

Emerging trends in smart libraries: A systematic review of university needs, sustainability, and challenges

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Abstract

The rapid advancement of technology has transformed academic libraries into smart libraries that use emerging technologies to enhance user experience and access to information. This systematic review of the literature published between 2015 and 2025 examines the development and operation of smart libraries in universities, focussing on key requirements, sustainability strategies, and implementation challenges. Findings indicate that successful smart libraries rely on modern technologies, robust infrastructure, continuous staff training, and clear governance policies. Common challenges include limited funding, data management difficulties, insufficient technical expertise, and legal constraints. Universities that implement smart library solutions report improved access and higher user satisfaction, highlighting their transformative potential. This review provides policymakers and educational leaders with actionable insights to guide effective implementation and foster innovation and lifelong learning.

Keywords

library innovation, information access, technological infrastructure, digital divide, digital transformation, smart libraries

Introduction

Universities worldwide increasingly recognise the potential of smart libraries to support research, teaching, learning, and collaboration. Despite this, the adoption of such innovative systems remains constrained, particularly in LMICs and other resource-limited settings, due to operational challenges. These challenges can be broadly categorised into hard infrastructure and soft infrastructure limitations (Achugbue et al., 2023; Aslam et al., 2025). Hard infrastructure barriers include inadequate Information Communication Technology (ICT) facilities, unreliable electricity, limited broadband connectivity, and insufficient access to modern hardware and software, all of which hinder the deployment and sustainability of smart library systems (Adhikari and Paswan, 2024). Soft infrastructure challenges, such as limited digital literacy among users, insufficient technological competencies among library staff, and inadequate professional training opportunities, further constrain the effective use of smart library technologies (Darko Adjei and King, 2024). Together, these constraints indicate that implementing smart library systems requires not only technological investment but also the development of human capacity. The evolution of libraries demonstrates the long-standing interplay between

information management and technological advancement. Early libraries in ancient civilisations, including the Sumerians and Egyptians, preserved knowledge on clay tablets and scrolls (Jones, 1989; König et al., 2013). The invention of the printing press in the 15th century expanded access to information and facilitated the development of public libraries during the 18th and 19th centuries (Cartwright, 2020; Dittmar, 2011). In recent decades, technological advances and the growing demand for closer collaboration between librarians and users have driven transformations in library services and professional practices (Adigun et al., 2024). The late 20th century saw the emergence of digital libraries, which leveraged computers and the internet to provide networked access to resources, complementing traditional print collections while maintaining the mission of preserving knowledge (Candela et al., 2012). Building on these foundations, smart libraries

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integrate advanced technologies, such as AI-enhanced Internet of Things (IoT) systems, to improve operational efficiency, enhance user engagement, and fulfil social responsibilities (Orji and Echezonamanyira, 2021; Schöpfel, 2018).

In the literature, the terms smart libraries and intelligent libraries are often used interchangeably (Kotis et al., 2025; SreeKrishna et al., 2025). In this manuscript, however, smart libraries are adopted as a conceptual and analytical framework rather than a marketing label or a purely technological descriptor. It conceptualises smart libraries as socio-technical ecosystems in which emerging technologies such as artificial intelligence, the IoT, and data analytics are strategically embedded within governance structures, physical and digital environments, and participatory service models. This framing emphasises the systemic integration of technology, user-centred services, and operational efficiency within contemporary academic libraries. Smart libraries are environments that connect physical collections, digital resources, and library spaces to deliver comprehensive, personalised information services (Li et al., 2025). They leverage large-scale data analytics, intelligent management systems, and adaptive technologies to enhance accessibility, service quality, and organisational performance (Orji and Echezonamanyira, 2021; Schöpfel, 2018; Zimmerman and Chang, 2018). Situated within the broader academic and public knowledge infrastructure, smart libraries represent the intersection of technological innovation, human-centred design, and institutional strategy (Naikar and Paul, 2025). Unlike general digital transformation initiatives that focus primarily on digitisation or automation, smart libraries are distinguished by dynamic interactions among technology, people, services, and spaces, supported by real-time data use, personalisation, sustainability-oriented planning, and inclusive governance (Odunlade and Ojo, 2023). Universities that successfully align robust technological infrastructure with skilled human capacity are better positioned to strengthen community engagement and advance lifelong learning, innovation, and equitable access to knowledge (Ajani et al., 2023; Candela et al., 2012).

Smart technologies for smart libraries

Smart libraries represent a progressive approach to traditional library services, harnessing technology to enhance learning, accessibility, and community and user engagement (Subaveerapandiyana et al., 2025). Over time, traditional libraries have undergone significant transformations due to changes in their socioeconomic and technological environments (Byrkovych et al., 2023). As they evolve, these libraries are set to play a crucial role in shaping the future of information access and community support (Adigun et al., 2024). Consequently, libraries worldwide are adopting various emerging technologies and strategies to tailor their services to the unique needs of

their communities (Ajani et al., 2023). Terms like cloud computing, robotics, artificial intelligence (AI), virtual and augmented reality (VR), the IoT, blockchain, and the metaverse are gaining traction among library professionals and users alike (Carrion, 2024). Mengping (2023) emphasised that digital resources, such as e-books, online databases, and digital archives, are foundational to the smart library concept. The terminology surrounding these advancements, particularly the concept of “Intelligent Libraries,” has generated debate. Adigun et al. (2024) pointed out that integrating these technologies enables efficient resource management, personalised user experiences, and improved access to information (Su and Chen, 2022). A notable example of this integration is the use of meaningful labels to enhance service models. Smart libraries leverage cutting-edge technologies to improve service delivery (Hussain, 2020). While some experts consider Intelligent Libraries to be synonymous with smart libraries, public opinion on this distinction varies. Critics contend that labelling these initiatives as Intelligent Libraries is primarily a marketing tactic intended to improve public perception of libraries (Mupaikwa, 2025). They contend that this terminology pressures librarians to translate abstract concepts into practical applications that support the knowledge system during the Fifth Industrial Revolution (5IR; Mupaikwa, 2025). The early 2000s marked the emergence of technologies such as Radio-Frequency Identification (RFID), which enabled automated tracking of library materials and self-checkout systems (Mohideen et al., 2012). According to Manuwa et al. (2023), libraries globally utilise RFID technology to identify and track inventory, manage the movement of materials, and facilitate check-out and check-in processes. As IoT technology advanced, libraries began incorporating smart devices for inventory management, environmental monitoring, and enhancing user experiences (Mishra, 2023).

