security for digital libraries” and “Lack of copyright and intellectual property issues” are assigned to level II.

Table 4: Partition of Reachability Matrix - First Iteration

Barriers	Reachability set	Antecedent set	Interaction set	Level
1	1,2	1,4,5,6,7,8,9,10	1	
2	2	1,2,3,4,5,6,7,8,9,10	2	I
3	2,3	3,4,5,6,7,8,9,10	3	
4	1,2,3,4,10	4,5,6,7,8,9	4	
5	1,2,3,4,5,6,8,9,10	5,7	5	
6	1,2,3,4,6	5,6,7	6	
7	1,2,3,4,5,6,7,8,9,10	7	7	
8	1,2,3,4,8,10	5,7,8	8	
9	1,2,3,4,9,10	5,7,9	9	
10	1,2,3,10	4,5,6,7,8,9,10	10	

Table 5: Partition of Reachability Matrix - Second Iteration

Barriers	Reachability set	Antecedent set	Interaction set	Level
1	1	1,4,5,6,7,8,9,10	1	II
3	3	3,4,5,6,7,8,9,10	3	II
4	1,3,4,10	4,5,6,7,8,9	4	
5	1,3,4,5,6,8,9,10	5,7	5	
6	1,3,4,6	5,6,7	6	
7	1,3,4,5,6,7,8,9,10	7	7	
8	1,3,4,8,10	5,7,8	8	
9	1,3,4,9,10,	5,7,9	9	
10	1,3,10	4,5,6,7,8,9,10	10	

In the third iteration (Table 6), “Lack of awareness of digital library benefits” is positioned at level III. Table 7 shows the fourth iteration, where “Lack of skilled manpower” is categorised at level IV. In the next iteration (Table 8), “Lack of management support”, “Lack of physical infrastructure”, and “Lack of technological infrastructure” are assigned to level V. In the subsequent iteration (Table 9), “Lack of financial resources” is identified at level VI. Table 10 shows the second-to-last iteration, where “Lack of institutional policy” is categorised at level VII.

Table 6: Partition of Reachability Matrix - Third Iteration

Barriers	Reachability set	Antecedent set	Interaction set	Level
4	4,10	4,5,6,7,8,9	4	
5	4,5,6,8,9,10	5,7	5	
6	4,6	5,6,7	6	
7	4,5,6,7,8,9,10	7	7	
8	4,8,10	5,7,8	8	
9	4,9,10,	5,7,9	9	
10	10	4,5,6,7,8,9,10	10	III

Table 7: Partition of Reachability Matrix - Fourth Iteration

Barriers	Reachability set	Antecedent set	Interaction set	Level
4	4	4,5,6,7,8,9	4	IV
5	4,5,6,8,9	5,7	5	
6	4,6	5,6,7	6	
7	4,5,6,7,8,9	7	7	
8	4,8	5,7,8	8	
9	4,9	5,7,9	9	

Table 8: Partition of Reachability Matrix - Fifth Iteration

Barriers	Reachability set	Antecedent set	Interaction set	Level
5	5,6,8,9	5,7	5	
6	6	5,6,7	6	V
7	5,6,7,8,9	7	7	
8	8	5,7,8	8	V
9	9	5,7,9	9	V

Table 9: Partition of Reachability Matrix - Sixth Iteration

Barriers	Reachability set	Antecedent set	Interaction set	Level
5	5	5,7	5	VI
7	5,7	7	7	

Table 10: Partition of Reachability Matrix - Seventh Iteration

Barriers	Reachability set	Antecedent set	Interaction set	Level
7	7	7	7	VII

Finally, Table 11 provides a summary of the results from all iterations.

Table 11: A Summary of the Results from All Iterations.