Mishra (2023) noted that IoT integration also includes lighting and energy management, enabling automated adjustments based on natural light levels and occupancy, resulting in cost savings and environmental benefits. Additionally, IoT devices can monitor patron movements, providing valuable analytics and insights into user behaviour that can enhance library layout and service delivery. Libraries increasingly leverage big data to inform collection development and service improvements by analysing usage patterns to better meet user needs (Adewojo and Dunmade, 2024). A key feature of smart libraries is their ability to provide seamless access to a wide array of digital resources, including e-books, online journals, and multimedia content. This facilitates remote learning and research, promoting inclusivity for users unable to visit physical locations. Furthermore, smart libraries enhance interactive, immersive experiences through technologies such as augmented reality (AR) and VR, making the learning process more engaging

and multidimensional (Naikar and Paul, 2025). AR and VR technologies are reshaping user engagement and educational offerings in libraries, providing patrons with immersive experiences (Adewojo and Dunmade, 2024). Cox (2023) highlighted that IoT collects real-time data on library usage and operations, while AR and VR create immersive, interactive experiences. Additionally, Adewojo and Dunmade (2024) emphasised that big data analytics enables the analysis of large datasets, yielding valuable insights to further enhance library services.

Service-led principle

Building on digital library developments, smart libraries adopt a service-led principle, emphasising that library services should be designed around users' needs, preferences, and behaviours (Cao et al., 2018). This user-centric approach directly helps mitigate resistance to change, as users are more likely to adopt technologies and workflows that align with their expectations and daily practices. For example, intuitive self-service interfaces, personalised resource recommendations, and automated borrowing systems reduce the effort required to interact with new digital tools, thereby fostering acceptance and engagement among diverse user groups (Orji and Echezonamanyira, 2021). By centring services on the user experience, smart libraries can transform resistance into collaboration, ensuring that technological innovations translate into effective and widely adopted practices.

Rationale for conducting this systematic review of reviews

This systematic review of reviews was conducted to synthesise existing literature on smart libraries and their integration of modern technologies, providing both a comprehensive overview and actionable insights for research and practice. Several key rationales underpin this approach:

- (a) Comprehensive synthesis of evidence: By aggregating findings from multiple reviews, this study offers a broad understanding of current trends, challenges, and innovations in smart libraries. This approach captures diverse perspectives and methodologies, enriching knowledge of how libraries are evolving in response to technological advancements and changing user expectations.
- (b) Identification of research gaps: Analysing existing reviews allows for the identification of gaps in the literature, particularly regarding user needs, technology integration, and system interoperability. Recognising these gaps is essential to guide future research that addresses relevant and emerging

issues in smart library development (Hou, 2020; Khan et al., 2025).

- (c) Efficiency and knowledge consolidation: This method enables researchers and practitioners to assess the literature more efficiently, avoiding duplication of effort while drawing on extensive analyses. It provides a synthesised, high-level understanding of the field, particularly valuable to policymakers and library managers seeking to implement evidence-based innovations.
- (d) Forward-looking insights: By examining trends, technological convergence, and standardisation highlighted in previous reviews, this study identifies potential directions for future research and practice. Emphasising these areas supports the long-term interoperability and sustainability of smart library systems (Hou, 2020; Khan et al., 2025).
- (e) Practical relevance: Synthesising evidence from diverse studies generates actionable recommendations for librarians, ICT professionals, and decision-makers. These insights can inform the design and deployment of smart library services, ensuring that technological adoption aligns with user-centred principles and addresses operational challenges.

Why conduct reviews instead of other peer-reviewed papers

Reviews provide a comprehensive synthesis of existing research, allowing for a broader understanding of a topic rather than focussing on isolated studies. By aggregating findings from multiple sources, reviews facilitate a more complete picture of the current state of knowledge in a specific field. Additionally, reviews are instrumental in identifying trends and gaps in the literature. They highlight emerging methodologies and areas that require further exploration, guiding future research directions more effectively than individual studies can. This identification is crucial for ensuring that subsequent research addresses relevant and pressing issues. Moreover, reviews provide context by integrating findings from various studies, helping researchers and practitioners understand how individual studies fit into the broader body of knowledge. This contextual framework is essential for informed decision-making and practice. Time efficiency is another significant advantage of reviews. They condense vast amounts of information into accessible summaries, saving researchers time while keeping them informed about a specific area of study. Furthermore, reviews can provide evidence-based recommendations for practice, policy, or further research. By synthesising data from diverse studies, they present actionable insights that can influence real-world applications.

Table 1. The searching strings.

Database	Search string	Total results
Web of Science	TS=("smart librar*" OR "intelligent librar*") AND TS=("library develop*" OR "library advancement*") AND TS=(requirement* OR need*) AND TS=(sustainab* OR challenge* OR problem*) AND TS=("systematic review*" OR review*)	1706
Taylor and Francis	("smart librar*" OR "intelligent librar*") AND ("library develop*" OR "library advancement*") AND (requirement* OR need*) AND (sustainab* OR challenge* OR problem*) AND ("systematic review*" OR review*) AND (Publication Date: 01/01/2015–31/12/2025)	8576
Scopus	TITLE-ABS-KEY("smart librar*" OR "intelligent librar*") AND TITLE-ABS-KEY("library develop*" OR "library advancement*") AND TITLE-ABS-KEY(requirement* OR need*) AND TITLE-ABS-KEY(sustainab* OR challenge* OR problem*) AND TITLE-ABS-KEY("systematic review*" OR review*)	3941
Google Scholar	"smart library" AND review*	200
Total		14,423

Methods

Review question

What are the key requirements, sustainability practices, and challenges associated with the development and operation of smart libraries in universities?

Data sources and search strategy

This study reviewed peer-reviewed publications in academic journals, conference papers, books, book chapters, and working papers published between January 2015 and June 2025. This period is particularly relevant for capturing the evolution of smart libraries, as libraries increasingly adopted technologies such as AI, data analytics, and the Internet of Things (IoT) to enhance user experience and service delivery (Deja et al., 2021; Distanont et al., 2024; Lu and Lin, 2025; Naikar and Paul, 2025). The databases searched included Web of Science, Scopus, Taylor & Francis Online, and Google Scholar. Search strings combined keywords related to "smart libraries," "intelligent libraries," library development, technology requirements, sustainability, challenges, and systematic reviews, using Boolean operators for clarity and reproducibility. All searches were restricted to English-language publications published between 2015 and 2025. Table 1 explains the search strings conducted in this review.

Screening

After merging duplicates in CADIMA, an open-access online tool that enhances the evidence synthesis process by systematically gathering, evaluating, and integrating research findings, the relevant articles were screened based on their titles and abstracts (Kohl et al., 2018). Following this initial screening, the selected papers were reviewed in full text using several criteria.

Inclusion and exclusion criteria

Inclusion criteria

- Reviews, including literature review, systematic review, meta-analysis, narrative review, scoping review, critical review, rapid review, and umbrella review.
- Reviews addressing smart libraries and the emerging technologies in academic libraries.
- Reviews published between 2015 and 2025.
- Research articles published in the English Language.

Exclusion criteria

- Peer-reviewed scholarly communication, including research articles, books, book chapters, conference papers, and similar works.
- Articles not specifically addressing smart libraries or the application of emerging
- Reviews published from before 2015 and after 2025.
- Non-English publications.

Study quality assessment

As the review included only reviews, the Critical Appraisal Skills Programme (CASP) systematic review checklist (CASP, 2014) was used. Studies were rated as Y="Yes", N="No", NI="Not identified", and U=Uncertain. As before, two reviewers independently rated each study and resolved the disagreements. Appendix Table 1 illustrates the quality assessment measure undertaken in this review.

Data extraction

Once the screening and study quality assessment phases were completed, all selected articles were exported to Excel for data extraction and analysis. We used the data

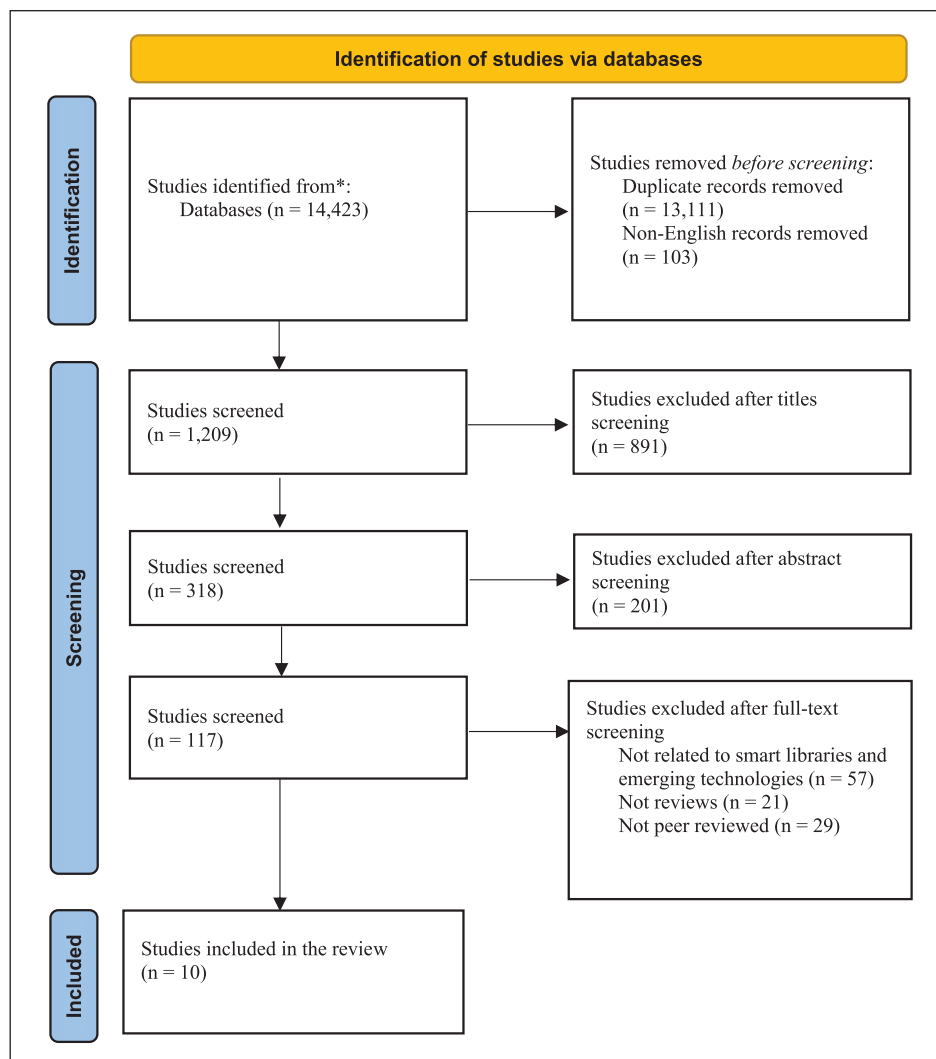


Figure 1. PRISMA diagram.

extraction form to extract data. The matrix extracted the following data: author(s), year, countries, requirements, sustainability, and challenges (Appendix Table 2).

Data analysis

The extracted data were synthesised and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist (Figure 1; Liberati et al., 2009).

Results

Search results

The comprehensive literature search across the selected databases identified 14,423 records. Following the removal of duplicates, titles and abstracts were systematically screened against predefined inclusion and

exclusion criteria; subsequently, full texts were assessed for eligibility and methodological quality. This rigorous, multi-stage screening process resulted in the inclusion of 10 review studies that met all eligibility criteria (Figure 1). The substantial reduction in the number of included studies reflects the intentional application of stringent criteria rather than a limitation of the review. Excluded records primarily comprised primary empirical studies, non-systematic or narrative reviews, conceptual papers, publications lacking a clear focus on smart libraries, or studies that did not meet established methodological quality thresholds. Additional exclusions resulted from database duplication. Inclusion was deliberately restricted to peer-reviewed articles demonstrating methodological transparency and explicit relevance to the technological, sustainability, or governance dimensions of smart libraries. Although the final number of included studies is limited, this outcome is consistent with the review's emphasis on synthesising high-quality, methodologically robust

evidence. By prioritising rigour over volume, the review enhances the credibility, analytical depth, and policy relevance of its findings, ensuring a reliable foundation for evidence-based smart library development and decision-making.

Data synthesis

The establishment and sustainability of smart libraries involve integrating various emerging technologies while addressing significant challenges. Core technologies such as the IoT, AI, data mining, and augmented reality are essential for enhancing service delivery and operational efficiency. These technologies facilitate improved user experiences and simplify library operations, as highlighted by multiple studies (Gul and Bano, 2019; Ketheeswaren, 2024). The adoption of advancements such as cloud computing and virtual reality further underscores the need to stay abreast of technological trends to meet user needs (Cao et al., 2018; Yunus et al., 2025). User experience and engagement are critical components of smart libraries. Additionally, libraries are developing user-centred programs that leverage ICTs to expand access and foster engagement (Sayogo et al., 2022). This shift towards user participation not only enriches the library experience but also encourages collaborative knowledge production among users and staff (Yunus et al., 2025). Training and capacity building are vital for the successful implementation of smart library initiatives. Continuous professional development for library staff is necessary to equip them with the skills to manage new technologies effectively (Cao et al., 2018). Simultaneously, educating users about available resources and technology fosters a knowledgeable community that actively engages with library services (Yunus et al., 2025). This dual focus on training ensures that both librarians and users can navigate the complexities of smart library environments.

Governance and management practices play a crucial role in the effective functioning of smart libraries. Smart governance, which incorporates technology and collaborative decision-making, enhances the efficiency and sustainability of library services (Cao et al., 2018; Yunus et al., 2025). This approach not only improves management practices but also facilitates stakeholder engagement, resulting in more responsive library services that better align with community needs. However, several challenges impede the realisation of smart libraries. Limited technological infrastructure and high implementation costs are significant barriers, especially in underserved regions where access to reliable internet and power supply is lacking (Mwantimwa and Msoffe, 2025). Additionally, resistance to change among both staff and users can hinder the adoption of new technologies, impacting overall service utilisation (Tella et al., 2025). Furthermore, data protection concerns are paramount, as maintaining user trust is

essential to the successful implementation of smart library solutions (Aliero et al., 2022). Libraries must balance the integration of advanced technologies with ecological and sustainability goals, ensuring that implementation does not increase energy consumption (Gul and Bano, 2019; Shahzad and Khan, 2023). Therefore, the synthesis of these findings underscores the complexity of establishing smart libraries. On the other hand, the findings from this systematic review of reviews are organised into three sections: requirements for establishing smart libraries, sustainability strategies to support their longevity, and the challenges that impede their establishment and sustainability within universities.