Barriers	Reachability set	Antecedent set	Interaction set	Level
1	1,2	1,4,5,6,7,8,9,10	1	II
2	2	1,2,3,4,5,6,7,8,9,10	2	I
3	2.3	3,4,5,6,7,8,9,10	3	II
4	1,2,3,4,10	4,5,6,7,8,9	4	IV
5	1,2,3,4,5,6,8,9,10	5,7	5	VI
6	1,2,3,4,6	5,6,7	6	V
7	1,2,3,4,5,6,7,8,9,10	7	7	VII
8	1,2,3,4,8,10	5,7,8	8	V
9	1,2,3,4,9,10,	5,7,9	9	V
10	1,2,3,10	4,5,6,7,8,9,10	10	III

(e) Creating the Diagraph for ISM Model

The hierarchical framework (Sindhwani & Malhotra, 2017) is constructed based on the partition levels established earlier, utilizing data from the final reachability matrix. This framework serves as the foundation for developing the ISM model. Arrows are used to indicate the relationships between the barriers. The framework was further reviewed and discussed with LIS experts recruited in this study to ensure there were no inconsistencies or misunderstandings regarding the concepts (Khurana et al., 2010). Figure 2 presents the final digraph illustrating the barriers to digital library development. This digraph visually represents the cause-and-effect or dependency relationships between the various factors influencing the system.

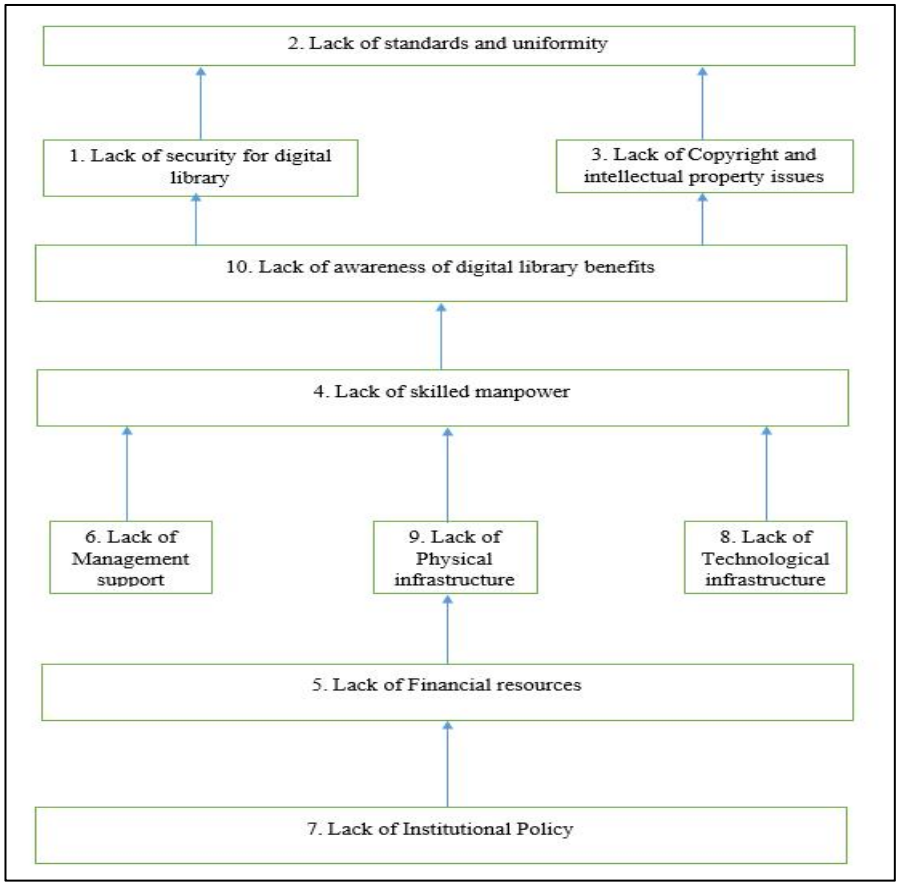

Figure 2: Final Digraph Illustrating the Barriers to Digital Library Development and Their Interrelationships