Requirements for smart libraries

Reviews have identified various requirements necessary for the implementation and development of smart libraries. Key among these requirements are emerging technologies, including generative AI, AI, blockchain, data mining, augmented reality (AR), virtual reality (VR), and cloud computing (Cao et al., 2018; Gul and Bano, 2019; Ketheeswaren, 2024; Mwantimwa and Msoffe, 2025; Shahzad and Khan, 2023; Tella et al., 2025). The importance of knowledgeable librarians has been emphasised (Aliero et al., 2022; Cao et al., 2018; Gul and Bano, 2019; Tella et al., 2025; Yunus et al., 2025), as they play a crucial role in managing these technologies while effectively serving tech-savvy patrons (Cao et al., 2018). Yunus et al. (2025) highlighted that librarians play a crucial role in managing smart libraries and, therefore, require extensive training. Service development is also required for the evolution of smart libraries. It involves enhancing library services to better meet user needs by integrating advanced technologies and improving operational practices (Aliero et al., 2022; Cao et al., 2018; Ketheeswaren, 2024; Mwantimwa and Msoffe, 2025; Tella et al., 2025). User training and engagement were also identified (Tella et al., 2025). The concept of smart people encompasses both library staff and users and operates alongside other smart library dimensions such as smart governance, smart spaces, smart environments, and smart buildings (Cao et al., 2018; Gul and Bano, 2019; Yunus et al., 2025). Gul and Bano (2019) emphasise the importance of smart buildings equipped with features such as automatic doors, intelligent lighting, self-service kiosks, and networked computers to enhance usability and efficiency. Within this framework, smart people are central, as they reflect not only the technological competencies of library staff but also users' engagement, digital literacy, and well-being.

Beyond physical and service-oriented interactions, the smart people dimension increasingly extends to digitally mediated social and cognitive support mechanisms, particularly within online library-supported discussion forums. Recent research demonstrates that automated

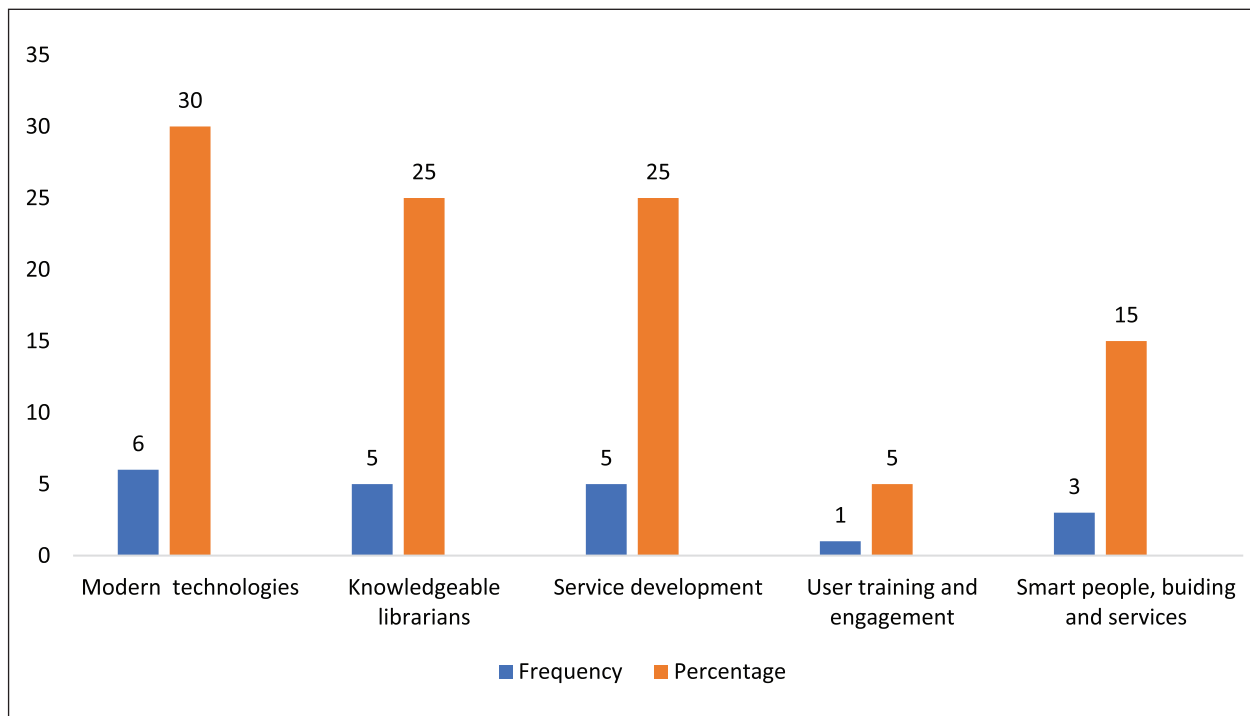


Figure 2. Requirements for smart libraries.

detection of social support, such as emotional encouragement, informational guidance, and peer interaction, can significantly influence students’ learning experiences and levels of academic burnout (Huang et al., 2025). By leveraging AI-driven analytics to monitor discussion forums, smart libraries can identify patterns of declining engagement or heightened burnout risk and facilitate timely interventions, such as targeted academic support, peer mentoring, or librarian-mediated guidance. Importantly, Huang et al. (2025) show that the effectiveness of such social support is moderated by students’ self-regulated learning capacities, underscoring the role of smart libraries in not only providing intelligent systems but also fostering adaptive, supportive learning environments. In this way, automated social support detection strengthens the smart people dimension by integrating user well-being, learning analytics, and personalised support into smart library services. Figure 2 elaborates more on the requirements for smart libraries.

Sustainability in smart libraries

Sustainability in smart libraries extends beyond technological efficiency to encompass environmental, social, and governance dimensions. Gul and Bano (2019) emphasise the importance of smart environments, mobile access, and knowledge creation as key components for sustaining smart libraries within universities. Cao et al. (2018) propose a service-led smart library model in which service

needs are treated as intended outcomes, highlighting the importance of aligning technological investments with long-term user and institutional goals. In this regard, Aliero et al. (2022) demonstrate how IoT technologies can transform conventional library buildings into energy-aware environments through smart HVAC systems, intelligent lighting, and energy optimisation strategies, thereby supporting environmental sustainability. Beyond infrastructure and energy management, sustainable smart libraries are increasingly shaped by institutional governance mechanisms and digitally enabled green management practices. Recent evidence suggests that institutional investor Environmental, Social, and Governance (ESG) activism plays a critical role in driving organisations towards improved green management and sustainability performance, particularly when supported by advanced digital intelligence contexts (Wu et al., 2024). Applied to smart libraries, this perspective underscores the importance of governance frameworks, accountability, and data-driven decision-making in ensuring that sustainability initiatives extend across procurement, resource management, and service delivery. Digital intelligence through data analytics, IoT platforms, and integrated management systems can enhance transparency, optimise resource utilisation, and align library operations with broader institutional sustainability strategies. Cao et al. (2018) further stress the need to strengthen smart user cultivation and continuous librarian education to support sustainable service innovation.

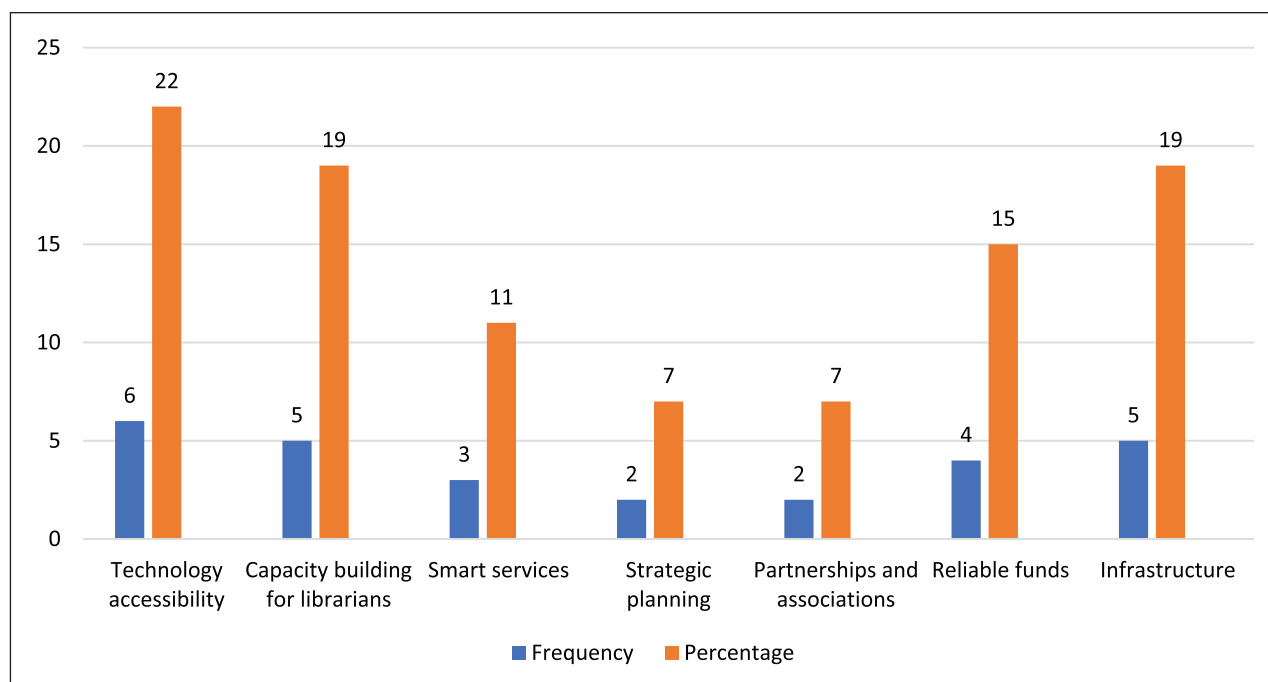


Figure 3. Sustainability for smart libraries.

Similarly, Yunus et al. (2025) highlight the enhancement of customer service and user experience as central to sustainable smart library systems, arguing that smart services integrate multiple service theories into a cohesive operational framework. To ensure long-term sustainability, libraries must engage in strategic planning that anticipates future growth, explores diverse funding models, and evaluates the social and economic impacts of smart library initiatives (Tella et al., 2025). Participation in online professional development programs, alongside emerging technologies such as blockchain and virtual reality, can further strengthen institutional resilience and innovation capacity (Shahzad et al., 2025; Shahzad and Khan, 2023). Figure 3 presents a detailed overview of sustainability dimensions in smart libraries.

Challenges in developing smart libraries

The establishment and sustainability of smart libraries face several significant challenges. According to Gul and Bano (2019), the organisation of e-resources such as e-journals, e-books, scholarly databases, and online eBook libraries presents a major hurdle, as these resources are essential for providing users with seamless access. Yunus et al. (2025) highlighted limited access to technology as a critical barrier. They identified two primary technological challenges for smart libraries: inadequate infrastructure and data management. Additionally, they pointed out that the high costs associated with rapidly evolving technologies further complicate the adoption of smart library practices. Key issues

include librarians' limited capacity to manage the growing volume of data and a lack of innovative strategies for effectively utilising it. There is also insufficient knowledge among library staff regarding the importance of data in enhancing library operations (Yunus et al., 2025). Tella et al. (2025) noted that resistance to change significantly hinders the adoption of smart technologies for service delivery. Financial constraints, inadequate infrastructure, and limited staff training further exacerbate these issues (Aliero et al., 2022; Mwantimwa and Msoffe, 2025; Shahzad et al., 2025; Tella et al., 2025). Integration complexity, user privacy concerns, high implementation costs, ongoing maintenance and upkeep, user resistance to change, data management difficulties, technology reliability issues, sustainability challenges, and the need for regulatory compliance were also identified (Aliero et al., 2022; Das and Islam, 2021). Figure 4 provides more detail on the challenges in developing smart libraries.

Discussion

The current review emphasised the increasing integration of emerging technologies in libraries, including cloud computing, generative AI, AI, AR, VR, data mining, robotics, the IoT, mobile internet, wearable devices, smart bookmarking apps, electronic resource management, and even drones and robots to ensure full integration of smart libraries worldwide (Cao et al., 2018; Gul and Bano, 2019; Ketheeswaren, 2024; Mwantimwa and Msoffe, 2025; Shahzad and Khan, 2023; Tella et al., 2025). Yunus et al. (2025) reinforced the need