From Figure 2, it is clear that barrier number 7, *Lack of Institutional Policy*, is the most critical barrier to adopting digital libraries. As an independent factor, it sits at the bottom of the digraph model created by ISM. If not addressed, this barrier will create a ripple effect that could undermine any digital library adoption efforts. The next major barrier is number 6, *Lack of Financial Resources*, which could significantly hinder the development of a digital library. The costs involved in digital library initiatives are substantial for any academic institutions such as university or college, making proper budget planning essential before embarking on such projects. Additionally, three other significant barriers, *Lack of Management Support* (barrier 6), *Lack of Physical Infrastructure* (barrier 9), and *Lack of Technological Infrastructure* (barrier 8), fall within the same level, indicating their interdependence with barriers 5 and 7. Lastly, *Lack of Standards and Uniformity* (barrier 2) is placed at the highest level in the ISM model, suggesting that it should be addressed last, after the elimination of more critical barriers. In conclusion, the ISM model provides a comprehensive framework, emphasizing that the barriers at the bottom of the digraph should be prioritised for elimination to effectively overcome challenges in adopting digital libraries.

MICMAC

Multiplication applied to classification (MICMAC) is a method used to analyse the driving and dependence power of barriers (Govindan et al., 2012; Modgil et al., 2022). The barriers are categorized into four quadrants: autonomous (Quadrant I), dependent (Quadrant II), linkage (Quadrant III), and independent (Quadrant IV), as shown in Figure 3. The barriers identified as independent fall into Quadrant IV, which includes the lack of institutional policies, financial resources, management support, technological infrastructure, and physical infrastructure. These barriers have strong driving power but weak dependence, meaning they influence other barriers but are not significantly influenced by them. While these barriers have minimal driving and dependence power, they function independently and have a notable impact on the system.

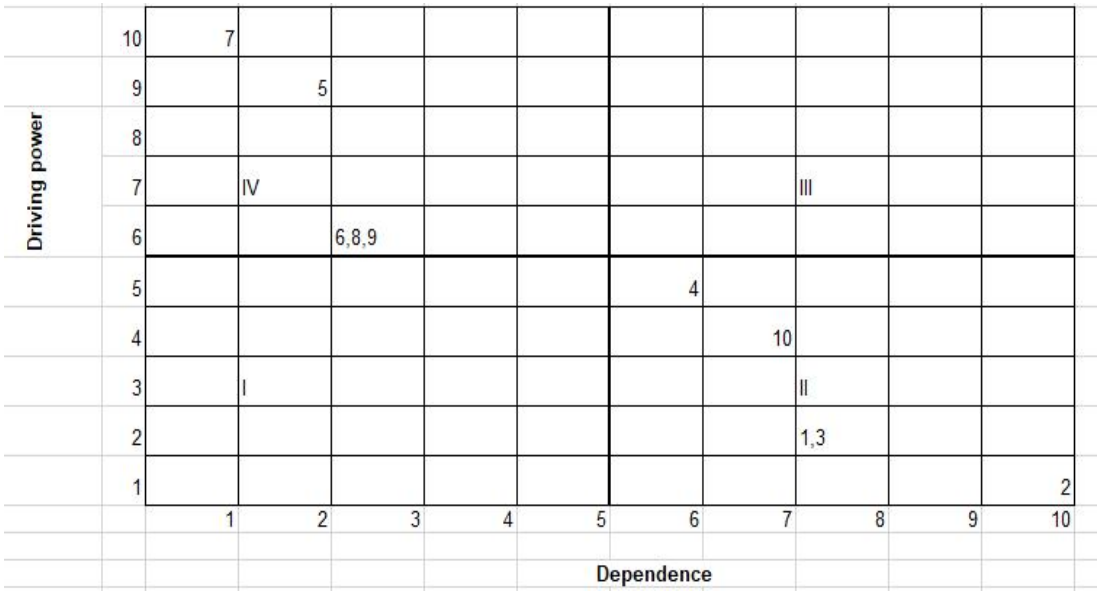

Figure 3: MICMAC Analysis of Barriers to Digital Library Development

In contrast, Quadrant II contains dependent barriers, which rely on other factors for their influence. These include the lack of security for digital libraries, the lack of standards and uniformity, copyright and intellectual property rights issues, and the lack of awareness of

the benefits of digital libraries. These barriers demonstrate high dependence, which affects their functionality and responsiveness (Govindan et al., 2012; Modgil et al., 2022). No barriers were found in Quadrants I and III.