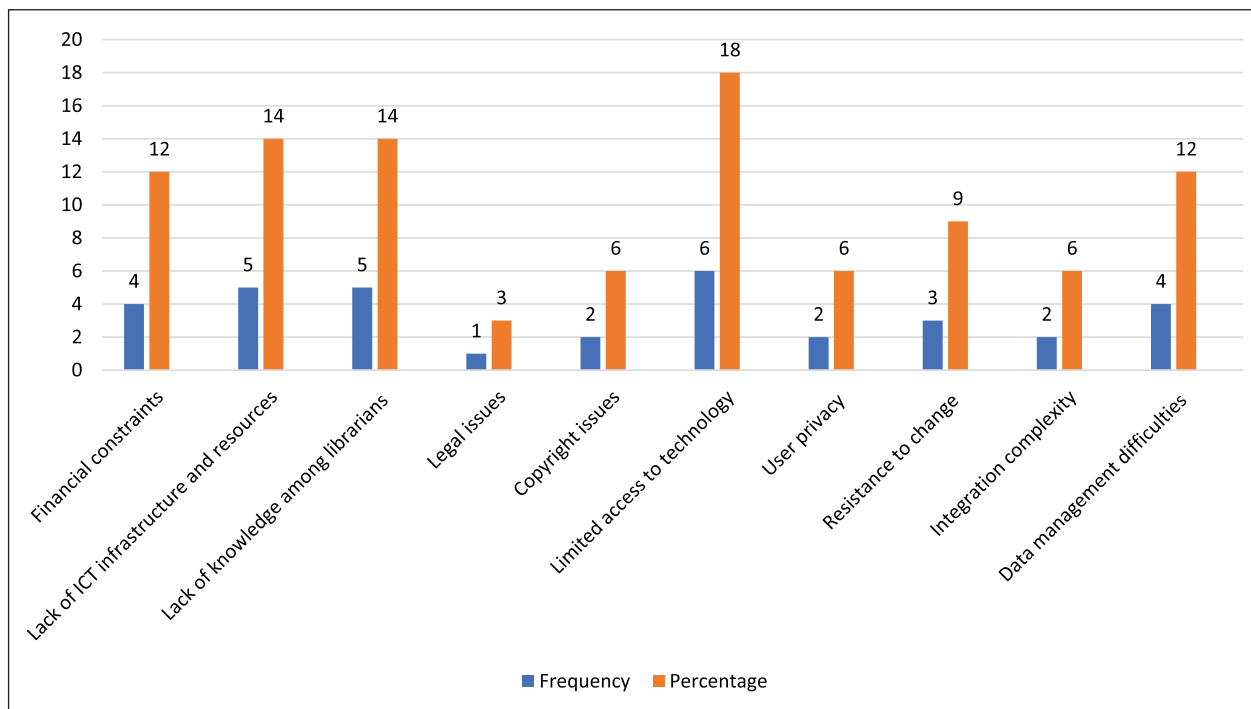


Figure 4. Challenges in developing smart libraries.

for smart technology to effectively implement smart library concepts. Supporting studies emphasise data mining, IoT, and AI as key technologies that bolster smart libraries (Ketheeswaren, 2024; Mosha, 2025; Okwu et al., 2024; Zeng et al., 2022). Okwu et al. (2024) highlighted that current trends in smart libraries are significantly shaped by technological advancements aimed at enhancing user experiences and streamlining operations. In addition to these technologies, Hussain and Ahmad (2021) identified other key innovations such as Geographical Information Systems (GIS), Integrated Library Systems (ILS), ambient intelligence, sensor technology, blockchain technology, Radio Frequency Identification (RFID), Closed-Circuit Television (CCTV), and Electronic Resources Management (ERM). Mishra (2020) explored the interplay of smart technologies, users, and services in modern libraries. Training and capacity building for both library staff and users are critical for the successful implementation of smart technologies (Aliero et al., 2022; Cao et al., 2018; Gul and Bano, 2019; Tella et al., 2025; Yunus et al., 2025). Abiolu and Akinyemi (2025) emphasised the importance of staff training, particularly in integrating AI technologies. The current review also highlighted the need to incorporate smart elements such as smart governance, smart users, smart buildings, and smart services (Cao et al., 2018; Gul and Bano, 2019; Yunus et al., 2025). The emphasis on smart places and smart buildings outlined by Yunus et al. (2025) aligns with Schöpfel’s (2018) concept of a smart place encompassing ecological sustainability, energy-efficient living, and innovative library

features. Jadhav and Shenoy (2020) further evaluated library smartness in terms of smart governance, identifying three key components: defining a sustainable future for libraries, fostering shared responsibility among stakeholders, and pinpointing funding sources for digitisation projects. Sayogo et al. (2022) noted that effective smart library management in Indonesia includes user participation in decision-making and the use of collective intelligence to foster creative programs through collaboration. Semantic technologies, data networks, and personalised environments contribute to a more intuitive search experience, moving away from traditional keyword searches towards natural language processing (Hubert and Chan, 2018; Kwanya et al., 2013). Naikar and Paul (2025) recommend a range of smart services, such as virtual reading rooms and information delivery via mobile devices and emphasise the relevance of AI and interactive technologies.

The current review also identified several sustainability items, including the provision of smart services, reliable funding, smart buildings, ICT resources and infrastructure, capacity building for library staff, as well as partnerships and library associations (Aliero et al., 2022; Cao et al., 2018; Das and Islam, 2021; Gul and Bano, 2019; Ketheeswaren, 2024; Mwantimwa and Msoffe, 2025; Shahzad and Khan, 2023; Tella et al., 2025). Sayogo et al. (2022) studied smart services in public libraries in Indonesia and identified three sustainability factors: ICT-driven programs, expanded access, and user-centred value-added services, such as entrepreneurship training. Adetayo

et al. (2021) emphasise the need for programs that enhance user education and encourage active participation in knowledge co-production. The current review also highlighted the importance of planning for the sustainability of smart libraries within universities (Shahzad and Khan, 2023; Tella et al., 2025). The same observation was reported by Johnson (2012). Tawalbeh et al. (2020) also observed that sustainability requires meticulous planning to accommodate future growth and changing needs, with funding models tailored to resource-constrained environments, such as public-private partnerships.

Guided by the conceptualisation of smart libraries as adaptive socio-technical systems, the challenges identified in this review, particularly limited technical expertise and data management constraints, are best understood as contextual design limitations rather than purely structural deficiencies. In low-resource environments, the development of smart libraries does not depend solely on advanced technological infrastructure; instead, it can be effectively supported by analytical survey-driven approaches that systematically assess data availability, staff capacity, and technological readiness. Such approaches enable libraries to adopt incremental and lightweight data practices, bridge the gap between analysis and investigation, and support evidence-based decision-making despite persistent data scarcity. Within the smart library framework, this strategy aligns technology adoption with institutional capacity, user needs, and long-term sustainability, reinforcing libraries' roles as responsive, learning-oriented systems. Nevertheless, the implementation of smart libraries continues to face substantial challenges, particularly in LMICs and other resource-constrained settings. These challenges include financial constraints, inadequate data management practices, insufficient ICT infrastructure, legal and copyright issues, limited access to technology, and gaps in staff knowledge and skills, all of which restrict users' access to essential information resources (Aliero et al., 2022; Gul and Bano, 2019; Mwantimwa and Msoffe, 2025; Shahzad et al., 2025; Tella et al., 2025; Yunus et al., 2025). Earlier studies similarly report limited access to modern technological tools, weak infrastructure, and insufficient librarian capacity to manage growing volumes of data (Sreekumar, 2012). Additional barriers include resistance to organisational change, the digital divide, privacy and confidentiality concerns, financial limitations, and inadequate staff training (Sayogo et al., 2022). These challenges are especially pronounced in rural and underdeveloped regions, where unreliable internet connectivity and unstable power supplies significantly hinder the implementation of smart library solutions (Mbunge et al., 2022). Financial constraints remain a critical barrier, as the acquisition and maintenance of hardware, software, and networking infrastructure, as well as ongoing staff training, require substantial and sustained investment. As a result, many libraries struggle to secure the funding necessary to

implement and scale smart library initiatives (Aliero et al., 2022; Mwantimwa and Msoffe, 2025; Shahzad et al., 2025; Tawalbeh et al., 2020; Tella et al., 2025). At the same time, robust data protection and governance mechanisms are essential. Libraries must comply with privacy regulations and maintain transparency regarding data collection, processing, and use to protect user trust (Aliero et al., 2022; Olalemi et al., 2025). In related smart building research, studies recommend privacy-preserving approaches such as contactless thermal comfort monitoring to enhance user acceptance while safeguarding personal data (Dikel et al., 2019; Luo et al., 2016).