DISCUSSION

Digital libraries play a crucial role in the effective and efficient preservation and dissemination of information. For any academic institutions aiming to implement a digital library, significant financial resources, time, and workforce are required. Through a extensive review of research publications, this study has identified and analysed the key barriers to the adoption of digital libraries. The primary objective was to uncover these barriers and understand their interrelationships. To achieve this, the study employed the ISM and MICMAC approaches to analyse the ten barriers.

The current study developed a behavioral and level-based relationship structure among the identified barriers using the diagraph ISM model. This approach focused on the interrelations across various layers, offering significant insights into how the barriers influence and interact with one another. Notably, the research highlights three dominant barriers to the adoption of digital libraries: lack of institutional policy, lack of management support, and lack of financial resources. These findings are consistent with the work of Dadzie and Van der Walt (2015) and Islam et al. (2018). Another critical barrier identified in the study is the lack of awareness of digital libraries. In developing countries, a significant gap exists between academic institutions and professional associations, with both groups often working in isolation. This lack of collaboration makes the implementation of digital libraries challenging (Liu et al., 2024). Even when public libraries aim to undergo digital transformation, persistent budget cuts create additional obstacles (Islam & Haider, 2024). Furthermore, the study found that the lack of management support directly leads to insufficient skilled manpower, which, in turn, exacerbates the lack of awareness regarding the benefits of digital libraries. These findings align with previous research by Gaur (2003), Bhattacharya (2004), Alhaji (2007) and Liao and Wang (2021).

This research makes a significant contribution to the existing literature on digital libraries by focusing on specific barriers that impede their effective adoption. By describing, analyzing, and constructing a digraph ISM model, the study provides a novel perspective on the interrelationships among the barriers to digital library adoption. Additionally, the study introduces a contextual linkage among these barriers using a MICMAC-based strategy. The framework developed in this study highlights the complexities and challenges involved in adopting digital libraries. Notably, no existing research has addressed the interdependencies between adoption barriers in digital libraries. The digraph and MICMAC models provide valuable insights for key stakeholders, including the government and policy-makers, college and university decision-makers, and the library community. For head librarians, the priority should be to focus on the independent barriers identified in the MICMAC analysis and work proactively to overcome them. Doing so would enable colleges and universities to better position themselves to embrace digital libraries.

While the current study makes a significant contribution to the body of knowledge on digital libraries, several limitations must be considered. The study identified only ten barriers to digital library adoption; future research could explore and prioritise additional barriers using interpretive modeling. Additionally, the ISM model developed in this study has not been statistically validated, which is an inherent limitation of the ISM methodology.

However, the application of ISM has successfully achieved the goal of discerning the hierarchical relationships among the primary barriers. Future research could explore the significance of these relationships using structural equation modeling and cross-sectional surveys. Moreover, scholars may apply other multi-criteria decision-making methodologies such as VIKOR, DEMATEL, and AHP to gain deeper insights into the interdependencies of factors within digital library adoption systems.

CONCLUSION

This study highlights the importance for policymakers in universities and other higher education institutions to prioritise the barriers identified, as addressing these will be key to the successful implementation of digital libraries. The findings of this study can assist institutional management in pinpointing areas that need improvement and in making informed, strategic decisions regarding the direction of digital library initiatives. The MICMAC analysis highlights that the most critical barriers to digital library adoption are independent factors. Therefore, targeted actions to mitigate these barriers can significantly support the government, as well as colleges and universities, in achieving success with their digital library projects. To ensure a successful and efficient digitisation effort in university and higher education libraries, it is essential to give due attention to the barriers identified in this study, along with the recommended solutions.