Importantly, limited technical expertise and data management challenges in resource-constrained environments can be mitigated through strategies informed by low-resource data research. Cao et al. (2026) argue that analytical surveys help bridge the gap between analysis and investigation by enabling institutions to systematically assess data limitations, identify feasible solutions, and implement lightweight analytics suitable for sparse or incomplete datasets. Applied to smart libraries, these approaches enable institutions to generate actionable insights from limited data, gradually build staff capacity, and introduce AI-driven or data-informed services in a phased, sustainable manner. Analytical surveys also support evidence-based planning, encourage collaboration through library consortia, and reframe data scarcity as a manageable design constraint rather than a prohibitive barrier. A further critical challenge in deploying AI and IoT technologies in libraries is navigating the complex landscape of data protection and regulatory compliance. This issue is particularly acute in jurisdictions with evolving legal frameworks governing personal information. Libraries must ensure that systems handling patron data comply with stringent regulations, such as the General Data Protection Regulation (GDPR) in Europe, which emphasises lawful processing, data minimisation, transparency, and robust security safeguards (Rajačić et al., 2025). Complementary national frameworks, including the UK Data Protection Act 2018, further reinforce these obligations (Mone and Sivakumar, 2022). In low- and middle-income countries, national legislation such as data protection laws in Ghana, Kenya, South Africa, and Uganda imposes similar requirements for the collection, storage, and sharing of personal information (Ghana Parliament, 2012; South African Parliament, 2013). At the regional level, initiatives such as the African Union Convention on Cyber Security and Personal Data Protection seek to harmonise privacy protections across Africa, although implementation remains uneven across member states (African Union Convention on Cyber Security and Personal Data Protection, 2014). Compliance with this diverse and fragmented legal environment complicates the deployment of AI- and IoT-enabled library systems but is essential for maintaining user trust,

mitigating legal risk, and ensuring ethical stewardship of patron data. As emerging technologies intensify privacy risks, regulatory compliance becomes not only a legal requirement but also a foundational pillar of sustainable and trustworthy smart library development (Mone and Sivakumar, 2022; Rajačić et al., 2025).

Practical and policy implications for implementing smart libraries in low- and middle-income countries (LMICs)

This systematic review highlights that the transition to smart libraries in low- and middle-income countries (LMICs) should follow a phased, strategic approach rather than the immediate adoption of advanced technologies (Cao et al., 2018; Gul and Bano, 2019). The process should begin with a needs and readiness assessment to identify priority user services, existing ICT infrastructure, staff digital competencies, and overall institutional capacity (Gul and Bano, 2019; Yunus et al., 2025). Based on this assessment, libraries can prioritise low-cost, scalable solutions suitable for LMIC environments, including cloud-based or open-source integrated library systems, mobile-access platforms, RFID-enabled circulation services, and basic data analytics tools (Ketheeswaren, 2024; Mwantimwa and Msoffe, 2025). Capacity building for both staff and users is essential throughout this transition, focussing on digital librarianship, data management, and AI literacy to enable effective use of smart technologies and minimise resistance to change (Aliero et al., 2022; Tella et al., 2025; Yunus et al., 2025). Sustainability can be enhanced through partnerships with government agencies, library consortia, and private-sector technology providers, alongside funding models tailored for resource-limited LMICs, such as public-private partnerships (Sayogo et al., 2022; Tawalbeh et al., 2020). At the policy level, integrating smart library initiatives into national ICT and education strategies, supported by clear data governance and privacy frameworks, is crucial to ensure ethical technology adoption, maintain user trust, and secure long-term operational viability (Mone and Sivakumar, 2022; Rajačić et al., 2025).

Study implications

The findings regarding the development of smart libraries carry significant implications for various stakeholders, including library administrators, policymakers, users, and educators. First and foremost, library administrators should prioritise strategic planning to address the challenges identified in the research. This includes investing in infrastructure improvements and ensuring access to modern technologies. By understanding the specific limitations of their institutions, libraries can create targeted initiatives to enhance service delivery. Professional development

also emerges as a critical area for improvement. The study highlights the necessity for ongoing training and education for library staff. Libraries should implement comprehensive training programs focussing on emerging technologies and data management practices. Empowering librarians with the skills needed to effectively utilise smart technologies will significantly improve user experiences and operational efficiency. Policymakers need to recognise the financial constraints libraries face and explore innovative funding models to support their transition to smart environments. Establishing public-private partnerships or seeking grants specifically aimed at enhancing library technology can provide the necessary financial backing. Ensuring adequate funding is crucial for overcoming infrastructure and technology barriers that hinder library development. Engaging users in the development and implementation of smart library services is vital. Libraries should actively solicit user feedback and involve community members in decision-making processes. This participatory approach fosters a sense of ownership among users and increases overall satisfaction with library services, making them more responsive to community needs. The growing reliance on digital technologies also underscores the importance of prioritising robust data protection measures. Libraries must develop clear policies and practices around data privacy to build user trust and ensure compliance with relevant regulations. Training staff on these issues is equally important, as it helps mitigate risks associated with data management. Additionally, the study emphasises the need for libraries to address the digital divide by making services accessible to all community members, particularly marginalised groups. Implementing outreach programs that target underserved populations will ensure equitable access to resources and technologies, fostering inclusivity within library services. Finally, ongoing research into the effectiveness of smart library initiatives is essential.

Conclusion and recommendations

The development of smart libraries presents both opportunities and challenges that must be strategically navigated to enhance service delivery and user engagement. The findings underscore the importance of addressing technological, infrastructural, and financial barriers while fostering the implementation of modern technologies and a user-centred environment. As libraries evolve in the digital age, they must leverage advanced technologies to improve accessibility and streamline operations. To facilitate this transition, several recommendations are proposed. First, library administrators should prioritise strategic investments in ICT infrastructure, resources, and modern technologies to meet the needs of “smart library users.” Comprehensive professional development programs should be established to equip library staff with the skills

necessary to manage and utilise new technologies effectively. Policymakers should consider innovative funding solutions, such as collaboration and partnerships, to engage more people and knowledge to implement and support smart libraries. Additionally, libraries must engage users actively in the development process, incorporating community feedback to tailor services that resonate with their specific needs. Robust data management is essential to instill user confidence in smart library solutions. Libraries should also develop clear policies and guidelines to ensure compliance with privacy regulations and prioritise transparency concerning smart library functionality. Finally, addressing the digital divide through targeted outreach initiatives will be crucial in making library services accessible to all segments of the community.