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AUTHOR DECLARATION

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AUTHORS CONTRIBUTION

Conceptualization: [all authors], Methodology: [R.K.K. Patnala], Formal analysis and investigation: [R.Raju], Writing - original draft preparation: [R.K.K. Patnala]; Writing - review and editing: [all authors]

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APPENDICES

Appendix 1: LIS Expert Profiles

Expert	Designation	Qualification	Years of professional experience
E1	University Librarian	PhD	40
E2	Deputy Librarian	PhD	30
E3	University Librarian	PhD	22
E4	Digital Librarian	PhD	23
E5	University Librarian	PhD	25
E6	Librarian and Head	PhD	23
E7	University Librarian	PhD	30
E8	Deputy Librarian	PhD	25

Appendix 2: Process of Filling the Excel Spreadsheet

The experts were provided the details between any two factors (i and j) and the associated direction of the relationship is questioned. The following four symbols are used to denote the direction of relationship between two factors (i and j):
(a) V for the relation from factor i to factor j (i.e., factor i will influence factor j)
(b) A for the relation from factor j to factor i (i.e., factor i will be influenced by factor j)
(c) X for both direction relations (i.e factors i and j will influence each other)
(d) O for no relation between the factors (i.e., barriers i and j are unrelated) (Sage, 1977; Warfield, 1982;

Appendix 3: Publications Used in the Analysis

No	Publications
1	Alhaji, I. U. (2007). Digitization of past question papers, dissertations, and theses: A case study of 30 Nigerian university libraries. *International Information & Library Review, 39*(3–4), 228–246. https://doi.org/10.1016/j.iilr.2007.07.002
2	Ameen, K. and Rafiq, M. (2009). Development of digital libraries in Pakistan, in Theng, Y.L., Foo, S., Goh, D. and Na, J.-C. (Eds). *Handbook of Research on Digital Libraries: Design, Development, and Impact*, Information Science Reference, *Hershey, PA,* pp. 482-491. IGI Global.
3	American Library Association (2013). *Digital literacy, libraries and public policy.* American Library Association.
4	Baro, E. E., Efe, B., & Oyeniran, K. G. (2014). Reference enquiries received through different channels: The challenges reference librarians face in university libraries in Nigeria. *Reference Services Review, 42*(3), 514–529. https://doi.org/10.1108/RSR-09-2013-0049.
5	Bhattacharya, P. (2004). Advances in digital library initiatives: A developing country perspective. *International Information & Library Review, 36*(3), 165–175. https://doi.org/10.1016/j.iilr.2003.10.008.
6	Bossaller, J., & Atiso, K. (2015). Sharing science: the state of institutional repositories in Ghana. *IFLA Journal, 41(*1), 25-39. doi: 10.1177/0340035214561582.
7	Candela, L., Castelli, D., & Pagano, P. (2007). A reference architecture for digital library systems: Principles and applications. *International DELOS Conference* (pp. 22-35). Berlin, Heidelberg: Springer Berlin Heidelberg. Doi: https://link.springer.com/chapter/ 10.1007/978-3-540-77088-6_3.
8	Chepesuik, R. (1997). The future is here: America's libraries go digital. *American Libraries*, *2*(1), 47-49. doi: https://eric.ed.gov/?id=EJ537902.
9	Dadzie, P.S. & Van der Walt, T. (2015). Planning for digitization of university libraries in Ghana: Challenges and prospects. *Library Philosophy and Practice,* 1206. https://digitalcommons.unl.edu/libphilprac/1206/.
10	Echezona, R.I., Ibegbulem, I.J., & Nwegbu, M.U. (2015). Bring back the users in academic libraries in the digital age. Paper presented at the *53rd National Conference and Annual General Meeting of Nigeria Library Association (NLA),* Oshogbo, Ogun State of Nigeria. (pp. 26-31).