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Ethical considerations

This study was approved by the College Ethics and Integrity Committee (Reference Number: College of Graduate Studies _ RERC_0487) on May 2, 2023.

Consent to participate

This was a systematic review, and all the data that were extracted from the published articles were in the public domain.

Author contributions

Conception or design of the work: NFVM and PN. Data collection: NFVM. Data analysis and interpretation: NFVM and PN. Drafting and the article: NFVM and PN. Critically reviewed, edited, and approved the final manuscript: NFVM and PN.

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Not applicable.

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Appendices

Table 1. Quality assessment CASP systematic review (CASP checklist).

Authors	1	2	3	4	5	6	7	8	9	10
Gul and Bano (2019)	N	Y	U	N	NI	NI	NI	N	U	U
Cao et al. (2018)	N	NI	U	N	NI	NI	NI	N	NI	NI
Yunus et al. (2025)	Y	Y	Y	NI	N	U	U	Y	N	NI
Tella et al. (2025)	NI	NI	N	N	Y	Y	Y	Y	U	NI
Das and Islam (2021)	Y	Y	Y	NI	NI	Y	Y	Y	NI	NI
Shahzad and Khan (2023).	Y	Y	Y	NI	Y	Y	Y	Y	N	U
Shahzad et al. (2025)	Y	Y	Y	NI	NI	Y	Y	NI	NI	U
Aliero et al. (2022)	Y	Y	Y	Y	NI	Y	Y	Y	U	NI
Mwantomwa and Msoffe (2025).	Y	Y	NI	NI	NI	Y	Y	Y	NI	NI
Ketheeswaren (2024).	Y	NI	N	N	NI	NI	Y	Y	NI	Y

Questions in the checklist

1. Did the review address a clearly focused question?
2. Did the authors look for the right type of papers?
3. Do you think all the important, relevant studies were included?
4. Did the review’s authors do enough to assess quality of the included studies?
5. If the results of the review have been combined, was it reasonable to do so?
6. What are the overall results of the review?
7. How precise are the results?
8. Can the results be applied to the local population?
9. Were all important outcomes considered?
10. Are the benefits worth the harms and costs?

Note. Y: yes; N: no; NI: not identified; U: uncertain.

Table 2. Data extraction.

S.No.	Author	Country	Databases/protocol	Requirements	Sustainability	Challenges
1	Gul and Bano (2019)	Not identified	Clarivate Analytics's Web of Science and Sciverse Scopus	Emerging and innovative technologies which integrate to form smart libraries. Knowledgeable librarians	Creation of smart environments, mobile access, creation of new knowledge, adaptivity, smart technologies for content formation, smart detection of knowledge, and smart and innovative services.	Arrangement of e-resources within smart libraries
2	Cao et al. (2018)	Not identified	Not identified	Technology, service and human	Provide smart services including service leading principle, resource integration principle, and people-oriented principle. Employ the strategies to strengthen smart user cultivation and librarian education. Offer high-quality services. This could include leisure options such as cafés and cultural activity rooms, as well as creating a comfortable and inviting atmosphere.	Rapid technological environment changes; extensive and rapid growth of data; and the increase in and diversification of user needs. The definition of a smart library and its distinctions from other library types remain unclear.
3	Yunus et al. (2025)	China, Nigeria, Russia, India, Jamaica, Indonesia, France, the United States, Taiwan and Pakistan. In particular, China, Nigeria, Russia and India	Scopus and Web of Science (WoS), Google Scholar, Review protocol Reporting standards for Systematic Evidence Syntheses (ROSES).	Smart technology is one of the elements that needed to be included to form a smart library. The smart people which are focused on both users and library staff. Training for both library users and librarians	Improved service concept that provides excellent customer service and a great user experience. Trained librarians and library users	Limited access to technology Librarians' limited ability to manage rapidly growing data. Limited ability to use data innovatively A lack of knowledge about the importance of data
4	Tella et al. (2025)	Nigeria South Africa	PubMed, Google Scholar, and Research gate	Smart governance Integration of advanced technologies such as cloud computing, data mining, and AI. Service building, user cultivation, and librarian training	Develop meticulous planning to accommodate future growth and evolving needs. Investigate and implement various funding models Examine social and economic impacts of smart libraries initiatives	Resistance to change Privacy and confidentiality Financial constraints Inadequate infrastructure, limited staff training
5	Das and Islam (2021)	Not identified	Web of Science, Scopus, LISA and LISTA	Modern technologies: AI, ML	Training for library users Capacity building for library staff Dedicated funds	Lack of security of the library and resources Lack of jobs
6	Shahzad and Khan (2023).	Saudi Arabia China India Taiwan Nigeria Spain Iran	Scopus, Web of Science (WoS), Wiley InterScience, Emerald, Google Scholar, IEEE Xplore, Taylor & Francis, Elsevier, SpringerLink, ERIC, Association of Computing Machinery (ACM) and EBSCO.	Latest tools, methods and techniques	Participation in online professional development (OPD) programmes Employ blockchain technology	A shortage of skilled manpower, the unavailability of adequate IT infrastructure, a lack of technical support, copyright issues, poor planning and ineffective library leadership

(continued)

Table 2. (continued)

S. No.	Author	Country	Databases/protocol	Requirements	Sustainability	Challenges
7	Shahzad et al. (2025)	Hong Kong, USA, Germany, Nigeria, Korea, Mexico, Taiwan, China, Canada, Finland	LISA, LISTA, Scopus, Web of Science, ERIC, ProQuest, EBSCO Host, Emerald, Wiley Inter Science, Association of Computing Machinery (ACM), Science Direct and IEEE Xplore	Financial resources, manpower requirements, project duration, and time involved, smart library systems to ensure access, user centric design, training to both users and library staff.	Strong partnerships and collaborations, Grants and funding assurance from the government and other organisations, adequate resources, workshops, seminars and promotional events, robust privacy policies and security protocols, a technical support team, ethical guidelines, training courses and mentorship programs, library leadership, associations, and professional groups, invest in innovative smart library systems	Financial constraints, legal concerns, health issues, technical infrastructure
8	Aliero et al. (2022)	Not provided	IEEE Explore, Science Direct, and Google Scholar	Modern technologies including IoT	Smart building	Integration complexity, user privacy concerns, high implementation costs, staff training and adaptation, maintenance and upkeep, user resistance to change, data management challenges, sustainability, and challenges, regulatory compliance
9	Mwantimwa and Msoffe (2025).	Not provided	Scopus and Google Scholar	Generative AI technologies such as Chatbots and Robots	Training, funds, capacity building for library staff, ICT infrastructure	Inadequate infrastructure Financial constraints
10	Ketheeswaren (2024).	Not provided	Scopus	User-centricity, technological integration, and emerging concepts like IoT and AI.	Training and support for library staff, budget, ICT infrastructure,	Inadequate knowledge using AI The lack of a comprehensive diachronic analysis hinders the ability to effectively adapt to emerging themes and capitalize on the new opportunities presented by technological advancements in smart libraries.