11	Ekwelem, V.O., Okpala, H.N., Igbokwe, J.C., & Ekwelem, C. (2018). Evaluation of online reference services: Reflections from Nigerian academic libraries. *Library Philosophy and Practice*, 1777. doi: https://digitalcommons.unl.edu/libphilprac/1777.
12	Fox, E.A. & ElSherbiny, N. (2011). Security and digital libraries. In K. H. Huang (Ed.), *Digital libraries: Methods and applications* (pp. 1–20). InTech. https://doi.org/10.5772/18156.
13	Gaur, R. C. (2003). Rethinking the Indian digital divide: The present state of digitization in Indian management libraries. *The International Information & Library Review, 35*(2–4), 189–203. https://doi.org/10.1080/10572317.2003.10762600.
14	Igbo, H.U., & Imo, N.T. (2020). Digital libraries and access to information in Nigerian federal universities; the impact of technology variables. *Journal of Information and Knowledge Management, 19*(2), paper 2050013. doi: 10.1142/S0219649220500136.
15	Igun, S.E. (2006).Human capital for Nigerian libraries in the 21st century. *Library Philosophy and Practic*e, 82. https://digitalcommons.unl.edu/libphilprac/82.
16	Institute of Museum and Library Services (IMLS) (2002). Status of technology and digitization in the nation's museums and libraries. *IMLS,* Washington, DC.
	Islam, A.Y.M.A., Ahmad, K., Rafi, M., & JianMing, Z. (2021). Performance-based evaluation of academic libraries in the big data era. *Journal of Information Science, 47*(4), 458-471. doi: https://doi.org/10.1177/01655515209185.
18	Islam, S. (2011). Towards digitization: Problems and prospects for the libraries of Bangladesh. Paper presented at the *World Congress of Muslim Librarians and Information Scientists 2011* (WCOMLIS 2011), 16-17 November, 2011, Kuala Lumpur, Malaysia. https://www.academia.edu/3342256/Towards_digitization_problems_and_ prospects_for_the_libraries_of_Bangladesh.
19	Iwhiwhu, B.E. & Eyekpegha, E.O. (2009). Digitization of Nigerian university libraries: From technology challenge to effective information delivery. *The Electronic Library*, *27*(3), 529-536. doi: 10.1108/02640470910966943.
20	Jain, S.J, & Behera, P.K. (2023). Visualizing the academic library of the future based on collections, spaces, technologies, and services. *International Journal of Information Science and Management (IJISM)*, *21*(1), 219-243. doi: https://doi.org/10.22034/ijism.2023.700794.
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24	Moghadami, M., Mantegh, H., & Malekolkalami, M. (2021). Challenges of creating and operating digital libraries in the digital age in Iran. *International Journal of Digital Content Management*, *2*(3), 115-130. doi: 10.22054/dcm.2021.13678
25	Mukherjee, S., & Patra, S. K. (2022). Digital library initiatives in North East India: A survey. *Indian Journal of Information, Library and Society, 35*(3-4), 203-218. http://eprints.rclis.org/44134/1/ilovepdf_merged.pdf.
26	Rafiq, M., Ameen, K., & Jabeen, M. (2018). Barriers to digitization in university libraries of Pakistan: A developing country's perspective. *The Electronic Library, 36(3): 457–470.* doi: https://doi.org/10.1108/EL-01-2017-0012.
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28	Ramzan, M. (2004). Levels of information technology (IT) applications in Muslim world libraries. *The Electronic Library, 22*(3), 274-280. doi: 10.1108/02640470410541688
29	Shoja, M.J. & Alvankar, E.A. (2013). Development of digital libraries and the end of literary and artistic property rights from the perspective of comparative and international law. *Journal of Legal Research, 12*(23), 184-214. doi: https://jlr.sdil.ac.ir/ article_32855_en.html.
30	Shuva, N. Z. (2012). Building digital libraries in Bangladesh: A developing country perspective. *The International Information & Library Review*, *44*(3), 132-146. doi: 10.1080/10572317.2012.10762924.
31	Tyrväinen, P. (2005). Concepts and a Design for Fair Use and Privacy in DRM. *D-Lib Magazine*, *11*(2), 1082-9873. doi: 10.1045/february2005-tyrvainen
32	Uutoni, W. E. (2014). *Evaluation of digital reference services in academic libraries in Namibia* (Doctoral dissertation, University of Sweden).
33	Zimerman, M. (2010). Protect your library's computers. *New Library World*, 111(5/6), 203-212.